

Implementation and validation of CALET flight model in GEANT4 simulation

Presentation by

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CALET - Technical Int. Meeting June 25 2015 - Pisa, Italy

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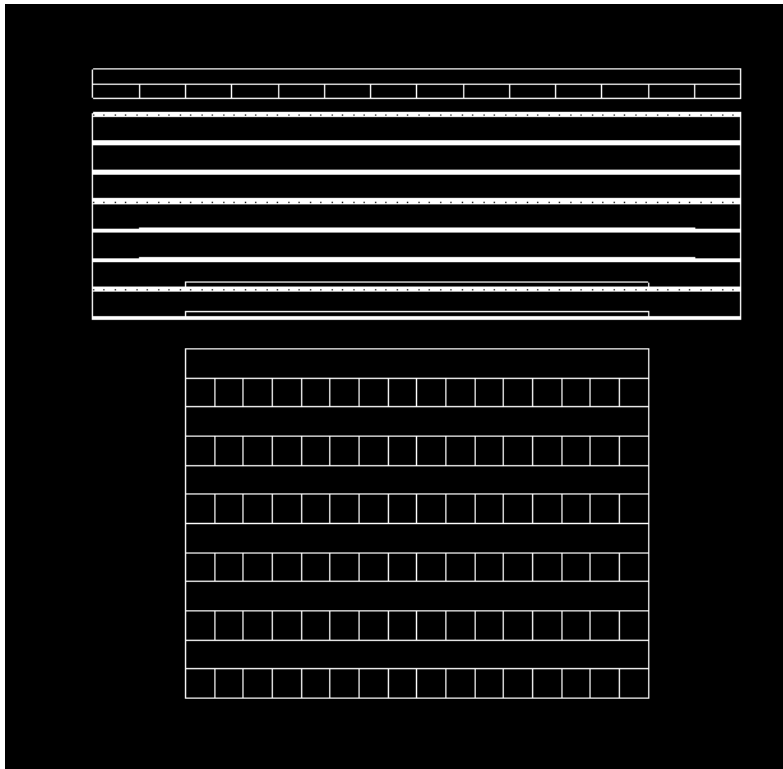


Calet flight model in GEANT4

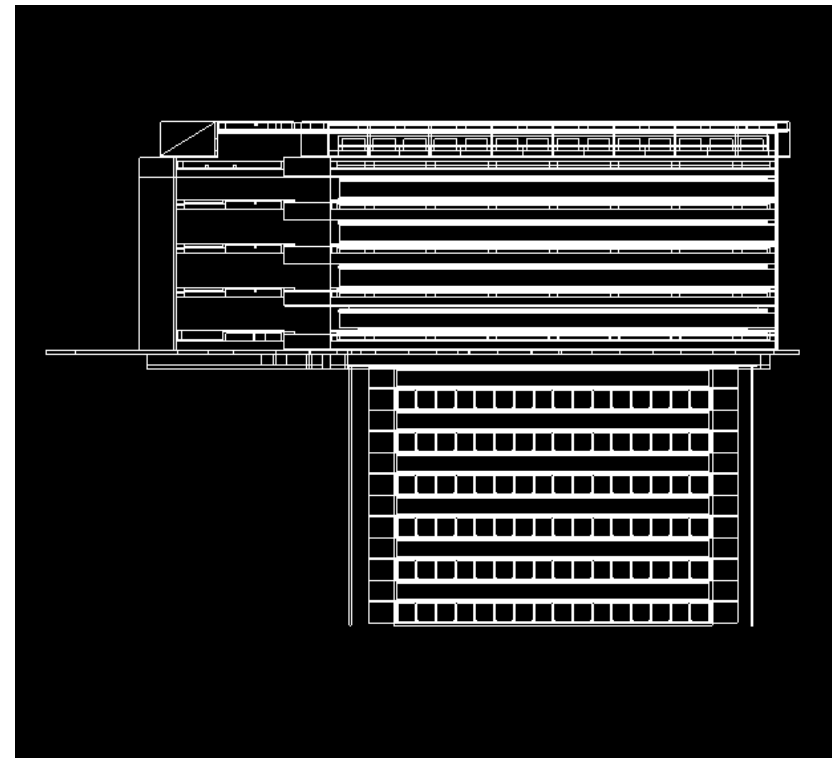
- *Lorenzo Pacini*
- *Nicola Mori*

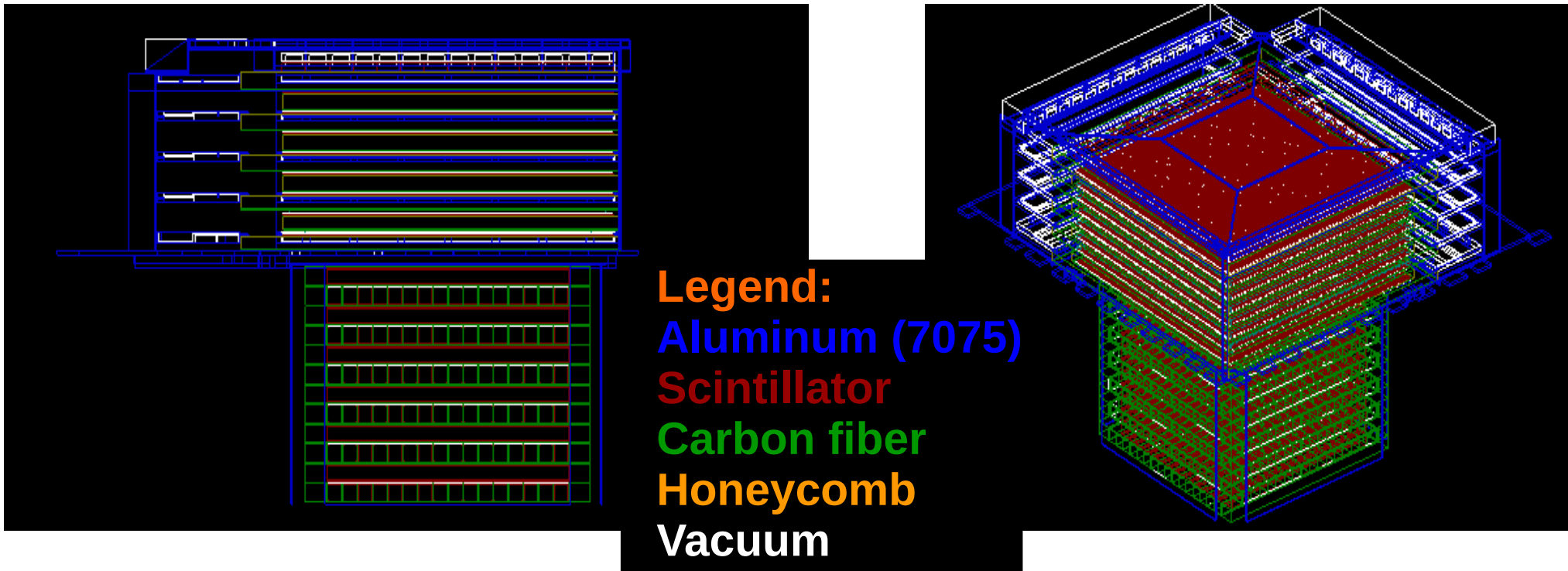
- We developed the Calet flight model in GEANT4
- Shape and size of the supporting structures have been extracted from Epics config. files and replicated in details in the Geant4 geometry description.
- Some simplifications have been introduced (e.g.: honeycomb) as we did with FLUKA:
 - 1) honeycomb → homogeneous aluminum material, density = 0.3856g/cm³
 - 2) IMC and TASC lateral panel → single aluminum box

Calet simplified geometry: no supports and mechanical structures.



Calet new geometry
(figures are not in scale)

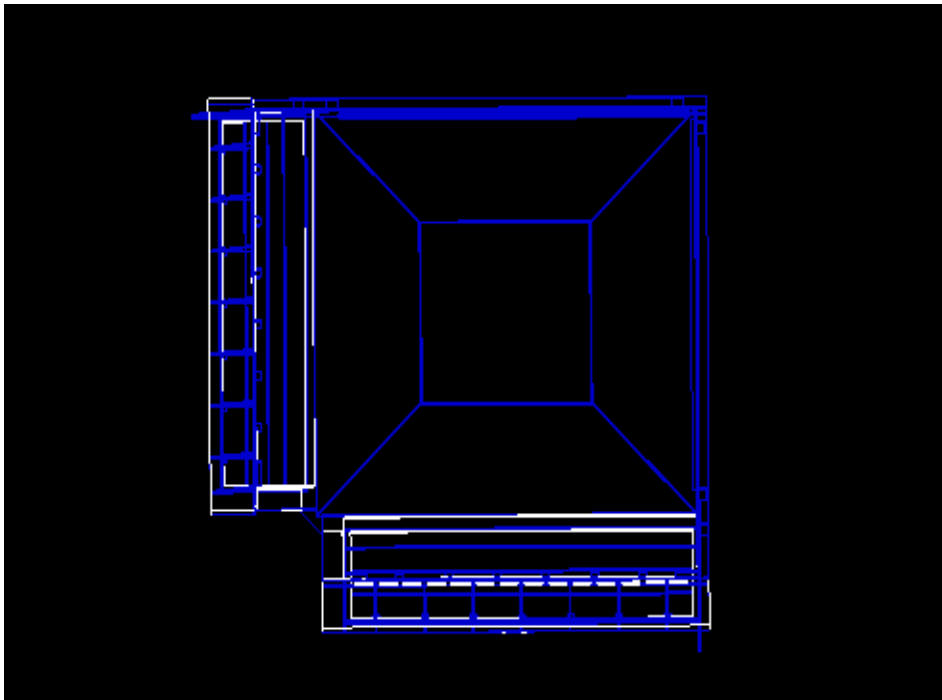




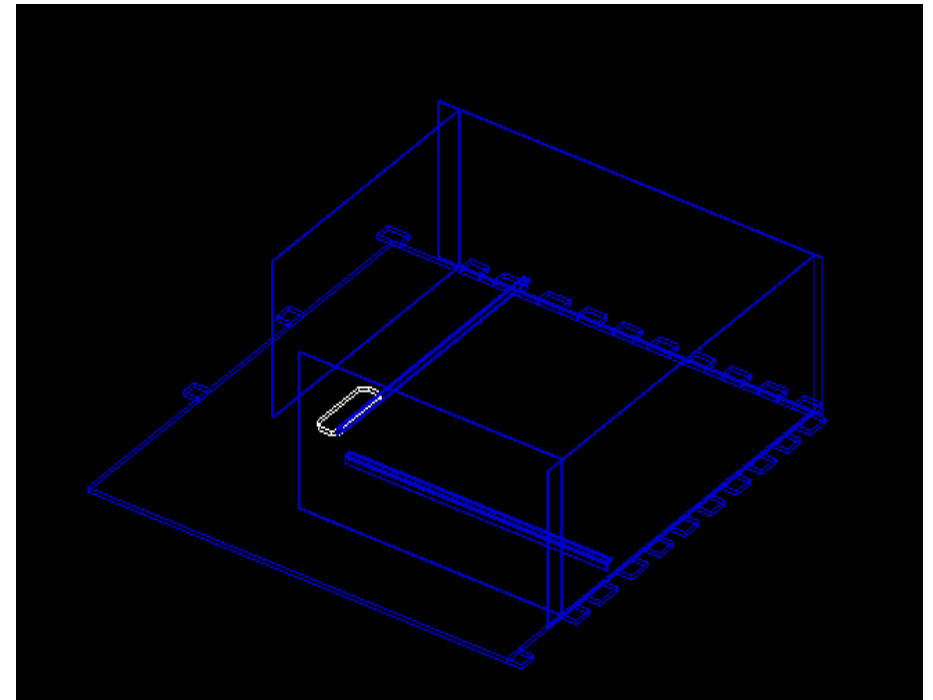
- Aluminum structures: lateral, base, top panel and PMT box in CHD and IMC
- Carbon fiber and honeycomb supports for scintillator (CHD, IMC, TASC)
- Scintillators and tungsten layers (also present in the simplified geometry).

CHD top panel, IMC lateral and base panel

- CHD top panel and PMT box



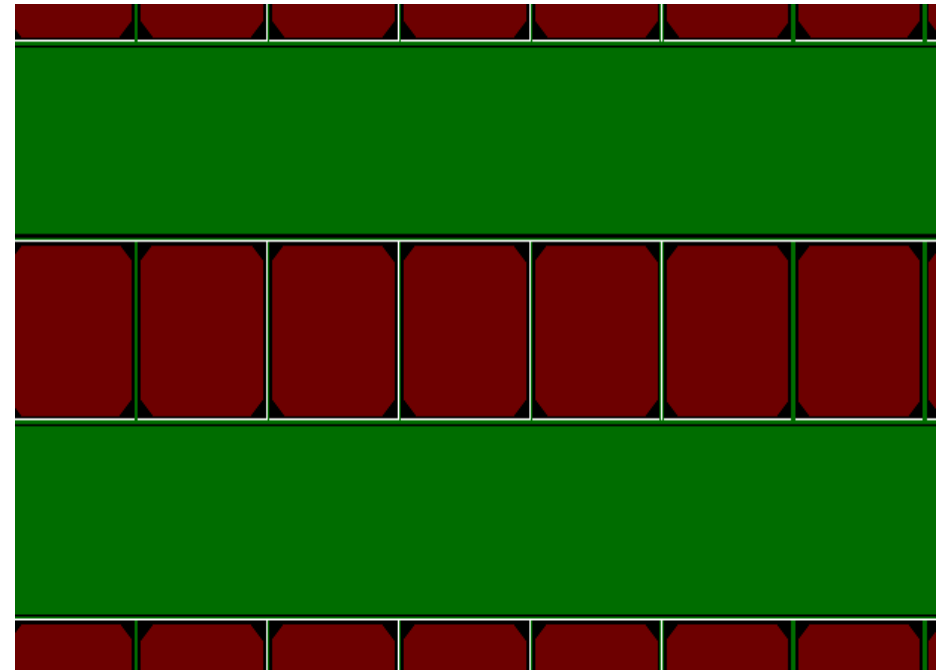
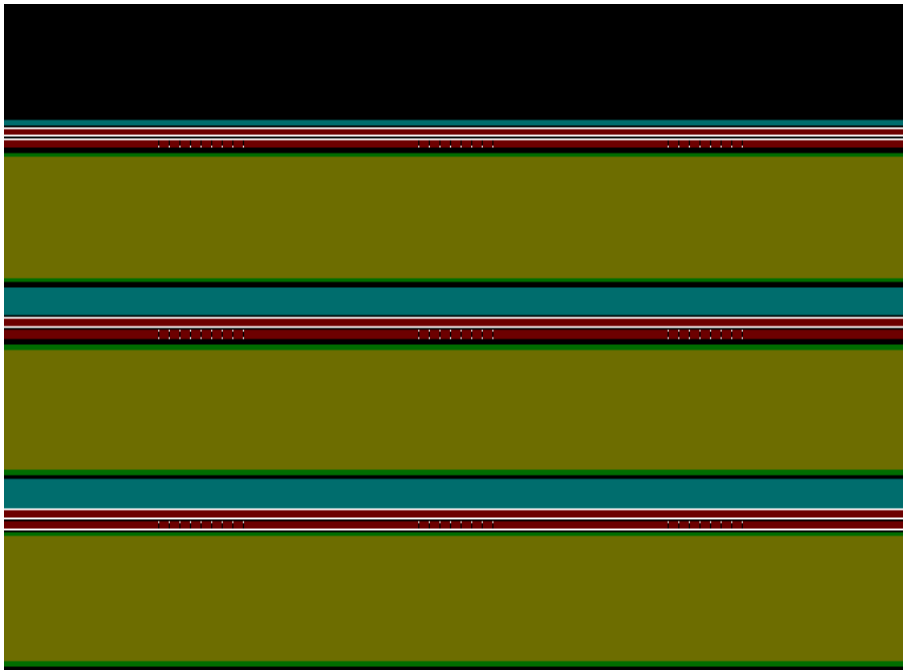
- IMC lateral and base panels



IMC and TASC layers

Legend:
Tungsten
Scintillator
Carbon fiber
Honeycomb
Vacuum

- In IMC: the supports are thin carbon fiber layers and big honeycomb structures
- In TASC: The supports are carbon fibers (no honeycomb)



Calet flight model benchmark

- *Lorenzo Pacini*
- *Caterina Checchia*
- *Francesco Palma*
- *Paolo Maestro*
- *Nicola Mori*

To validate the new GEANT4 geometry we performed common benchmarks with FLUKA and EPICS:

- **Proton** and **Electron** @ 10, 100, 1000, 10000 GeV
- Future works: ^{12}C and ^{56}Fe @ 10, 100, 1000, 10000 GeV/n kinetic energy

Particle:

- Normal incidence
- Generated in $4 \times 4 \text{ cm}^2$ area on top of CHD at the center of the detector

Interesting quantities for this presentation:

- Energy deposited in CHD, IMC and TASC.
- High energy trigger efficiency.

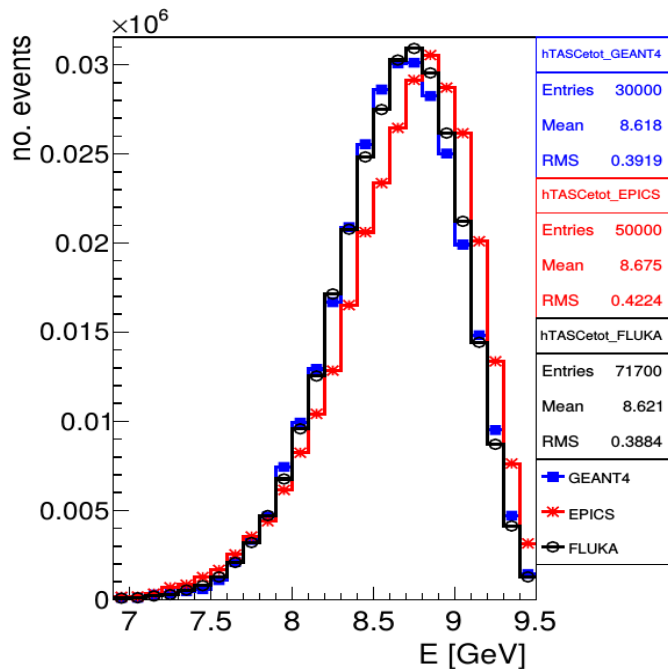
We also investigated the energy deposited in TASC, IMC layers, in IMC single fibers and TASC logs.

Software versions

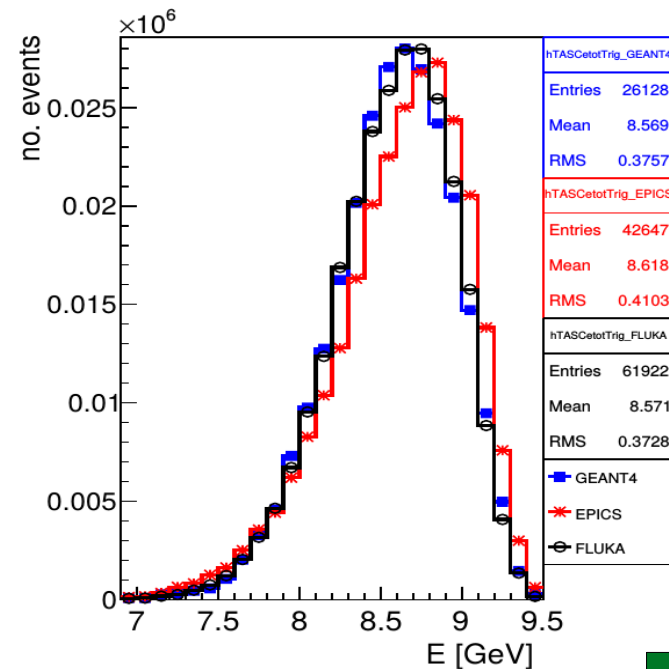
- GEANT4-09-06-patch-02
physics lists: FTFP_BERT
- EPICS9.167 Calet Cad model rev. 21 (COSMOS 7.645)
hadronic interacting model: DPMJET-III
- FLUKA 2011.2c.0
hadronic interacting model: DPMJET-III

All electrons @ 10 GeV.
Total energy in TASC.

H.E triggered electrons @ 10 GeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black



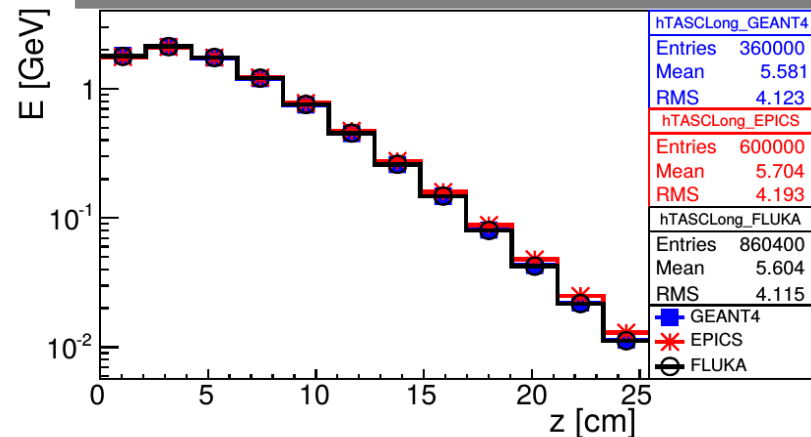
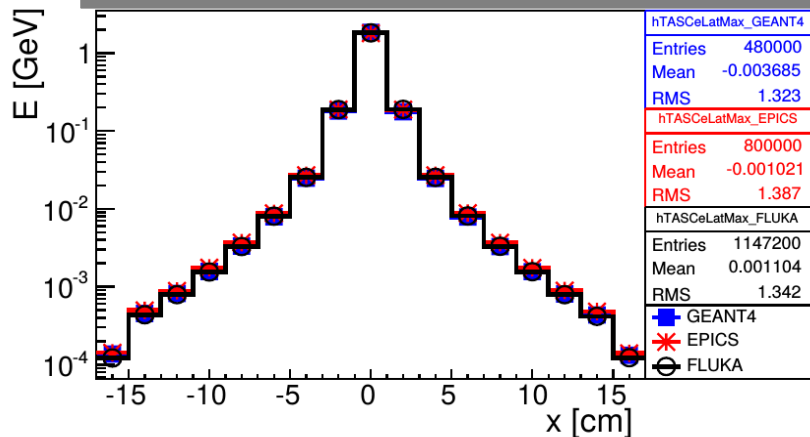
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	8.569	0.3757	8.65	0
EPICS	8.618	0.4103	8.85	2.312
FLUKA	8.571	0.3728	8.75	1.156

H.E.trigger
efficiency
GEANT 87.1%
EPICS 85.3%
FLUKA 86.4%

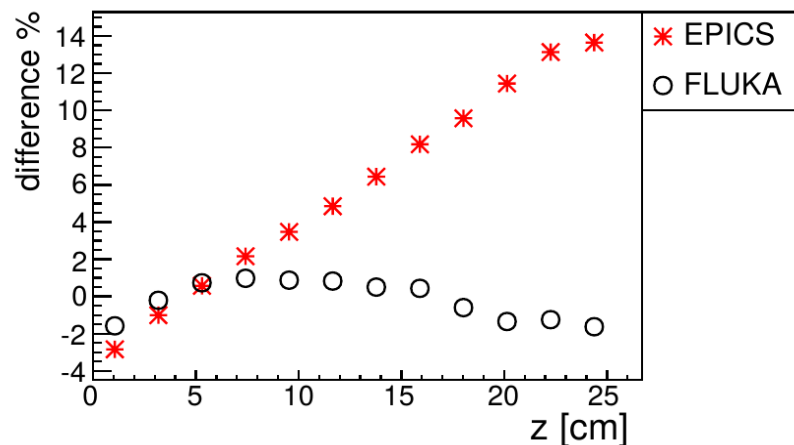
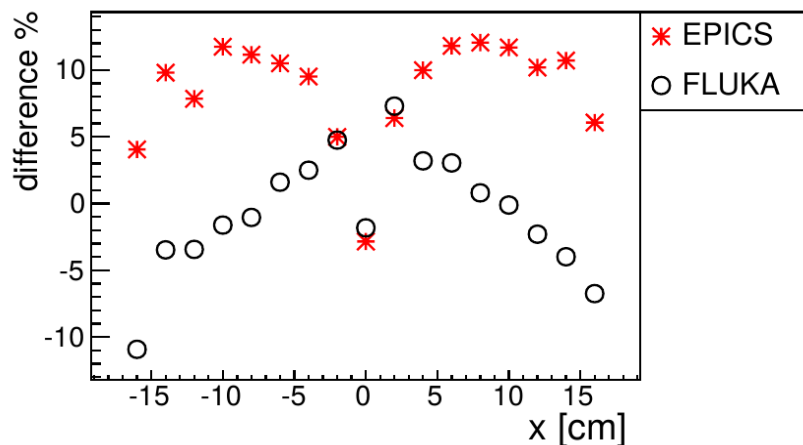
All electrons 10 @ GeV.
TASC lateral distr.

All electrons @ 10 GeV.
TASC longitudinal distr.



Difference with respect to GEANT4

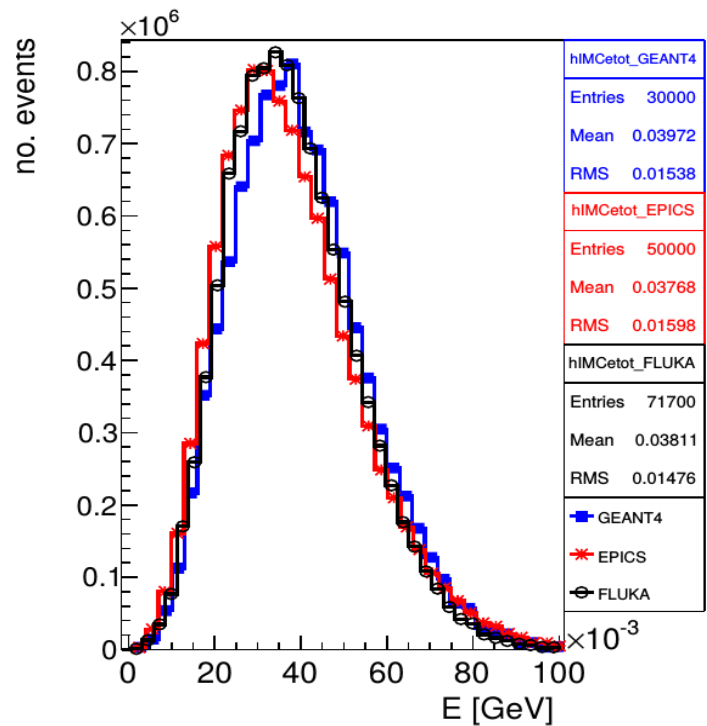
Difference with respect to GEANT4



diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

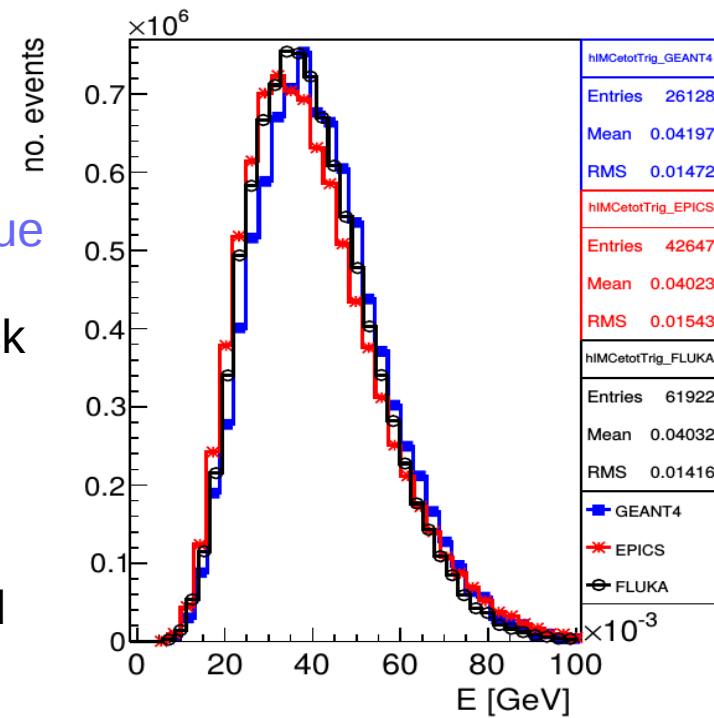
All electrons @ 10 GeV.
Total energy in IMC.

H.E triggered electrons @ 10 GeV.
Total energy in IMC.



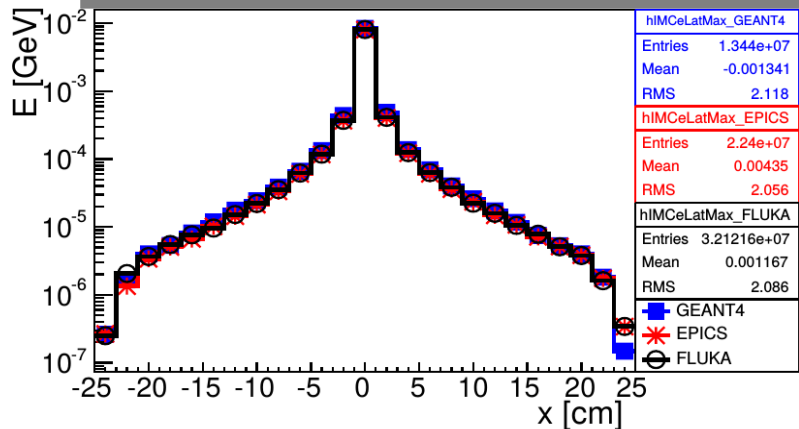
GEANT4 blue
EPICS red
FLUKA black

H.E. triggered
particle table:

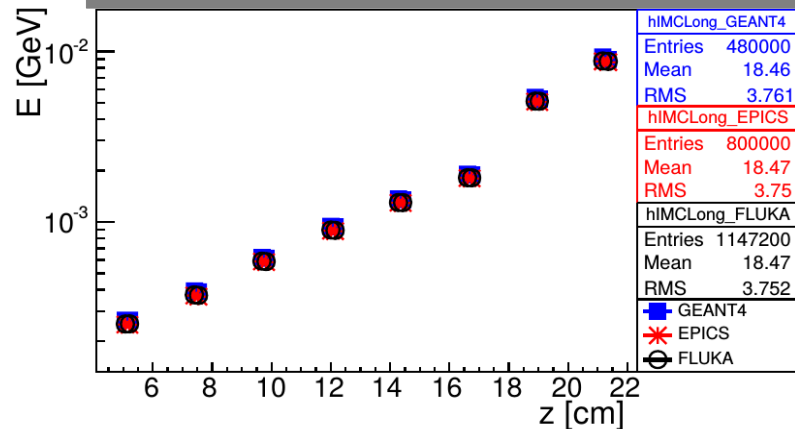


Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.04197	0.01472	0.03802	0
EPICS	0.04023	0.01543	0.03211	-15.54
FLUKA	0.04032	0.01416	0.03415	-10.19

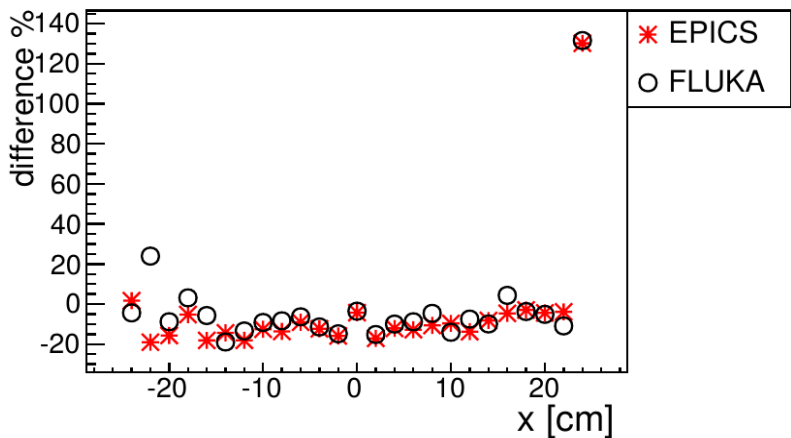
All electrons @ 10 GeV.
IMC lateral distr.



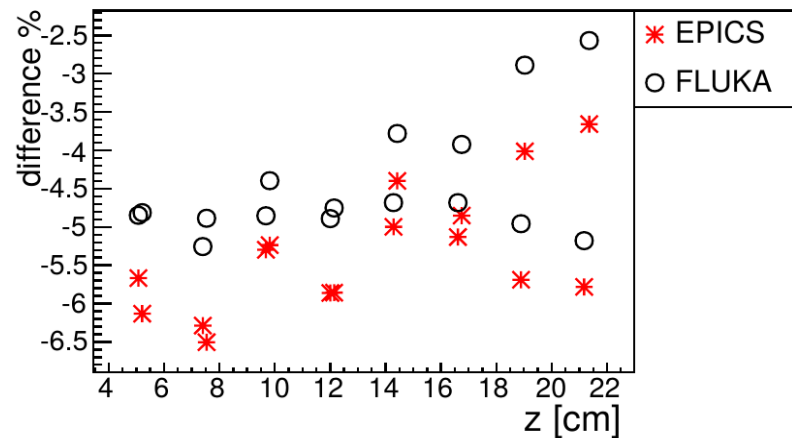
All electrons @ 10 GeV.
IMC longitudinal distr.



Difference with respect to GEANT4



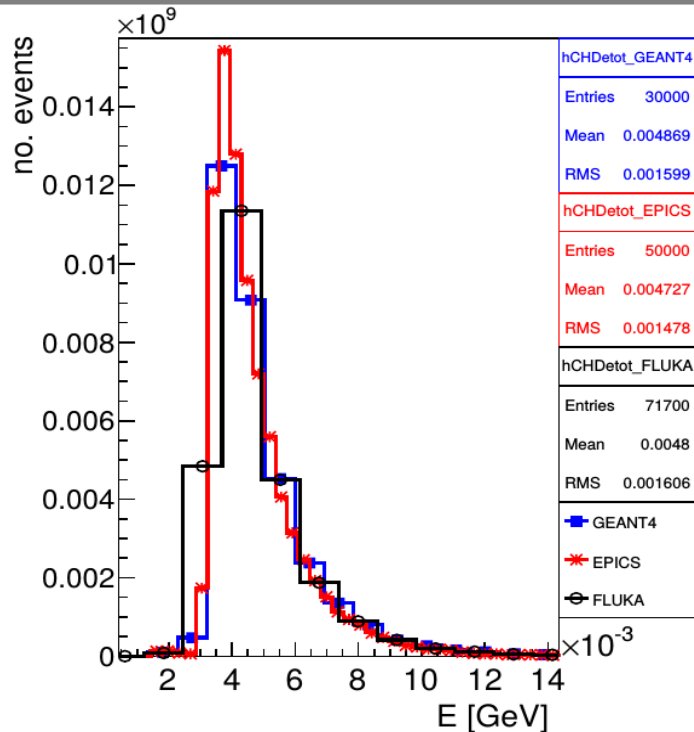
Difference with respect to GEANT4



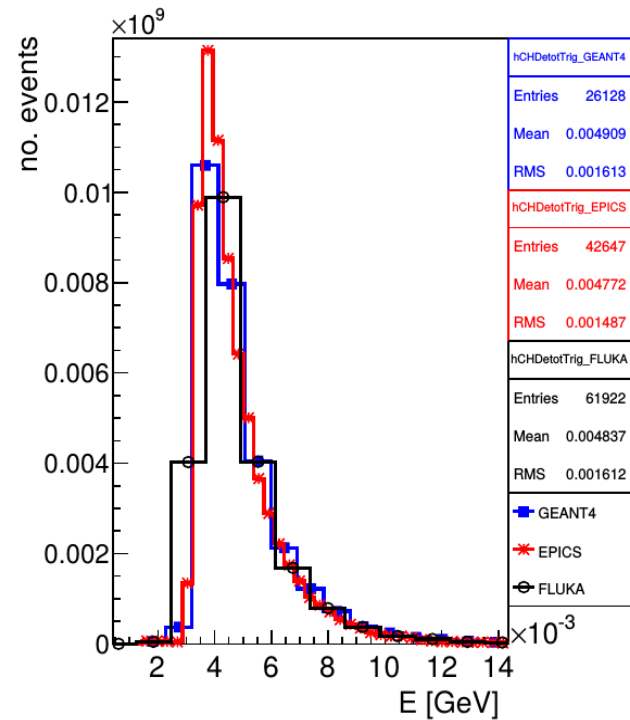
diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

All electrons @ 10 GeV.
Total energy in CHD.

H.E triggered electrons @ 10 GeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black



H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.004909	0.001613	0.003669	0
EPICS	0.004772	0.001487	0.003763	2.577
FLUKA	0.004837	0.001612	0.004302	17.24

Electrons @ 10 GeV results

- **TASC total energy: very similar distributions**, difference between bins with the highest energy deposit is 1-2 %
- TASC lateral and longitudinal distributions: good agreement around the maximum of the distributions; difference of order 10% in the low energy tails.
- **IMC total energy:** the shape of the distributions are very similar. The maximum position is about 10% higher in Epics and Fluka with respect to Geant4.
- IMC lateral and longitudinal distributions: quite good agreement, with discrepancies only in the low energy tails.
- **CHD total energy: very similar distributions**, the shape of the distributions are very similar.

Electrons @ 100 GeV results

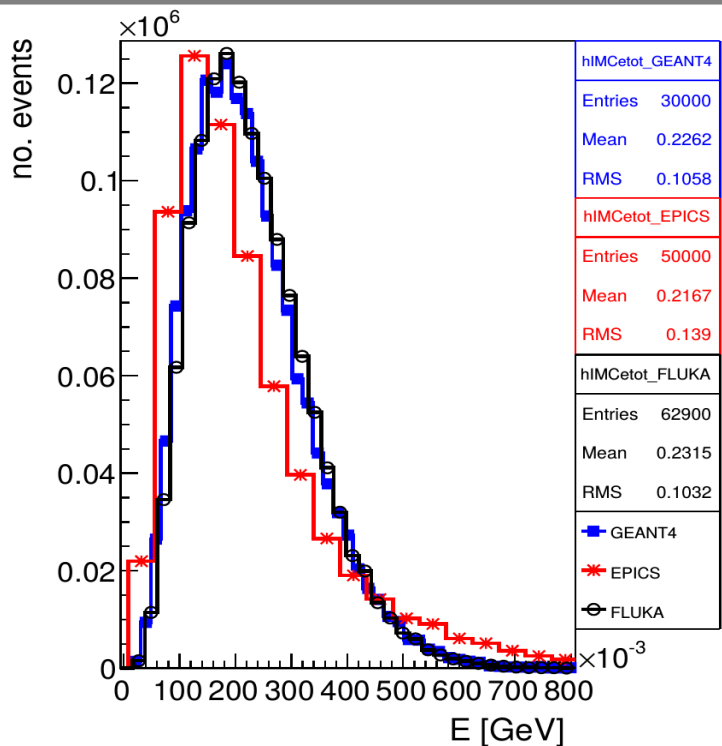
- **The results from the comparison of the three simulations are similar to the 10 GeV case** (plots and tables are in the backup slides)
- **TASC total energy: very similar distributions**, difference between bins with the highest energy deposit is about 0.7 % for EPICS with respect to GEANT4 and FLUKA
- TASC lateral and longitudinal distributions: large differences (10%) only for layers with low energy deposited
- **IMC total energy: distributions have similar shapes**, difference between maximum energy bins is about 20 % for EPICS with respect to GEANT4 and
- IMC lateral and longitudinal distributions: large difference (20%) only for layers with low energy deposited
- **CHD total energy: very similar distributions**, difference between maximum energy bins is about 2%

Electrons @ 1 TeV results

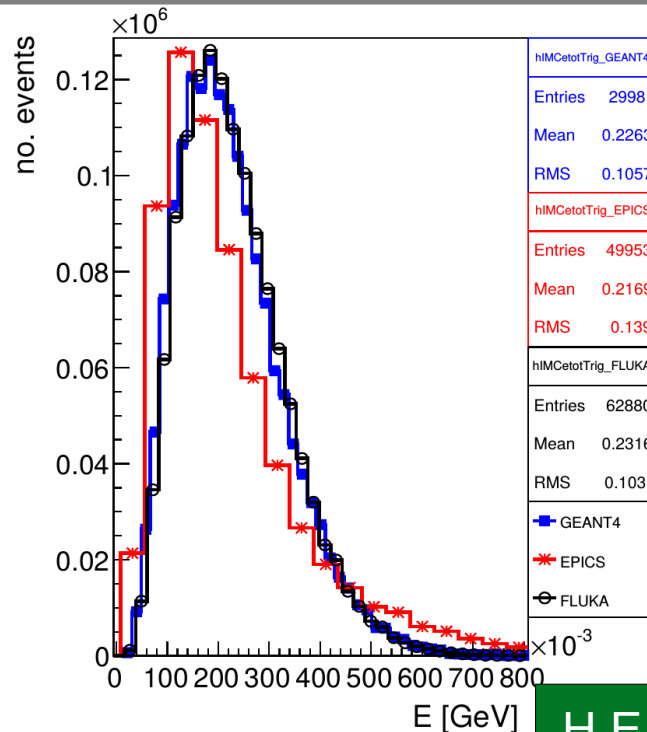
- **TASC total energy and distributions: similar results to the ones obtained at 10 and 100 GeV** (plots and tables are in the backup slides) .
- **IMC total energy: the shape of the EPICS distributions is remarkably different with respect to the GEANT4 and FLUKA ones;** the difference between the maximum energy bin is about 30% with respect to GEANT4 and FLUKA (see next slides)
- **CHD total energy: the shape of the EPICS distributions is remarkably different with respect to the GEANT4 and FLUKA ones;** the difference between the maximum energy bin is about 30% with respect to GEANT4 and FLUKA (see next slides)

All electrons @ 1 TeV.
Total energy in IMC.

H.E triggered electrons @ 1 TeV.
Total energy in IMC.



EPICS distributions are not in agreement with GEANT4 and FLUKA.



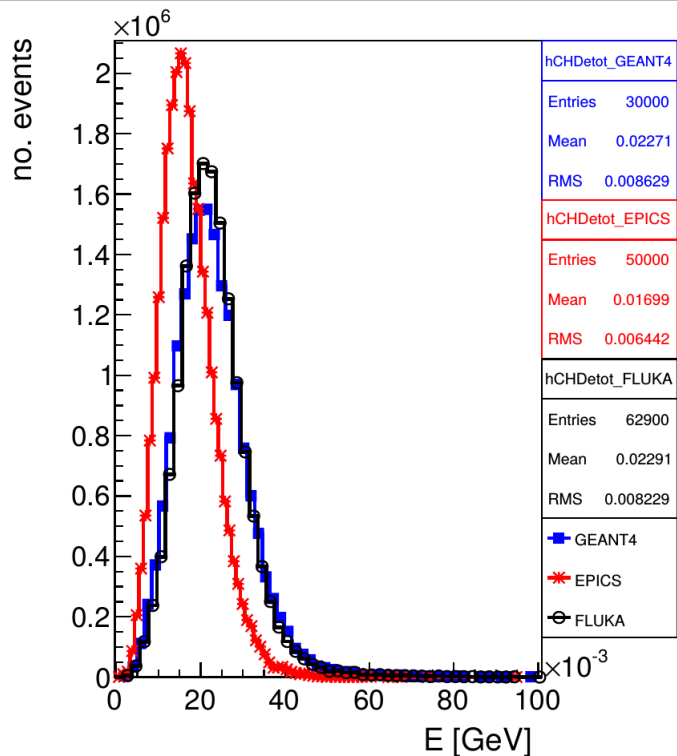
H.E. triggered particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.2263	0.1057	0.1844	0
EPICS	0.2169	0.139	0.1266	-31.34
FLUKA	0.2316	0.1031	0.1844	-0.042

H.E.trigger efficiency
GEANT 99.9%
EPICS 99.9%
FLUKA 99.9%

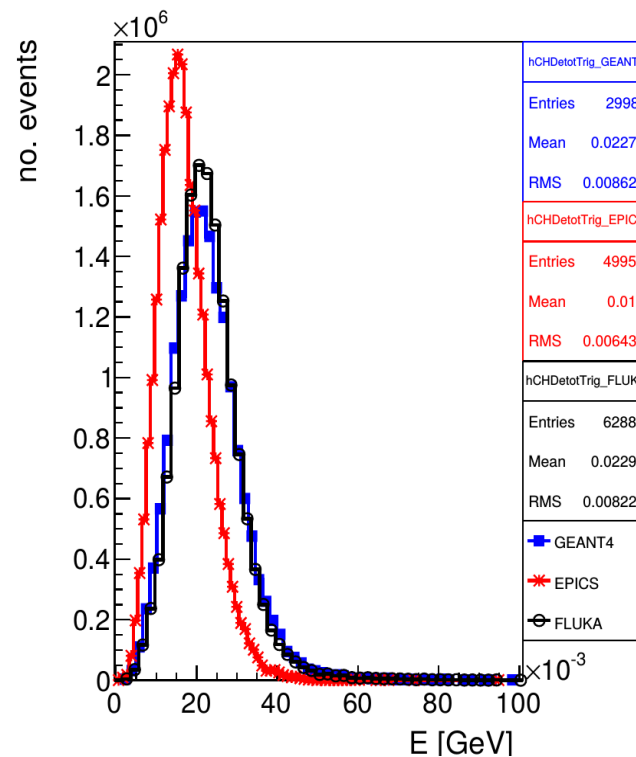
All electrons @ 1 TeV.
Total energy in CHD.

H.E triggered electrons @ 1 TeV.
Total energy in CHD.



EPICS distributions are not in agreement with GEANT4 and FLUKA.

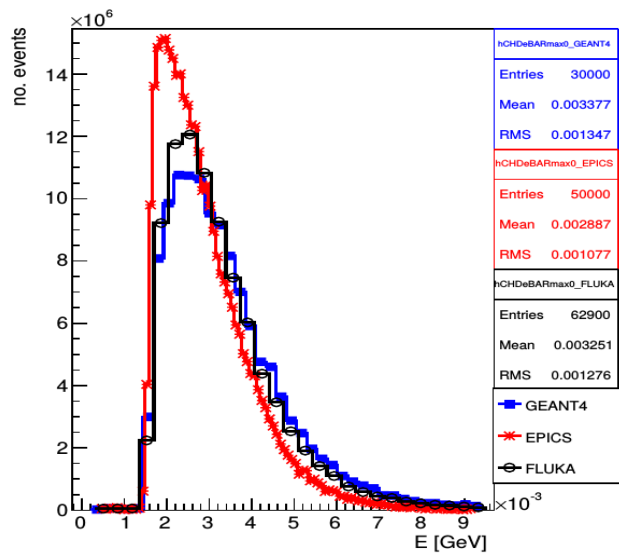
H.E. triggered particle table:



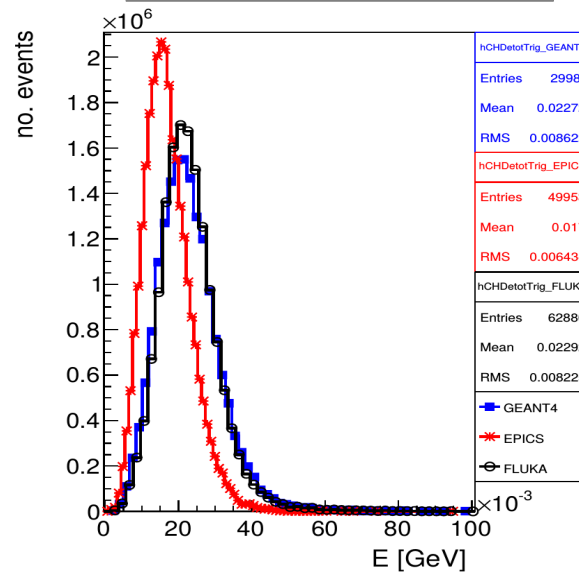
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.02272	0.008622	0.02148	0
EPICS	0.017	0.006434	0.01531	-28.74
FLUKA	0.02292	0.008225	0.0206	-4.088

- In order to understand these large differences in CHD (and IMC) distributions we have studied the energy deposited in the CHD paddle directly hit by the primary particle.

CHD single paddle



CHD total energy



The single bar distribution is in agreement with the MIP energy release, (mean ~ 2-3 MeV)

The CHD total energy is bigger than the MIPs energy release in the crossed bars (20 MeV vs. 4-6 MeV)

A possible explanation of these differences are:

- The total energy released in CHD (IMC) includes both the energy deposited by the primary particle in the two crossed paddles (fibers), and the signals due to backscatter particles in the nearby bars (fibers).
- The latter is expected to increase with the primary particle energy.
- The lower total energy deposited in IMC and CHD observed with Epics might be related to a **different treatment of the backscatter particles with respect to GEANT4/FLUKA.**

Electrons @ 10 TeV results

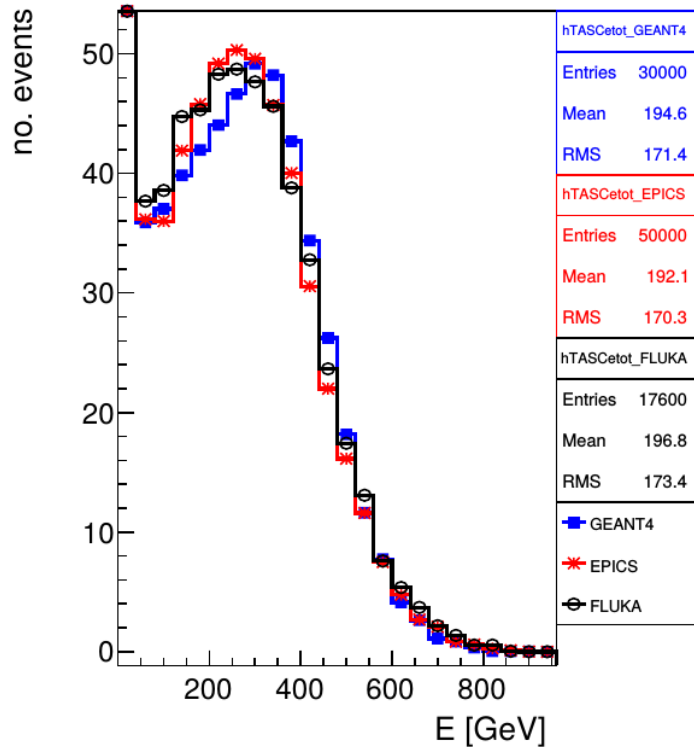
- **The results from the comparison of the three simulations are similar to the 1 TeV case** (plots and tables are in the backup slides) .
- TASC total energy and distributions: similar results to the ones obtained at 10, 100 and 1000 GeV
- **IMC total energy: the shape of the EPICS distributions is remarkably different with respect to the GEANT4 and FLUKA ones; the difference between the maximum energy bin is about 44 % with respect to GEANT4 and FLUKA**
- **CHD total energy: the shape of the EPICS distributions is remarkably different with respect to the GEANT4 and FLUKA ones; the difference between the maximum energy bin is about 42 % with respect to GEANT4 and FLUKA (see next slides)**

Proton benchmark

- **The TASC energy distributions of the three simulations are in good agreement at all the energy (see Maestro's presentations at the last TIM in Waseda)**
- **IMC and CHD show large discrepancies, especially for triggered proton.**
- I will show the plots for protons @ 1TeV. The other energies are in in the backup slides.

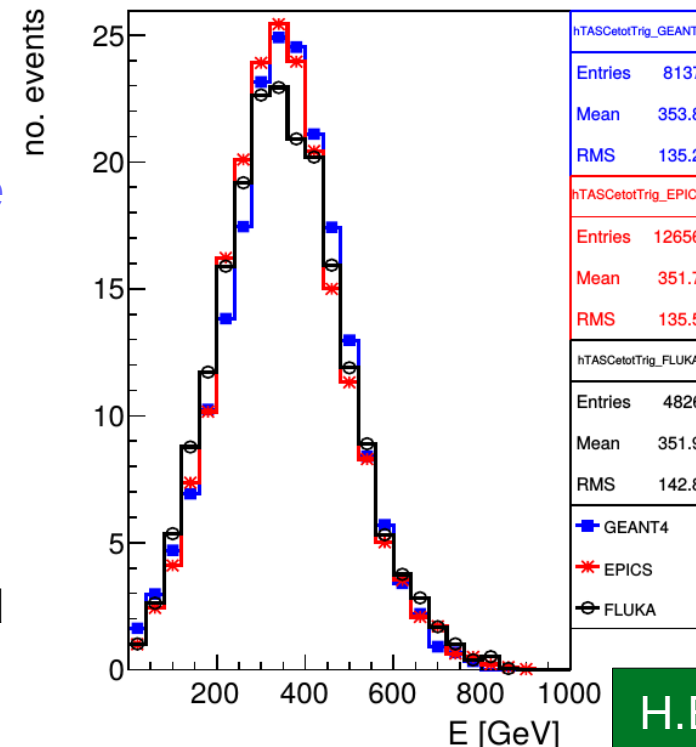
All protons @ 1 TeV.
Total energy in TASC.

H.E triggered protons @ 1 TeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

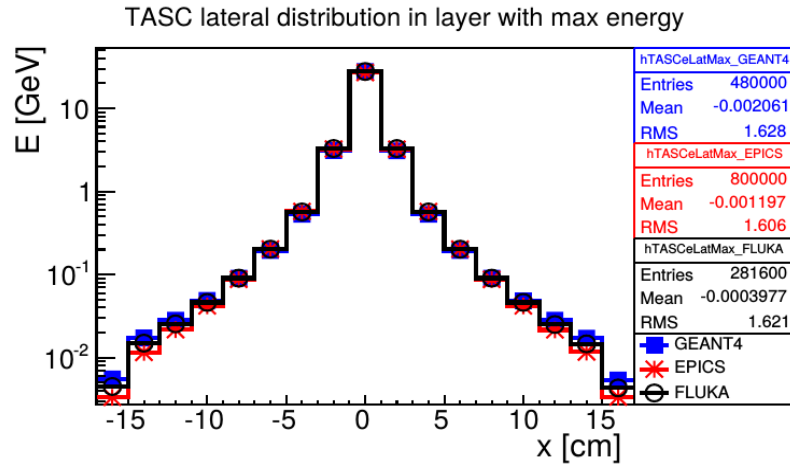
H.E. triggered
particle table:



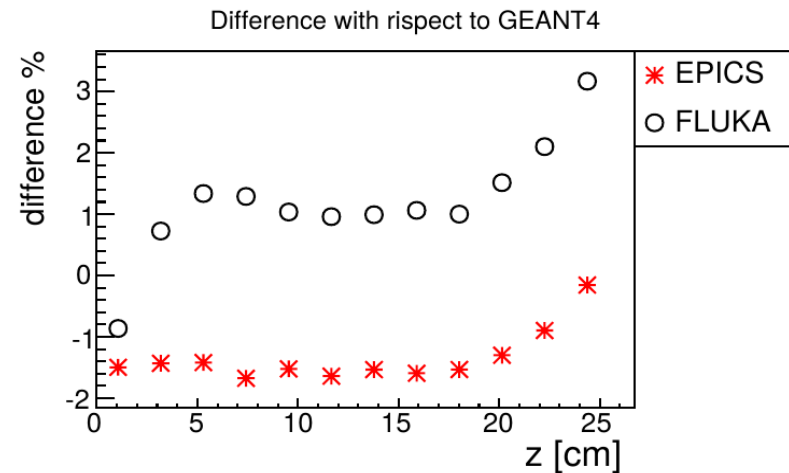
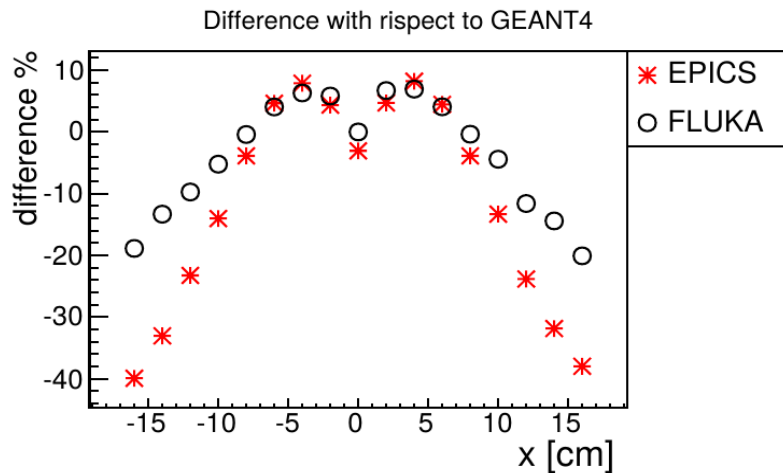
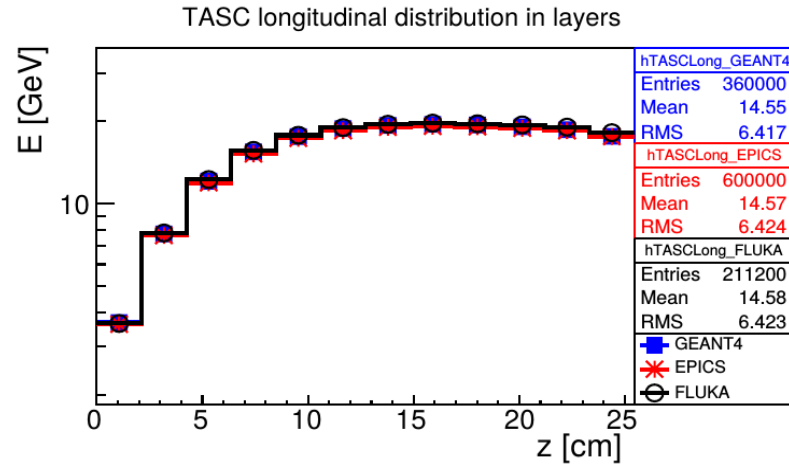
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	354.6	133.6	370.1	0
EPICS	352.3	134.4	330.1	-0.2
FLUKA	352.9	141.5	350.1	-0.2

H.E.trigger
efficiency
GEANT 27.1 %
EPICS 24.3%
FLUKA 27.4%

All protons @ 1 TeV.
TASC lateral distr.



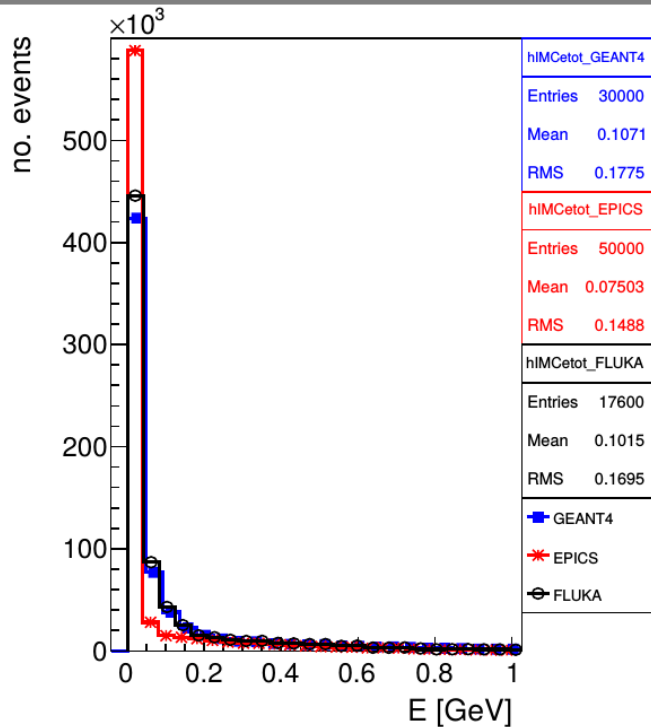
All protons @ 1 TeV.
TASC longitudinal distr.



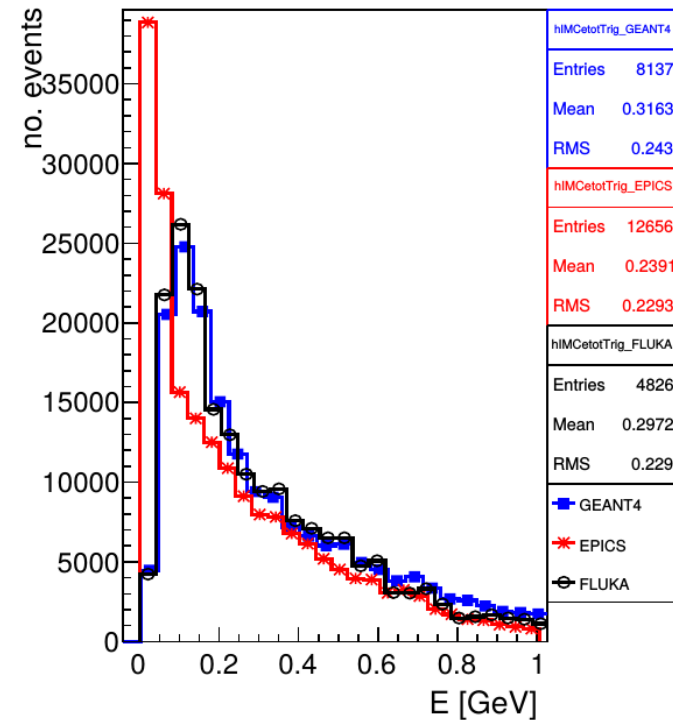
diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 1 TeV.
Total energy in IMC.

H.E triggered protons @ 1 TeV.
Total energy in IMC.



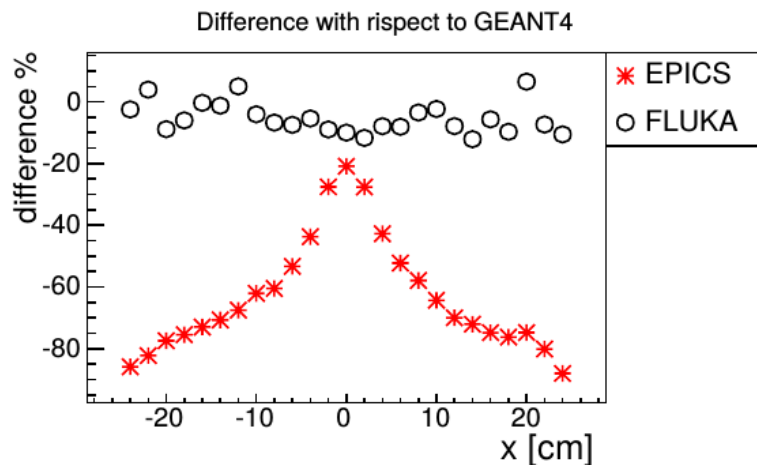
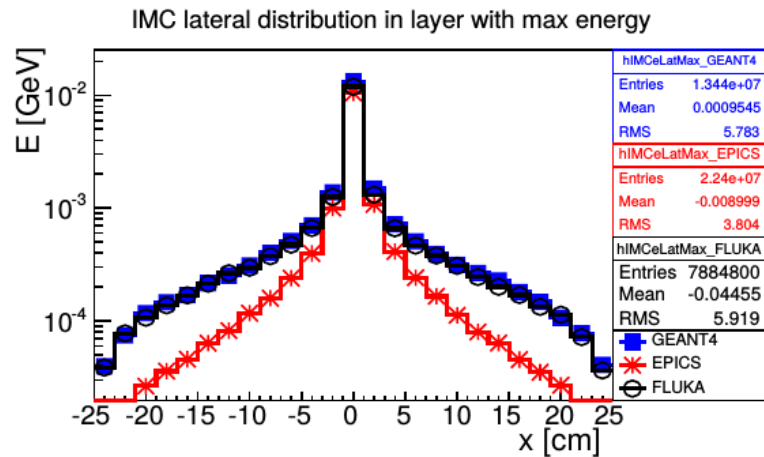
GEANT4 blue
EPICS red
FLUKA black



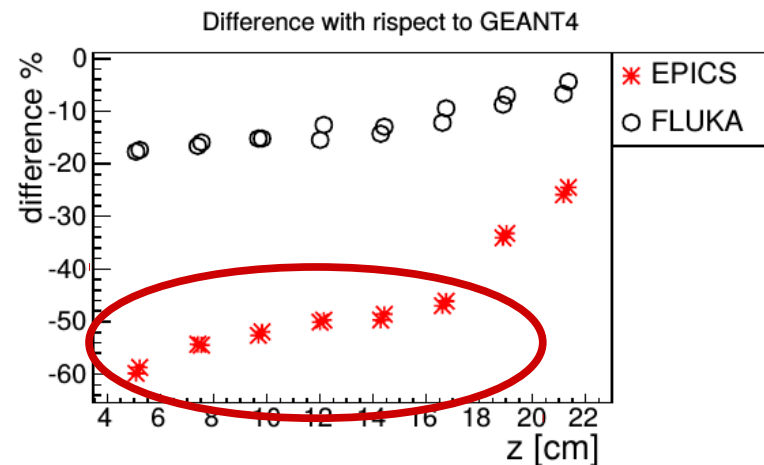
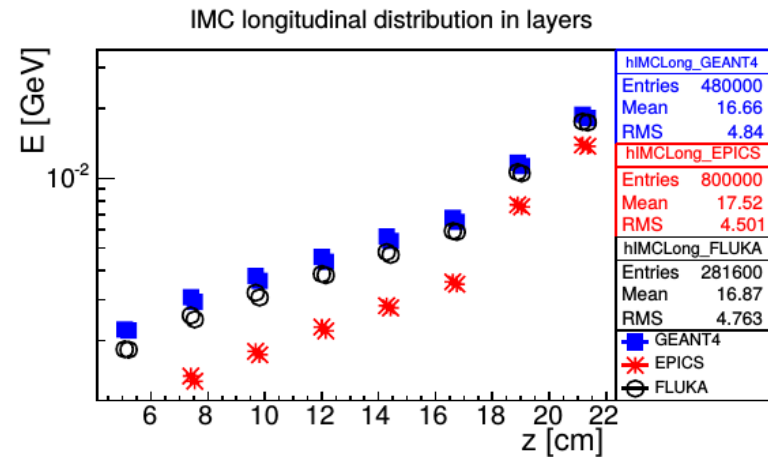
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.3163	0.243	0.1133	0
EPICS	0.2391	0.2293	0.02014	-82.23
FLUKA	0.2972	0.229	0.1031	-9.035

All protons @ 1 TeV.
IMC lateral distr.



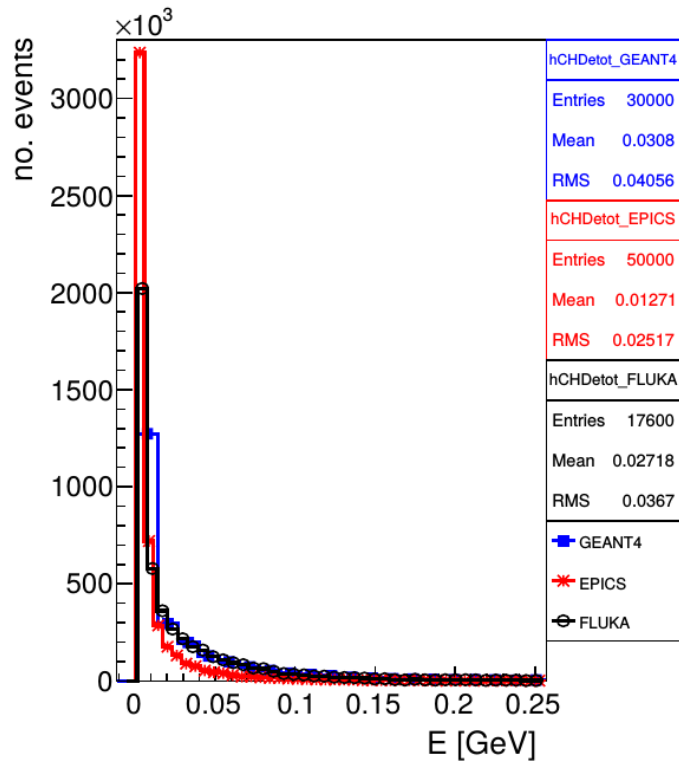
All protons @ 1 TeV.
IMC longitudinal distr.



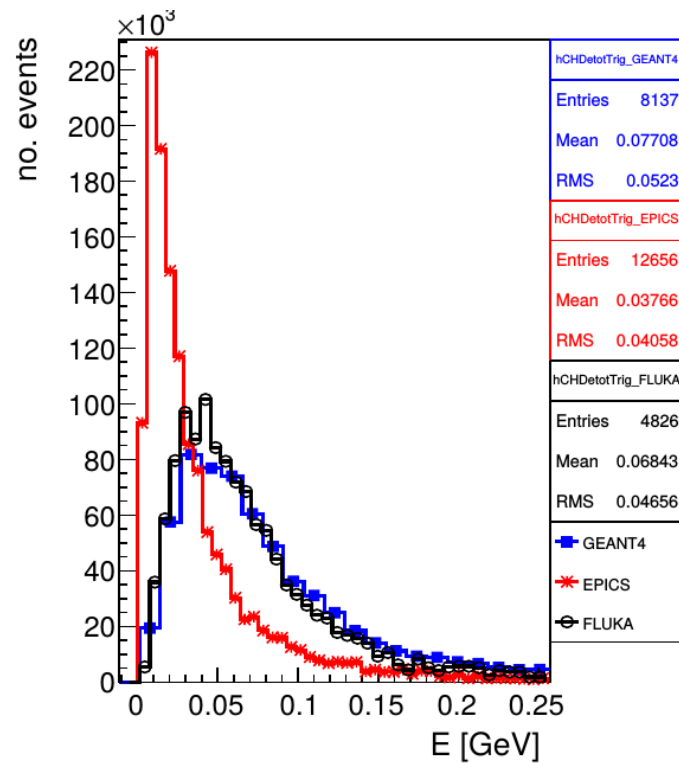
Very big differences in IMC for EPICS simulation with respect to FLUKA and GEANT4

All protons @ 1 TeV.
Total energy in CHD.

H.E triggered protons @ 1 TeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black



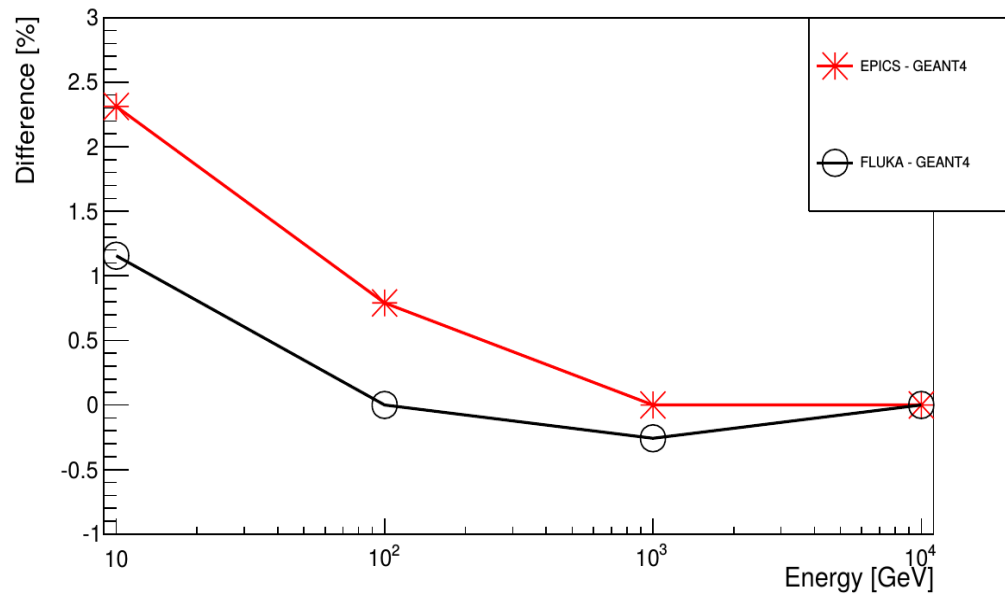
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.07708	0.0523	0.03331	0
EPICS	0.03766	0.04058	0.00871	-73.85
FLUKA	0.06843	0.04656	0.04241	27.3

Summary plots

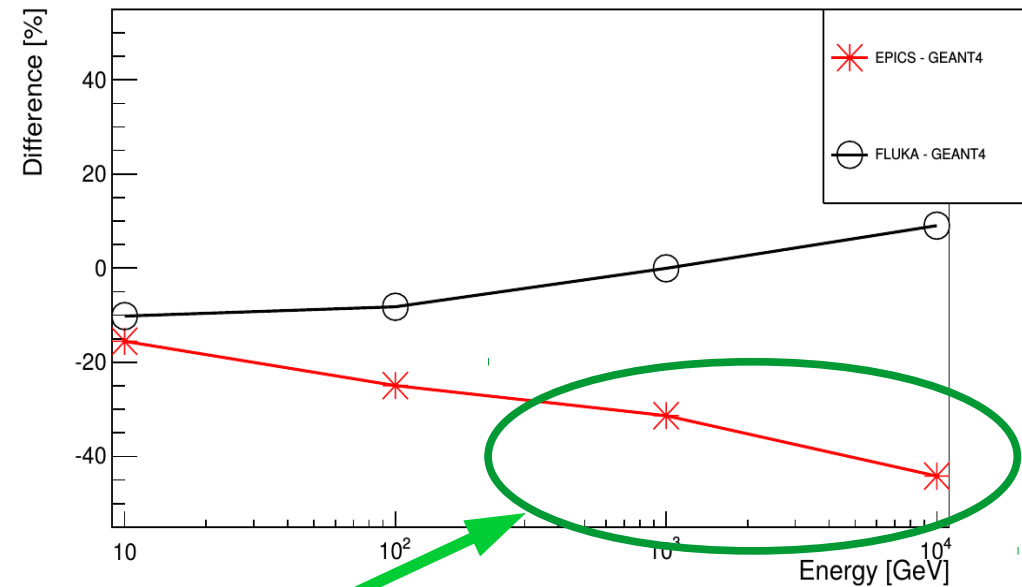
In order to summarize electrons and protons results I will show you some plots with the differences of EPICS and FLUKA with respect to GEANT4:

- Maximum energy bins deposited in TASC vs Energy, for H.E. triggered protons and electrons
- Maximum energy bins deposited in IMC vs Energy, for H.E. triggered protons and electrons
- Maximum energy bins deposited in CHD vs Energy, for H.E. triggered protons and electrons
- Trigger efficiency vs Energy, for H.E. triggered protons and electrons

Electrons: difference in TASC total energy maximum



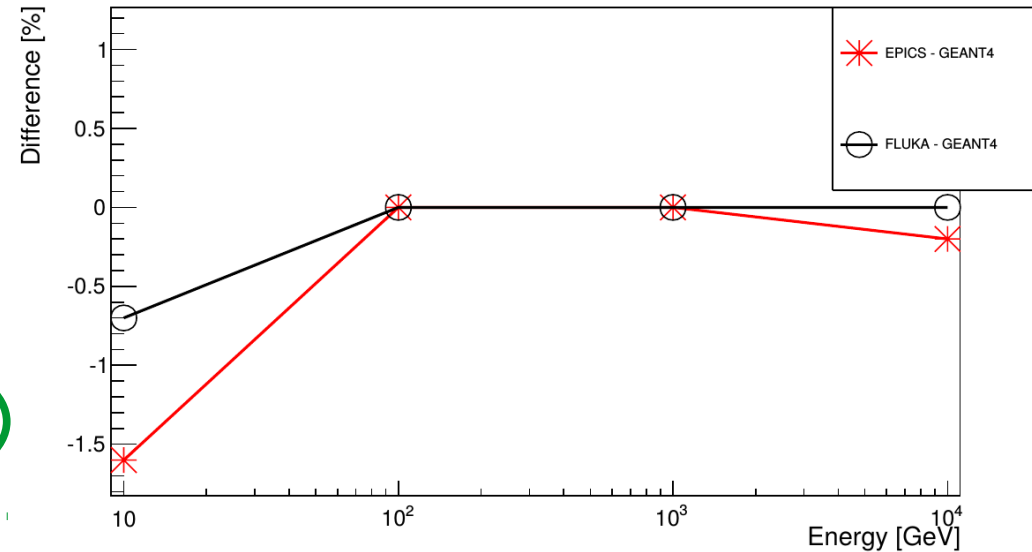
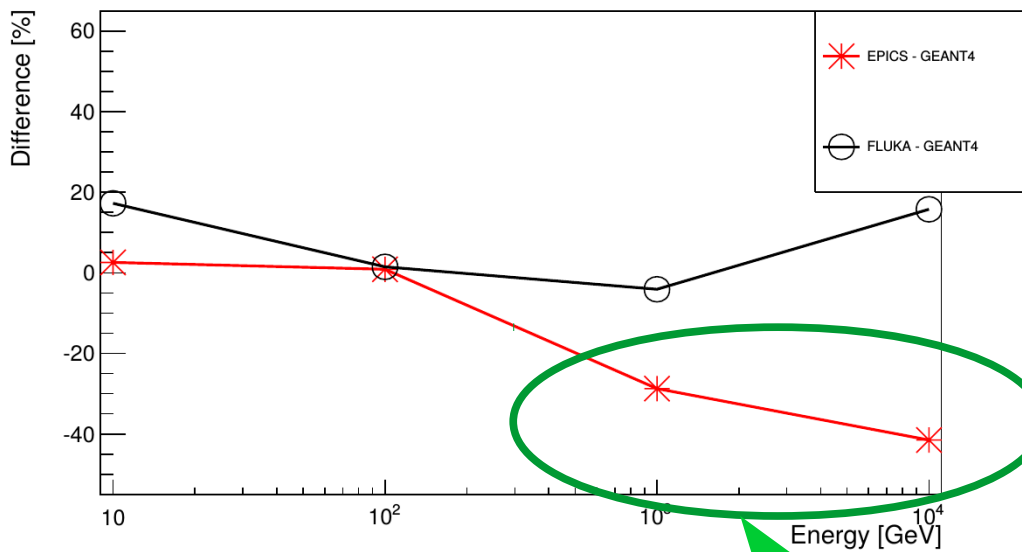
Electrons: difference in IMC total energy maximum



The shape of the distributions for EPICS is very different compared to GEANT4 and FLUKA ones.

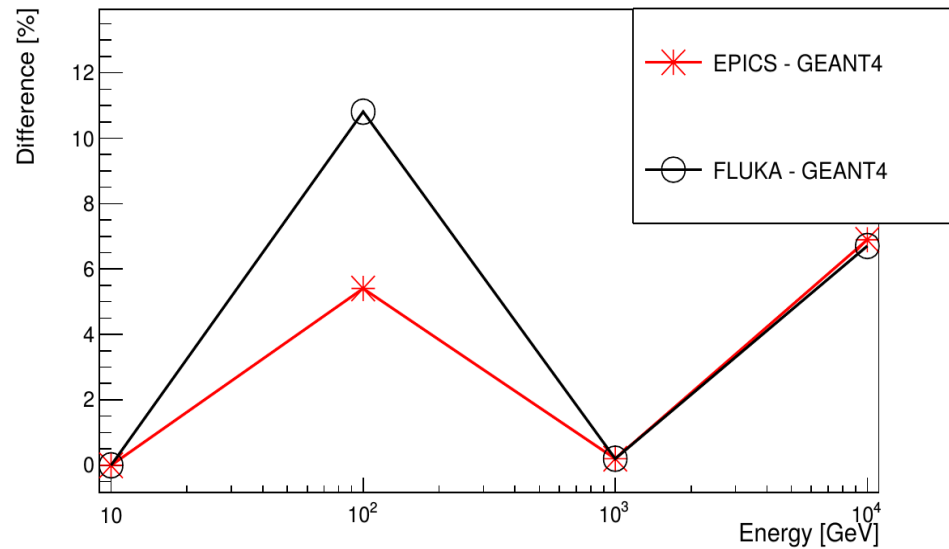
Electrons: difference in CHD total energy maximum

Electrons: difference in High Energy trigger efficiency

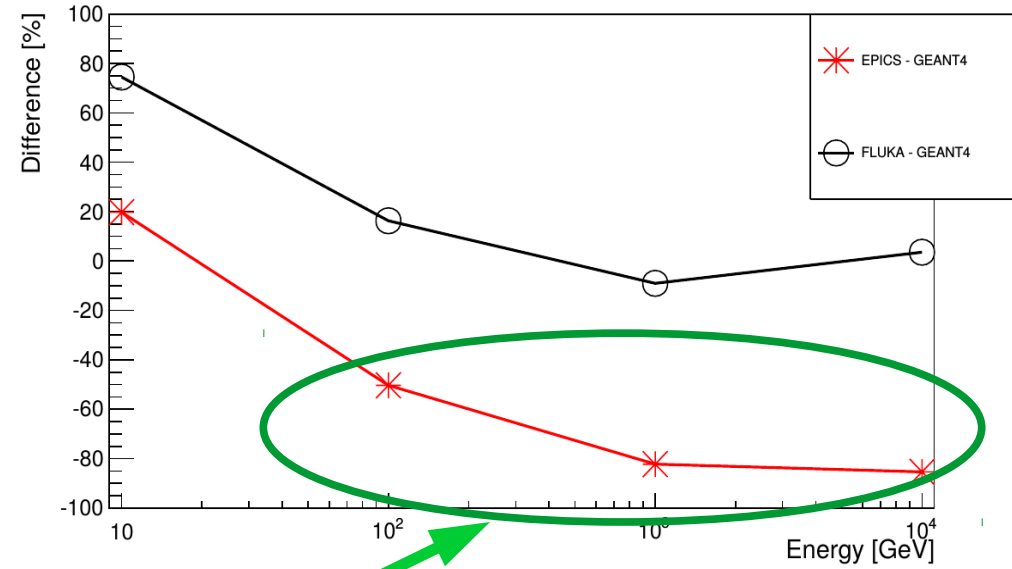


The shape of the distributions for EPICS is very different compared to GEANT4 and FLUKA ones.

Protons: difference in TASC total energy maximum



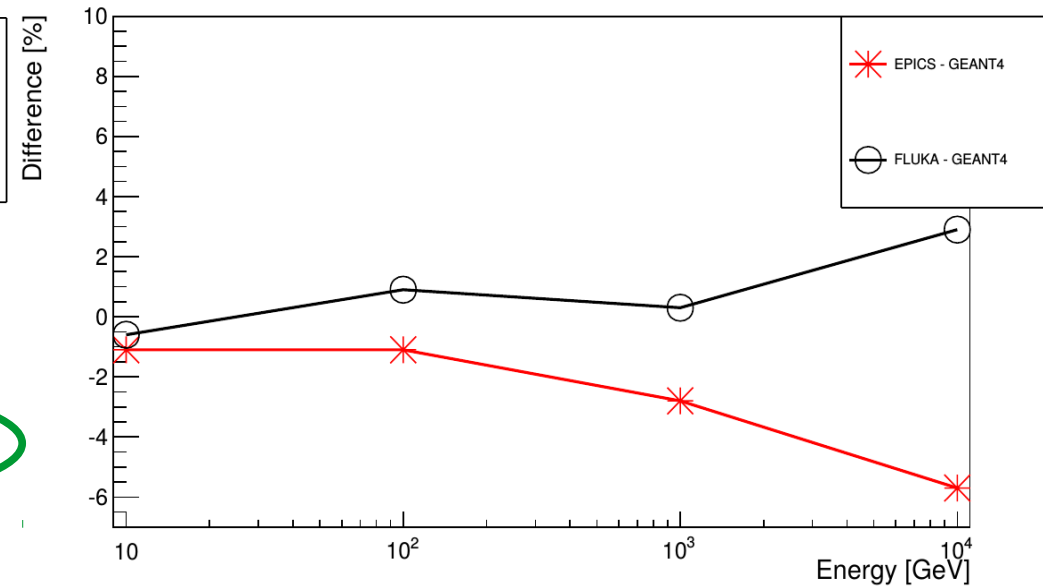
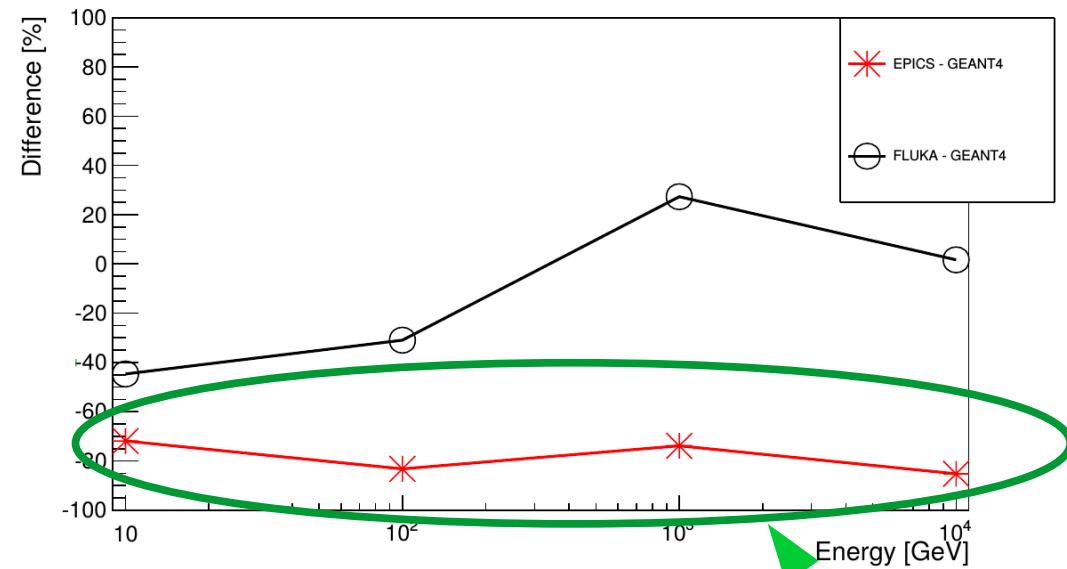
Protons: difference in IMC total energy maximum



The shape of the distributions for EPICS is very different compared to GEANT4 and FLUKA ones.

Protons: difference in CHD total energy maximum.

Protons: difference in High Energy trigger efficiency



The shape of the distributions for EPICS is very different compared to GEANT4 and FLUKA ones.

Conclusion

- Good agreements among the three simulations about the energy deposited in TASC and trigger efficiency
- As far as CHD and IMC response is concerned, we notice a quite good agreement between FLUKA and Geant4.
- **Instead there are significant differences between GEANT4 and EPICS, more and more pronounced as the primary particle energy increases.**
- Because of the good agreement between FLUKA and GEANT4, we can consider the new GEANT4 CALET flight model validated.
- Discrepancies with EPICS need to be investigated accurately.

Possible explanations

1) Different implementation of some volumes of the CALET Flight model in FLUKA/GEANT4 with respect to EPICS?

• *The most important simplification is **Honeycomb**.*

2) *Possible differences in the simulation of the back scattering particles?*

• *It seems that in Epics the amount of backscatter in CHD and IMC is lower.*

To check the conjecture 1) we also simulated electrons and protons with FLUKA, EPICS and GEANT4 using the Calet simplified geometry (Pisa model). The results of this simulations are shown in Caterina's presentation.

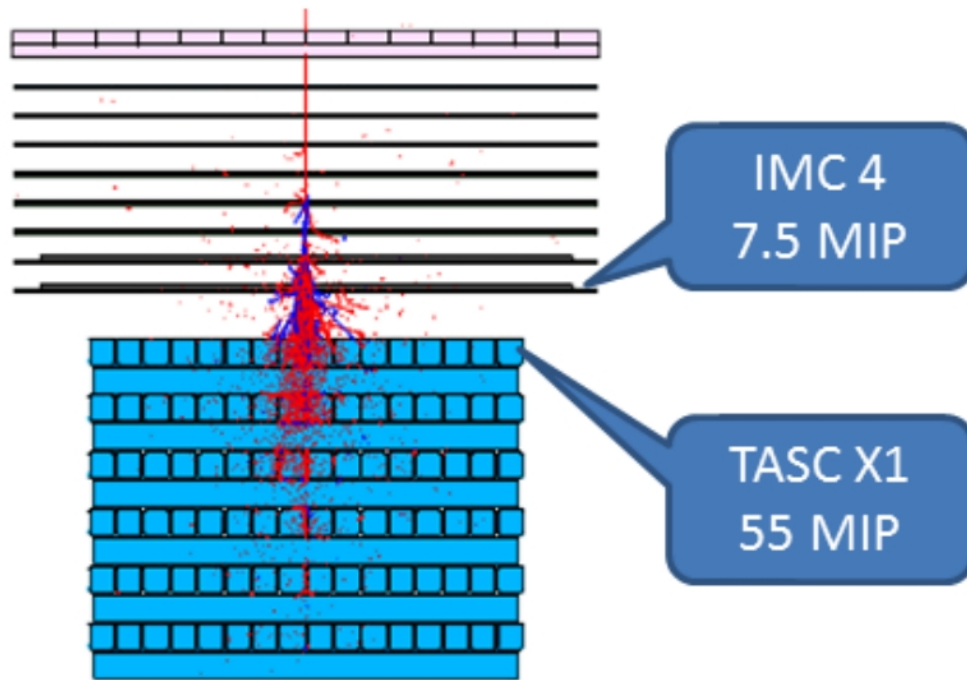
End Of Presentation

Any questions?

Backup slides

Calet High energy trigger

An example of HE event (e^- 10GeV)



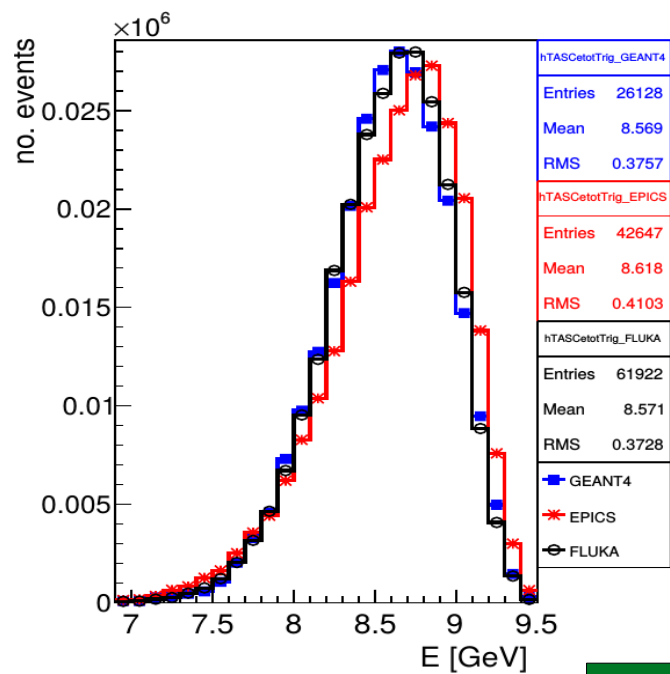
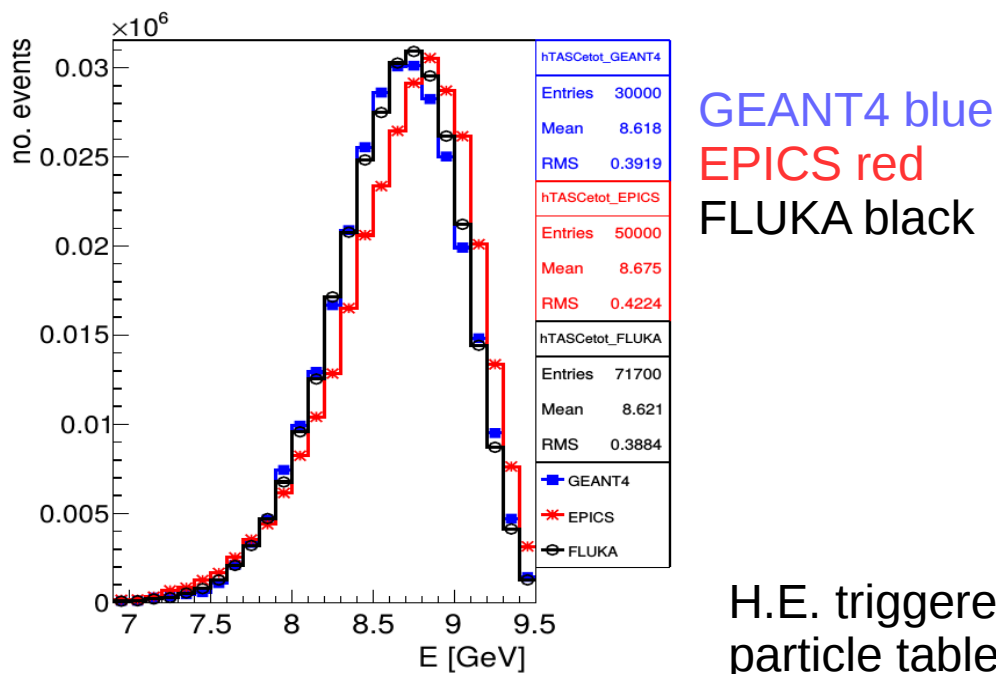
- This is the main trigger mode for CALET
- By requiring a large energy deposit in the middle of the detector,
- Energy in last 2 X layers of IMC > 7.5 MIPs
- Energy in last 2 Y layers of IMC > 7.5 MIPs
- Energy in the first X layers of TASC > 55 MIPs

Questa slide può essere utile ma non è strettamente necessaria. La tolgo?

Electrons plots and
tables: 10, 100, 1000,
10000 GeV

All electrons @ 10 GeV.
Total energy in TASC.

H.E triggered electrons @ 10 GeV.
Total energy in TASC.



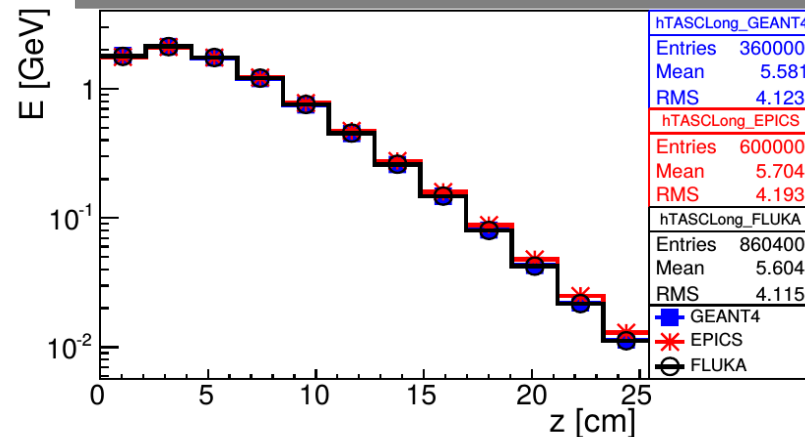
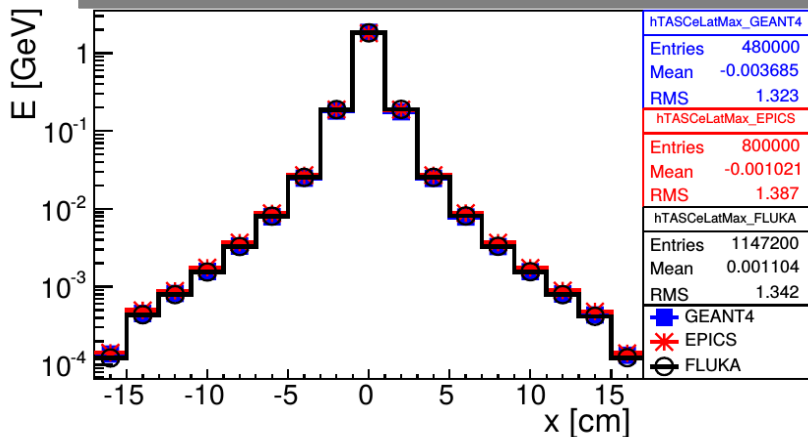
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	8.569	0.3757	8.65	0
EPICS	8.618	0.4103	8.85	2.312
FLUKA	8.571	0.3728	8.75	1.156

H.E.trigger
efficiency
GEANT 87.1%
EPICS 85.3%
FLUKA 86.4%

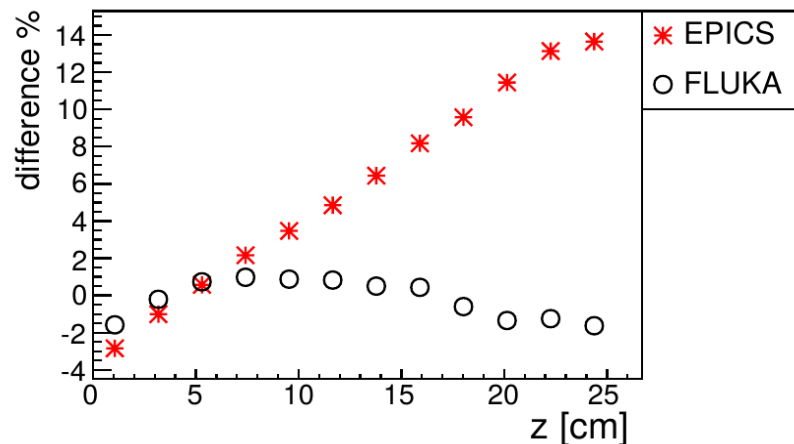
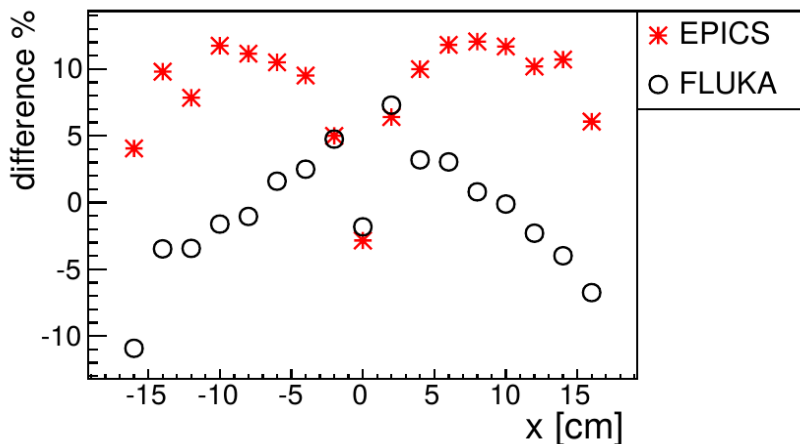
All electrons 10 @ GeV.
TASC lateral distr.

All electrons @ 10 GeV.
TASC longitudinal distr.



Difference with respect to GEANT4

Difference with respect to GEANT4

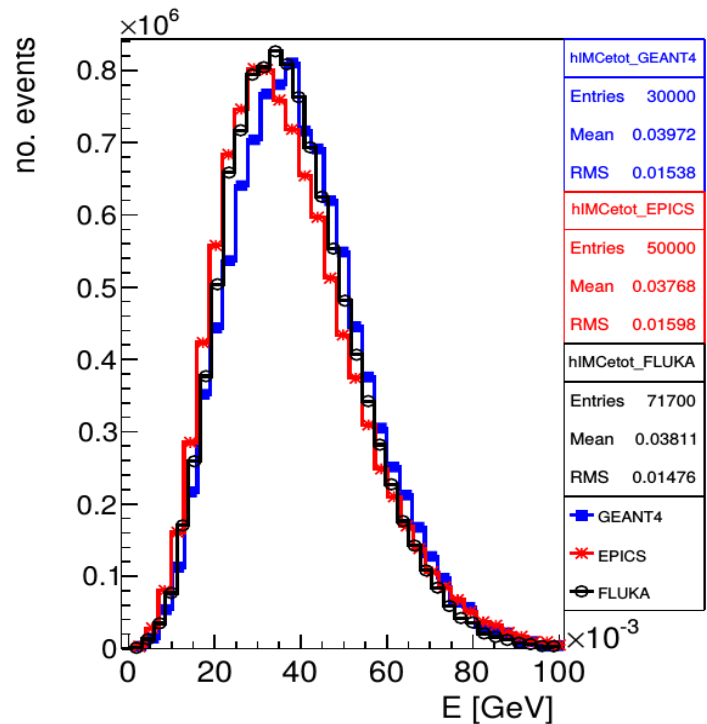


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

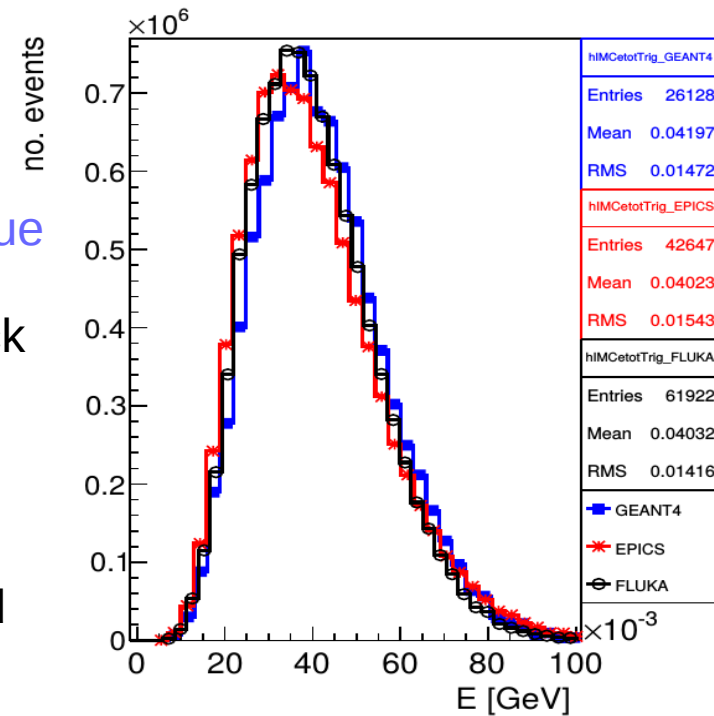
All electrons @ 10 GeV.
Total energy in IMC.

H.E triggered electrons @ 10 GeV.
Total energy in IMC.



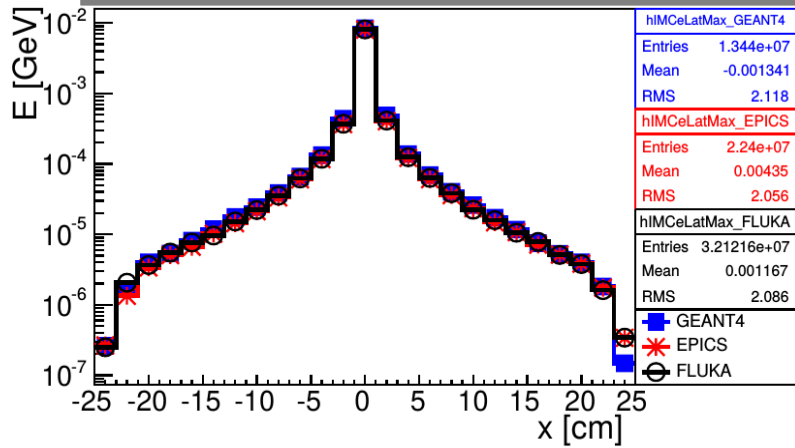
GEANT4 blue
EPICS red
FLUKA black

H.E. triggered
particle table:

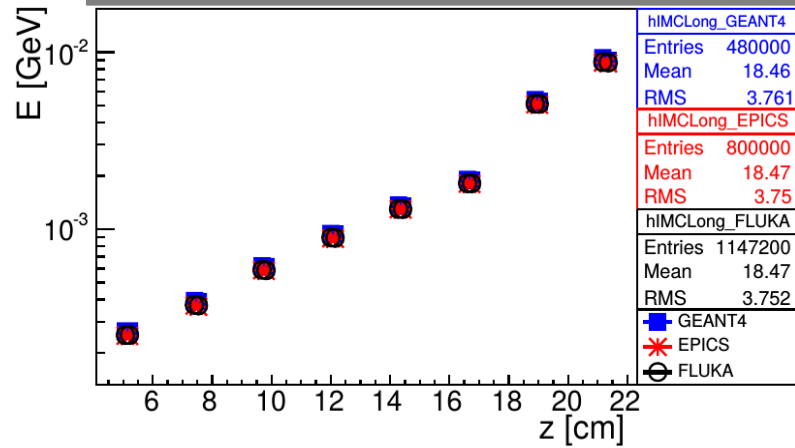


Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.04197	0.01472	0.03802	0
EPICS	0.04023	0.01543	0.03211	-15.54
FLUKA	0.04032	0.01416	0.03415	-10.19

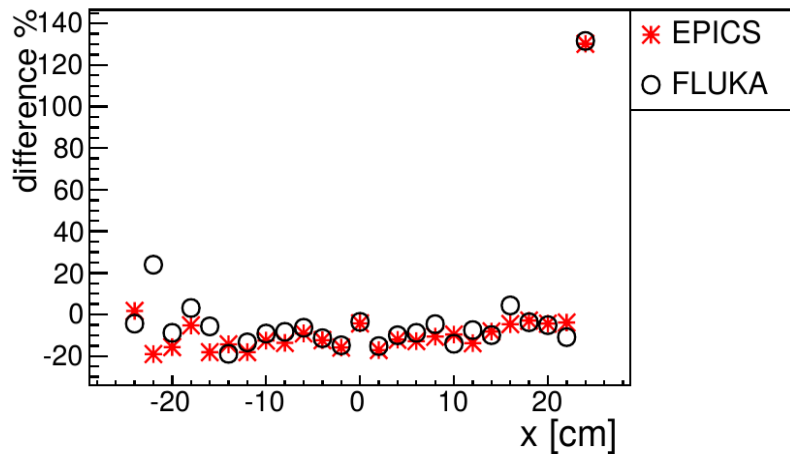
All electrons @ 10 GeV.
IMC lateral distr.



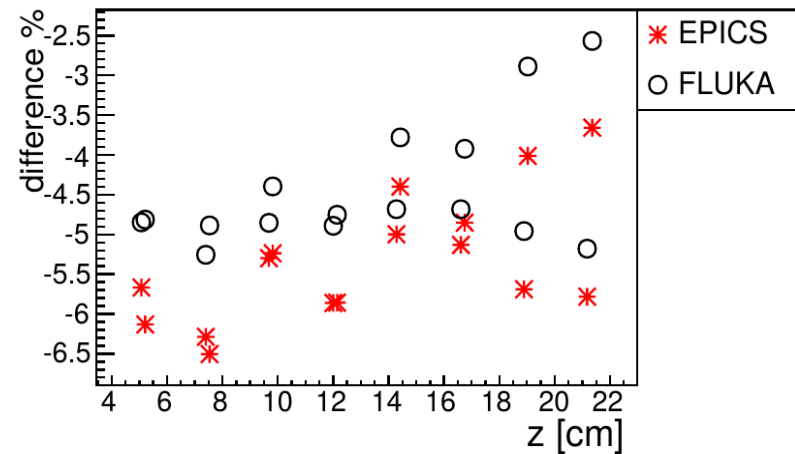
All electrons @ 10 GeV.
IMC longitudinal distr.



Difference with respect to GEANT4



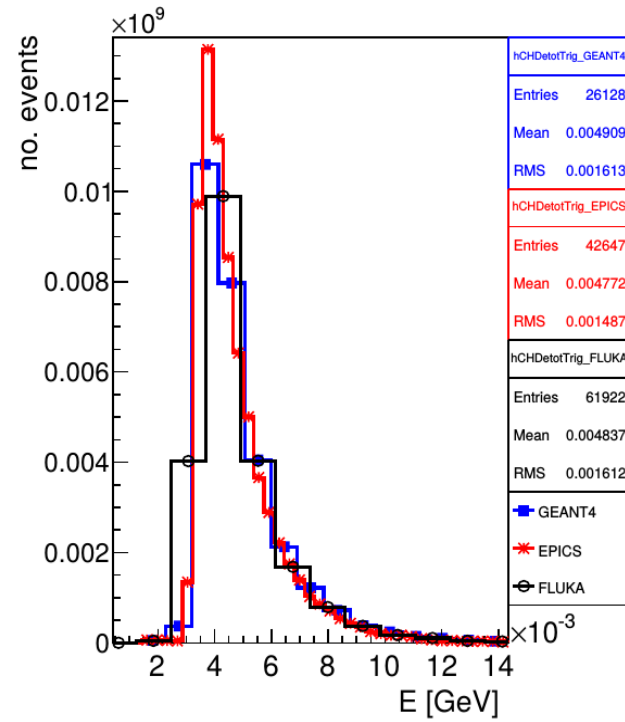
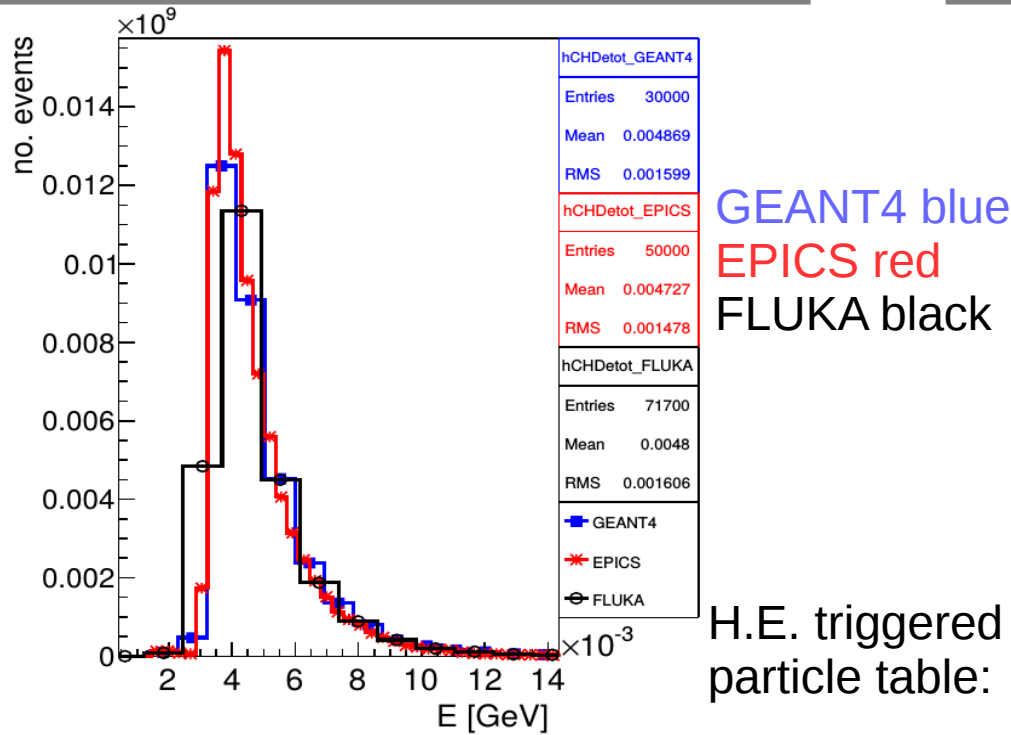
Difference with respect to GEANT4



diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

All electrons @ 10 GeV.
Total energy in CHD.

H.E triggered electrons @ 10 GeV.
Total energy in CHD.

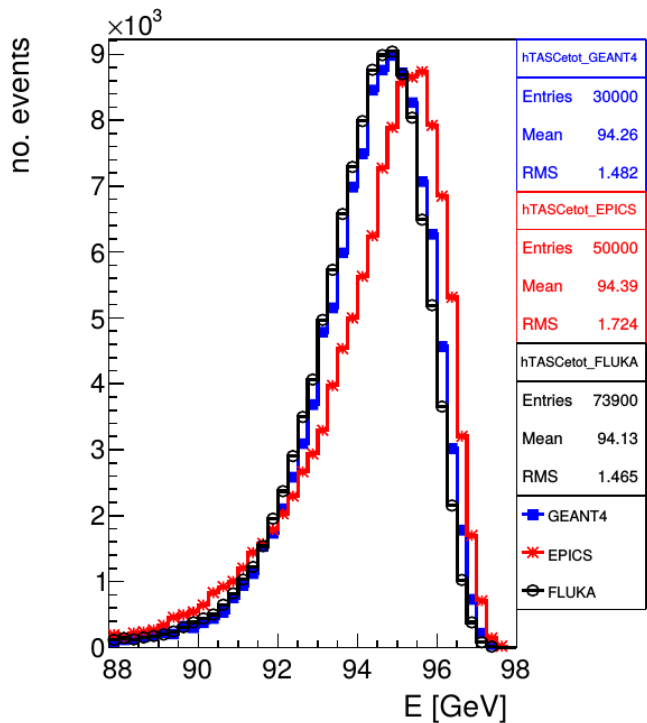


H.E. triggered
particle table:

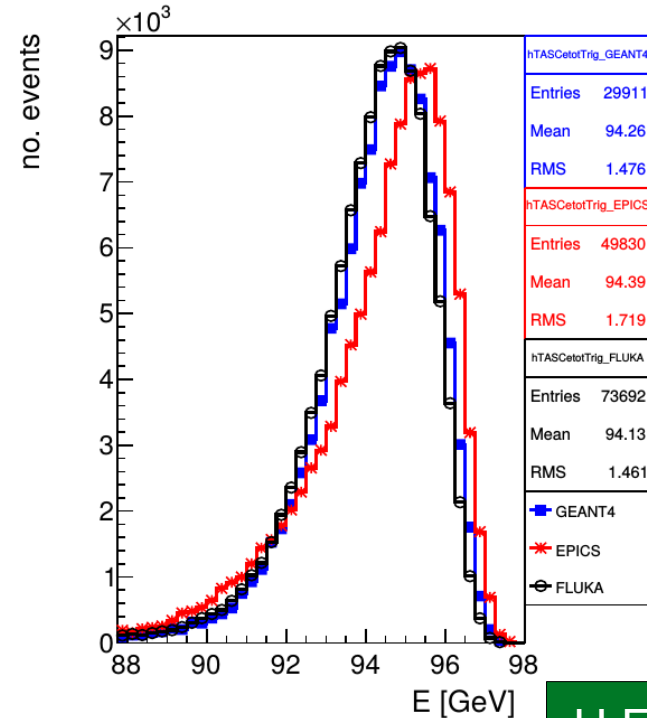
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.004909	0.001613	0.003669	0
EPICS	0.004772	0.001487	0.003763	2.577
FLUKA	0.004837	0.001612	0.004302	17.24

All electrons @ 100 GeV.
Total energy in TASC.

H.E triggered electrons @ 100 GeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black



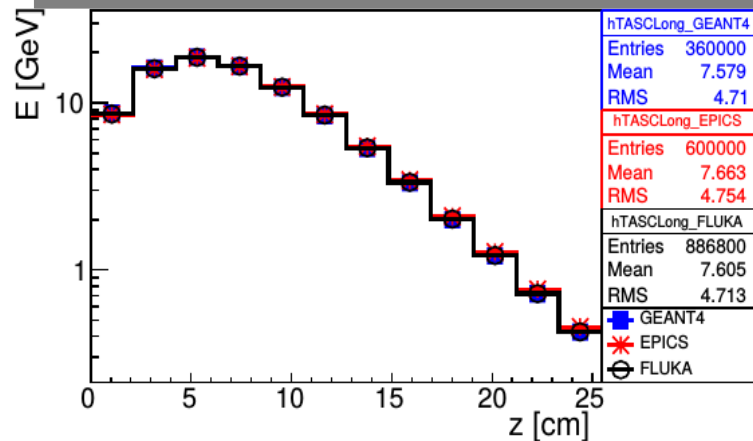
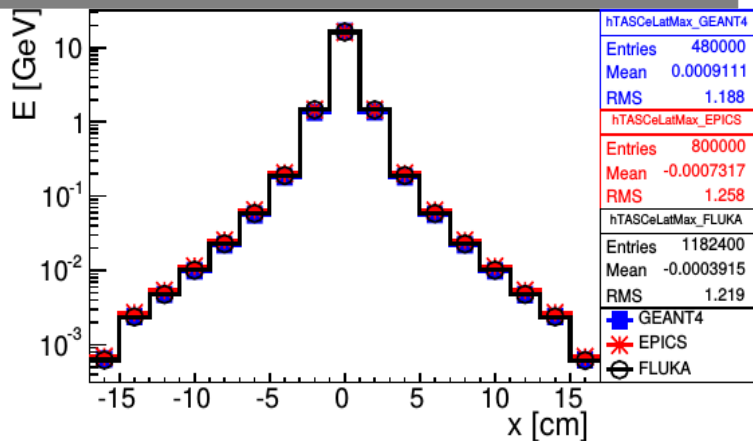
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	94.26	1.476	94.88	0
EPICS	94.39	1.719	95.63	0.7904
FLUKA	94.13	1.461	94.88	0

H.E.trigger
efficiency
GEANT 99.7%
EPICS 99.7%
FLUKA 99.7%

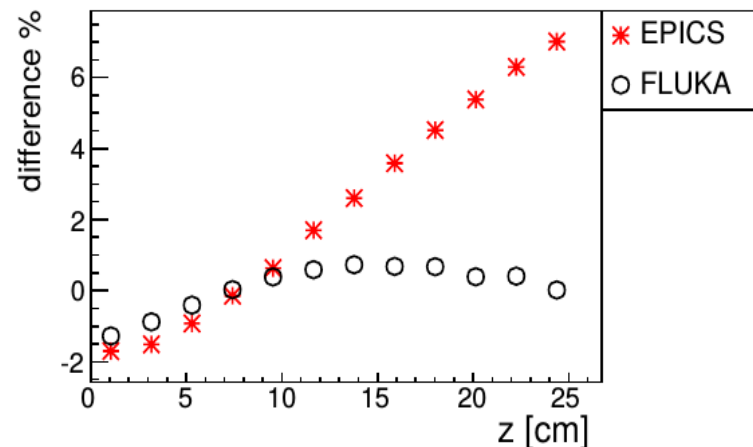
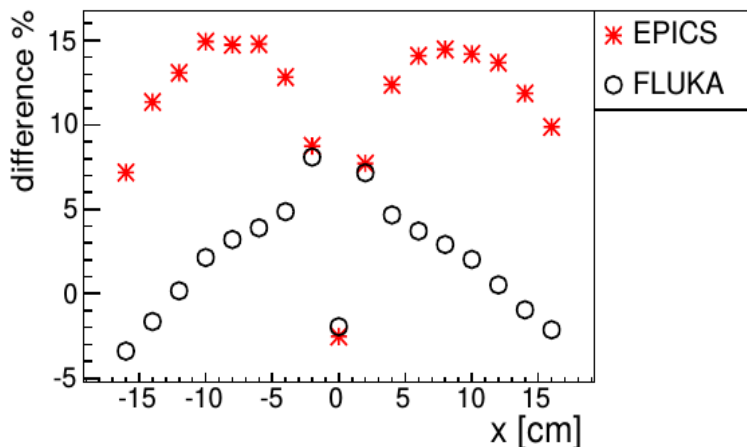
All electrons @ 100 GeV.
TASC lateral distr.

All electrons @ 100 GeV.
TASC longitudinal distr.



Difference with respect to GEANT4

Difference with respect to GEANT4

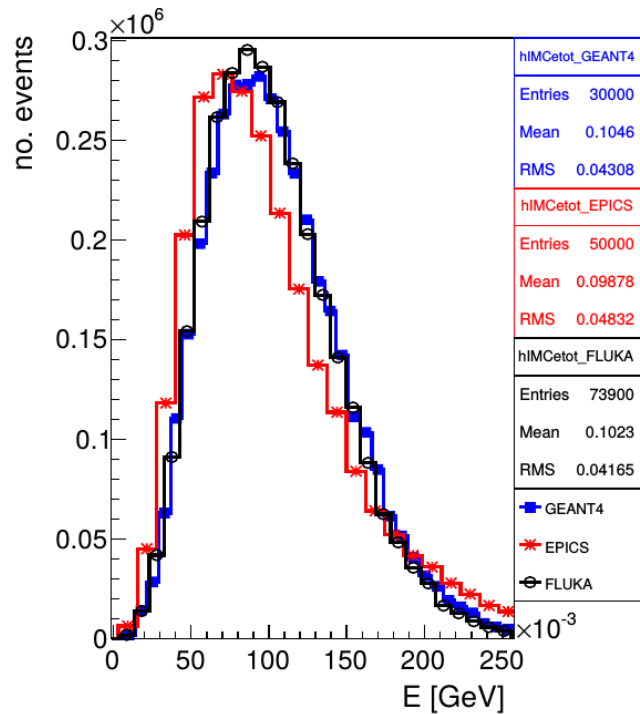


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

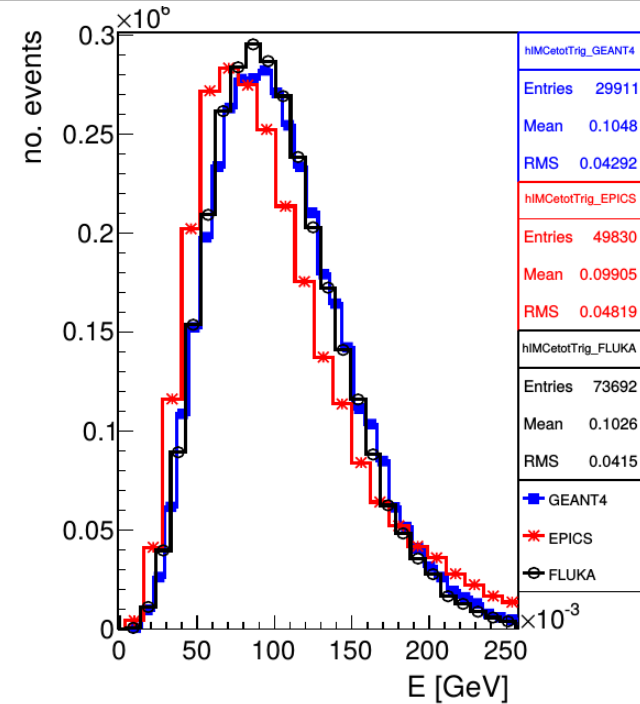
All electrons @ 100 GeV.
Total energy in IMC.

H.E triggered electrons @ 100 GeV.
Total energy in IMC.



GEANT4 blue
EPICS red
FLUKA black

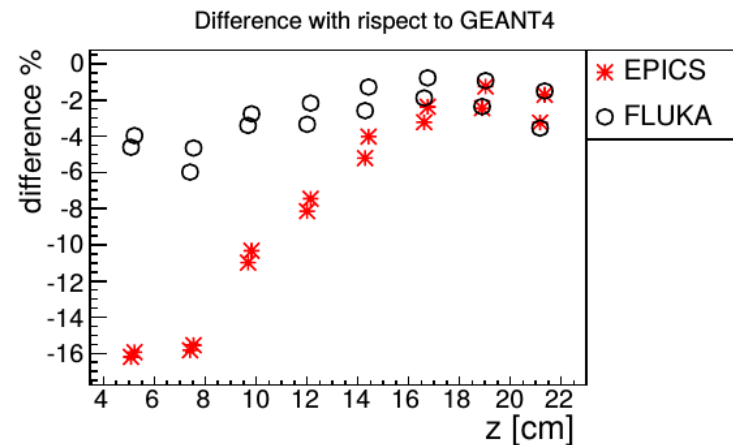
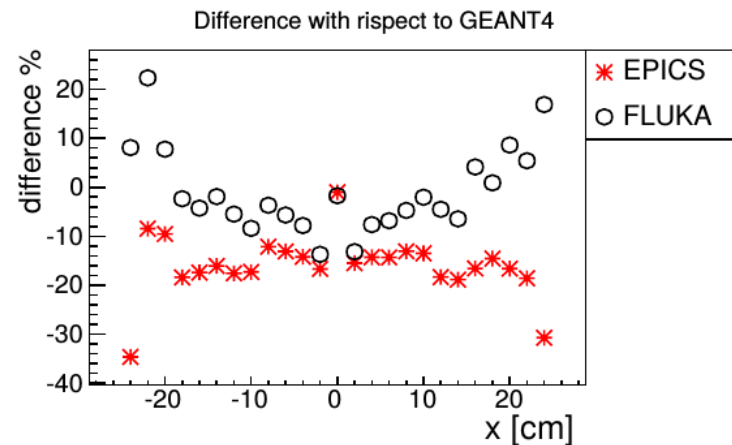
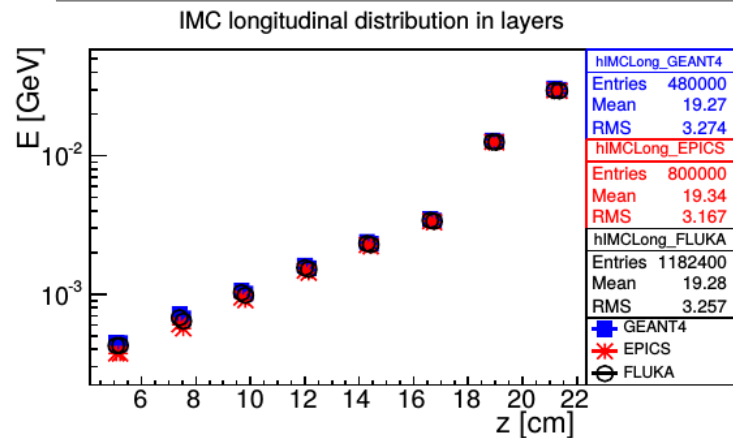
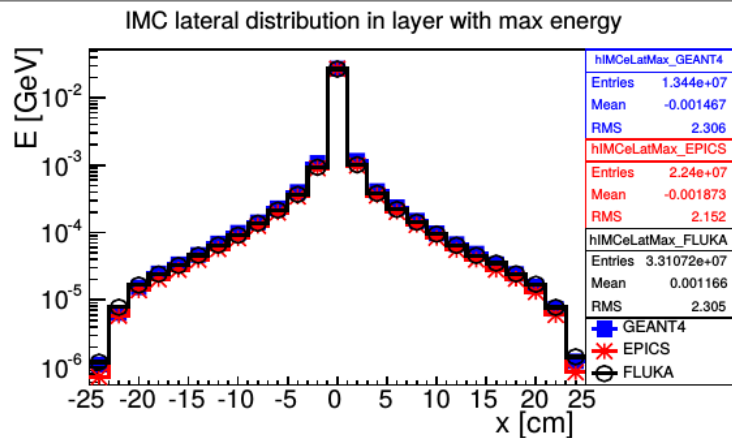
H.E. triggered
particle table:



Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.1048	0.04292	0.09389	0
EPICS	0.09905	0.04819	0.07047	-24.95
FLUKA	0.1026	0.0415	0.08618	-8.213

All electrons @ 100 GeV.
IMC lateral distr.

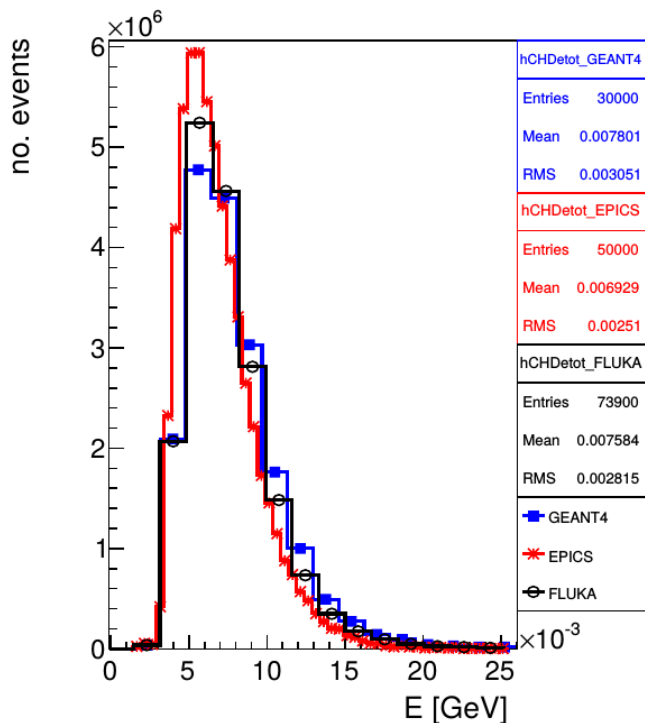
All electrons @ 100 GeV.
IMC longitudinal distr.



diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

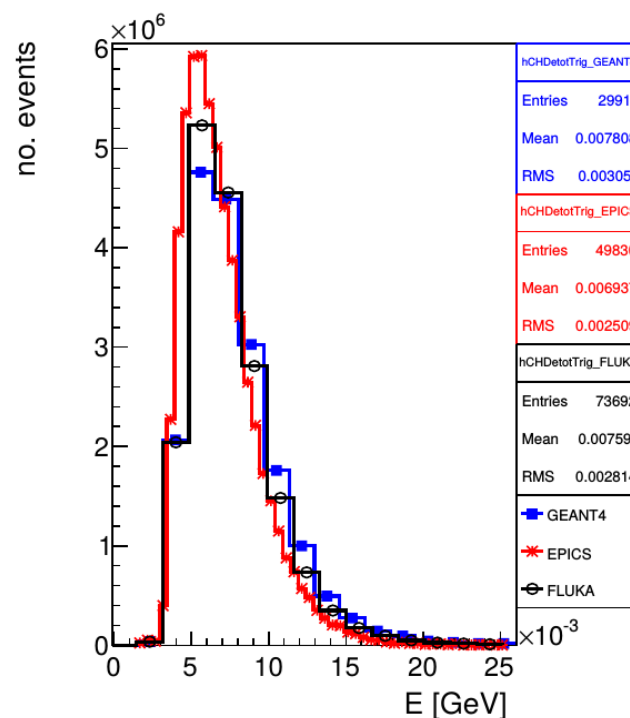
All electrons @ 100 GeV.
Total energy in CHD.

H.E triggered electrons @ 100 GeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black

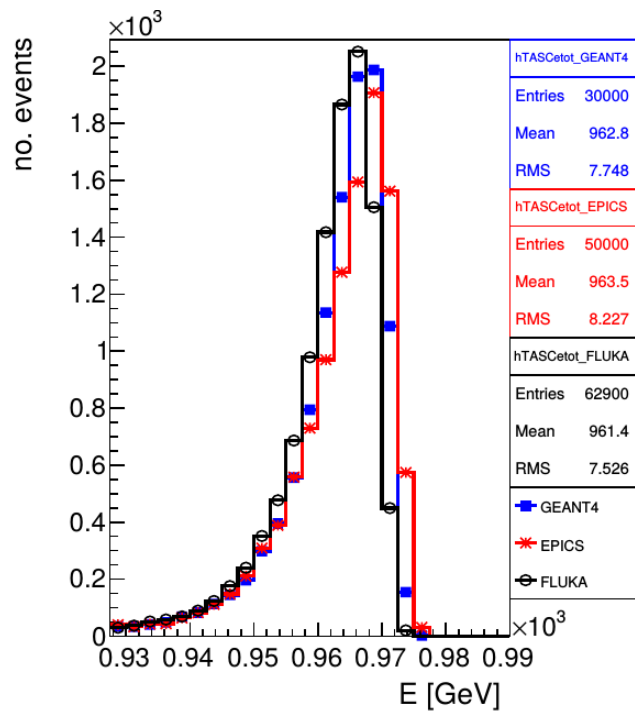
H.E. triggered
particle table:



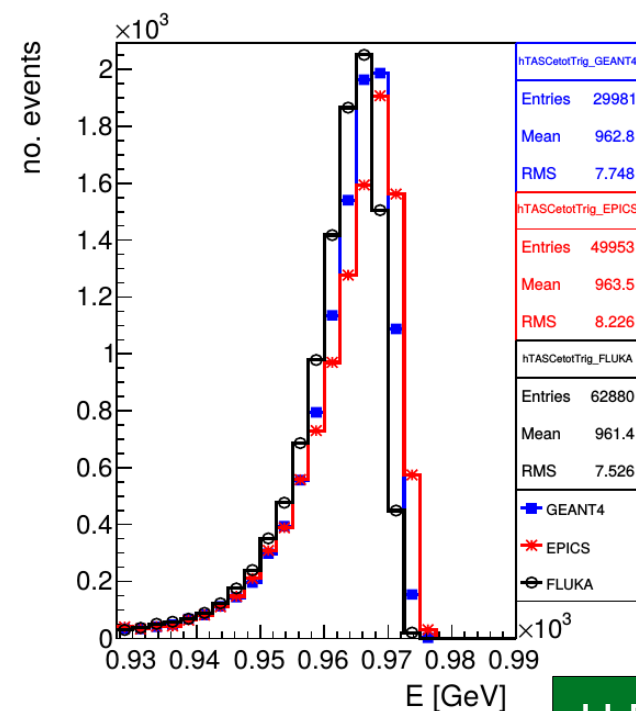
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.007808	0.003051	0.005603	0
EPICS	0.006937	0.002509	0.005652	0.8731
FLUKA	0.007591	0.002814	0.005686	1.48

All electrons @ 1 TeV.
Total energy in TASC.

H.E triggered electrons @ 1 TeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

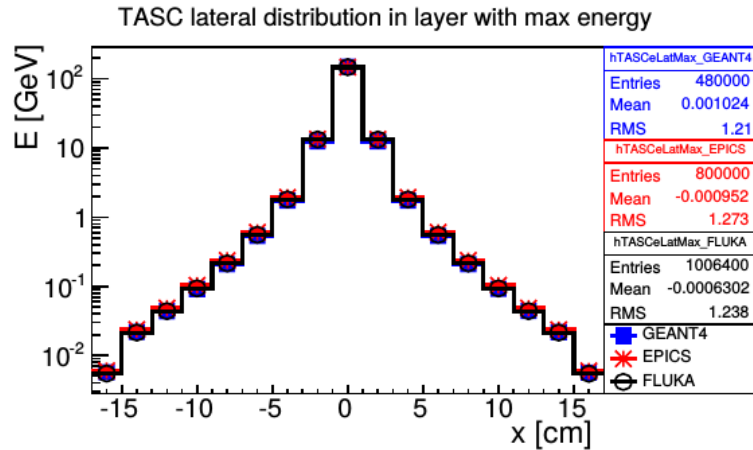


H.E. triggered
particle table:

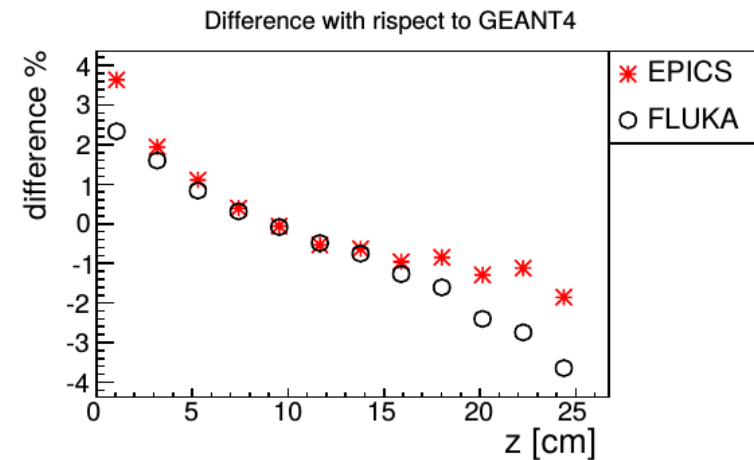
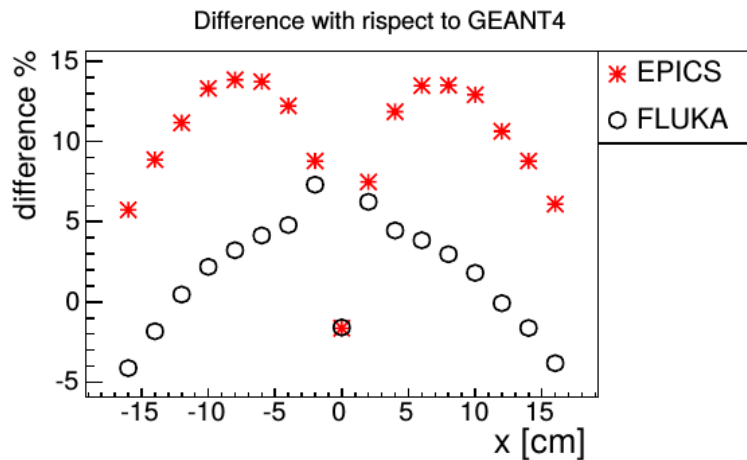
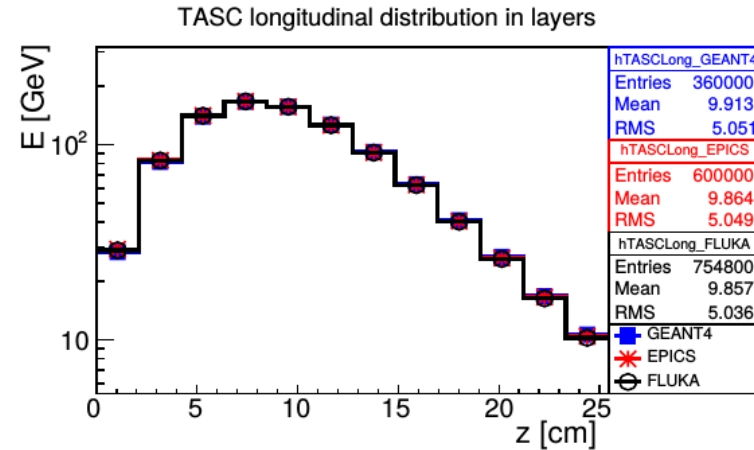
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	962.8	7.748	968.8	0
EPICS	963.5	8.226	968.8	0
FLUKA	961.4	7.526	966.3	-0.258

H.E.trigger
efficiency
GEANT 99.9%
EPICS 99.9%
FLUKA 99.9%

All electrons @ 1 TeV.
TASC lateral distr.



All electrons @ 1 TeV.
TASC longitudinal distr.

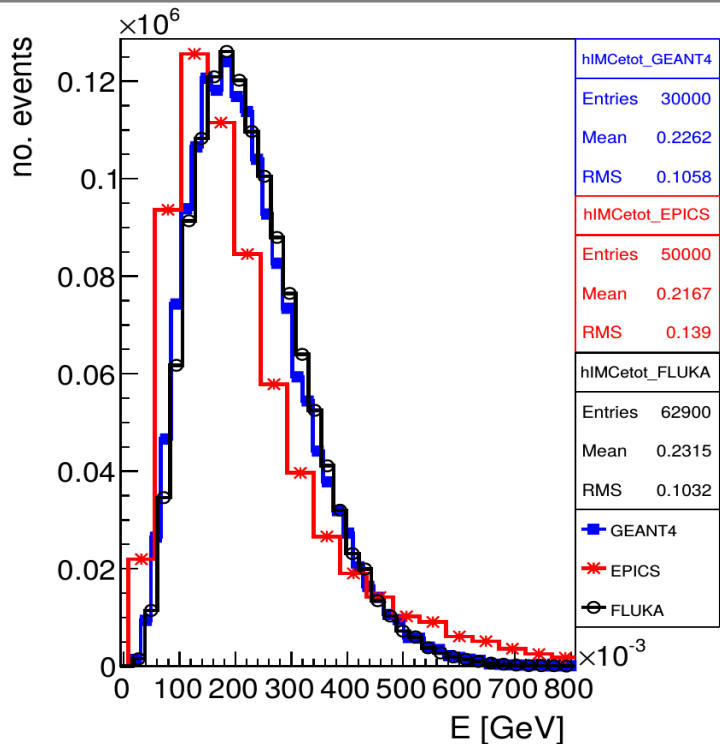


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

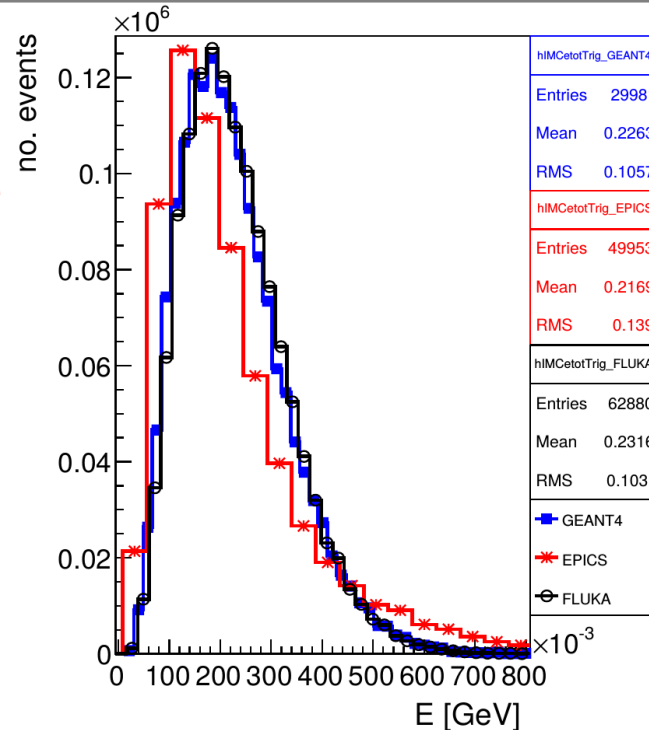
All electrons @ 1 TeV.
Total energy in IMC.

H.E triggered electrons @ 1 TeV.
Total energy in IMC.



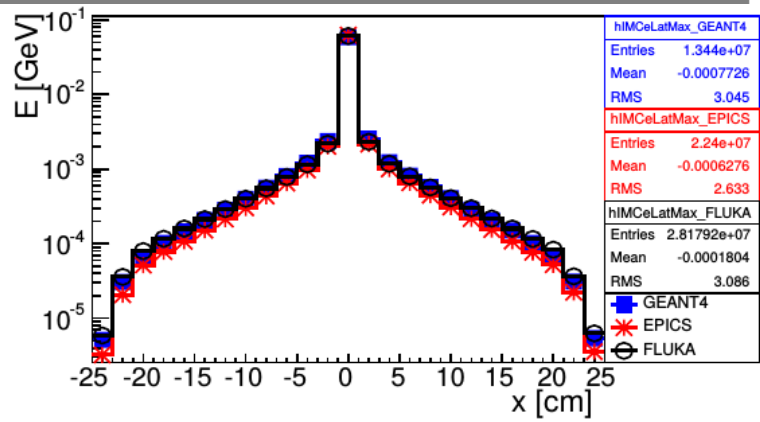
EPICS distributions are not in agreement with GEANT4 and FLUKA.

H.E. triggered particle table:

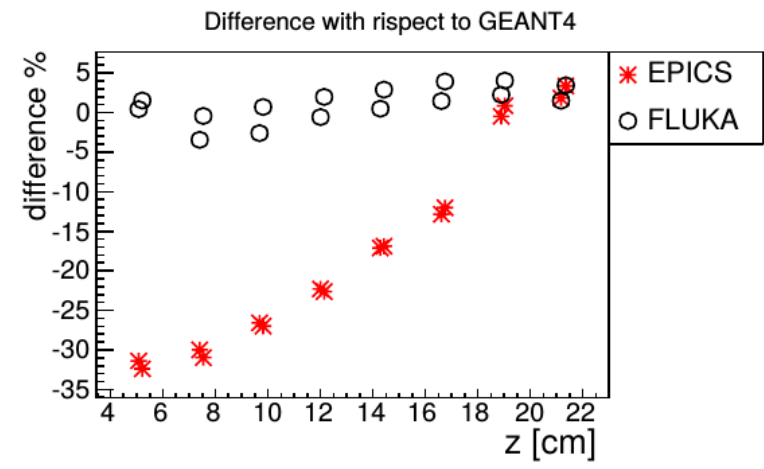
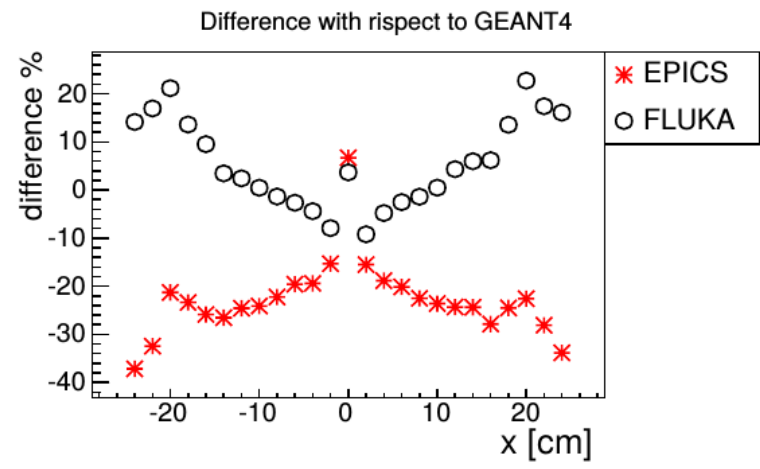
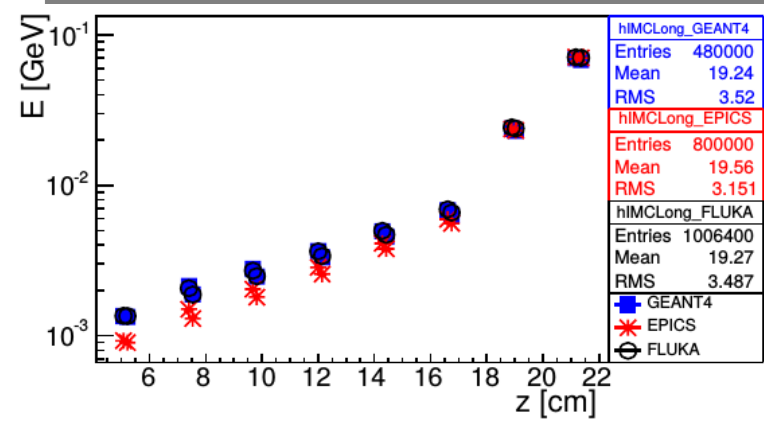


Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.2263	0.1057	0.1844	0
EPICS	0.2169	0.139	0.1266	-31.34
FLUKA	0.2316	0.1031	0.1844	-0.042

All electrons @ 1 TeV.
IMC lateral distr.



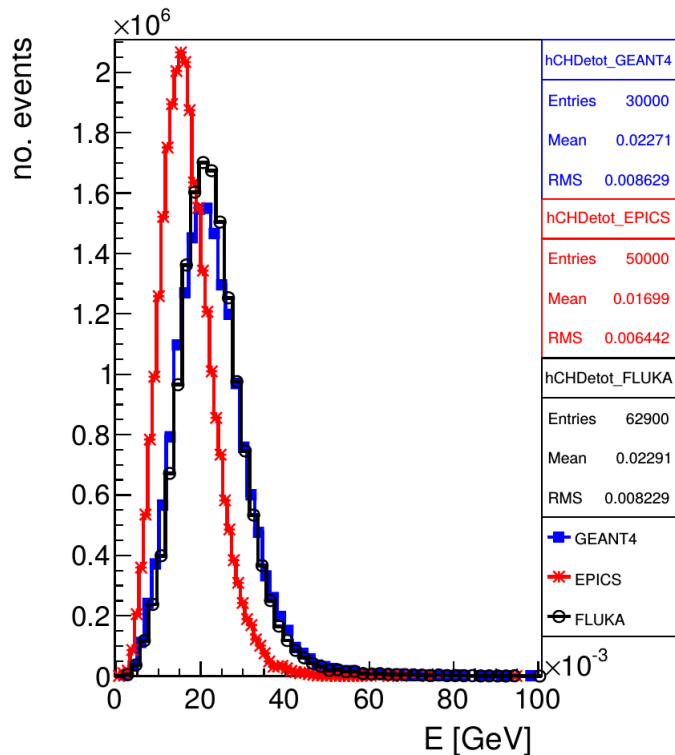
All electrons @ 1 TeV.
IMC longitudinal distr.



diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

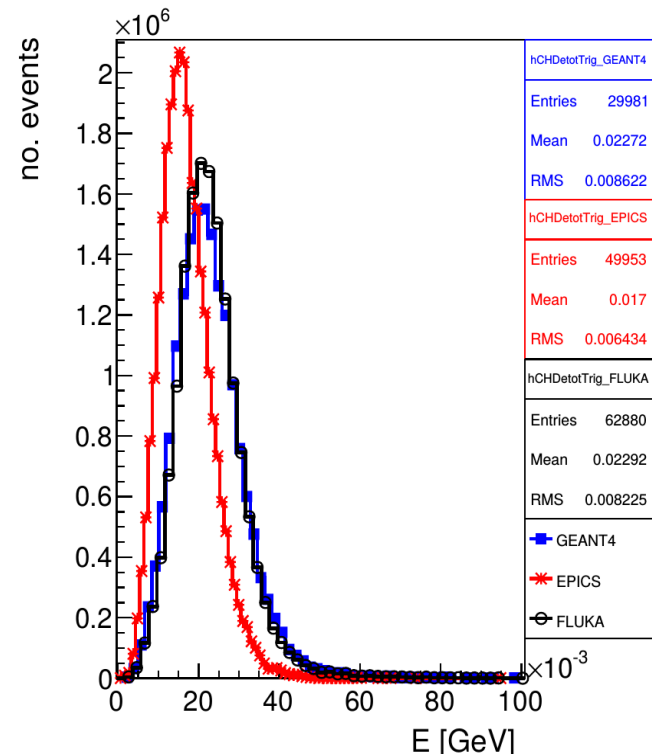
All electrons @ 1 TeV.
Total energy in CHD.

H.E triggered electrons @ 1 TeV.
Total energy in CHD.



EPICS distributions are not in agreement with GEANT4 and FLUKA.

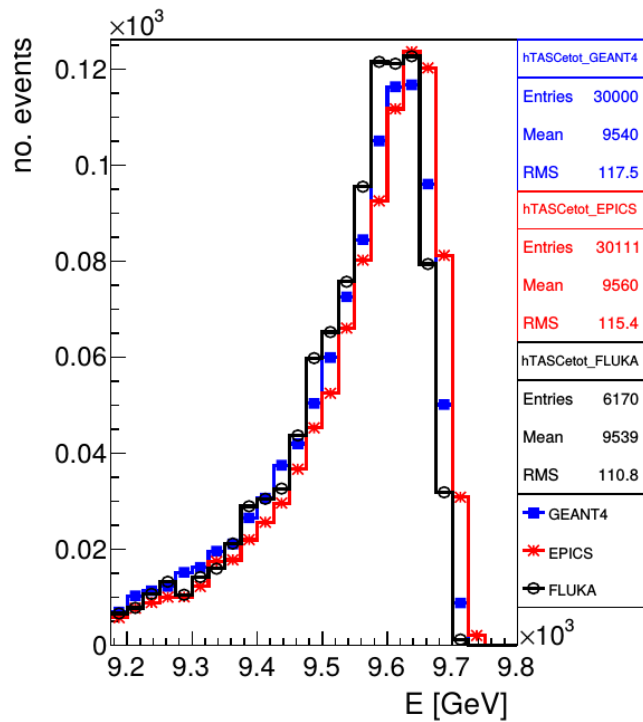
H.E. triggered particle table:



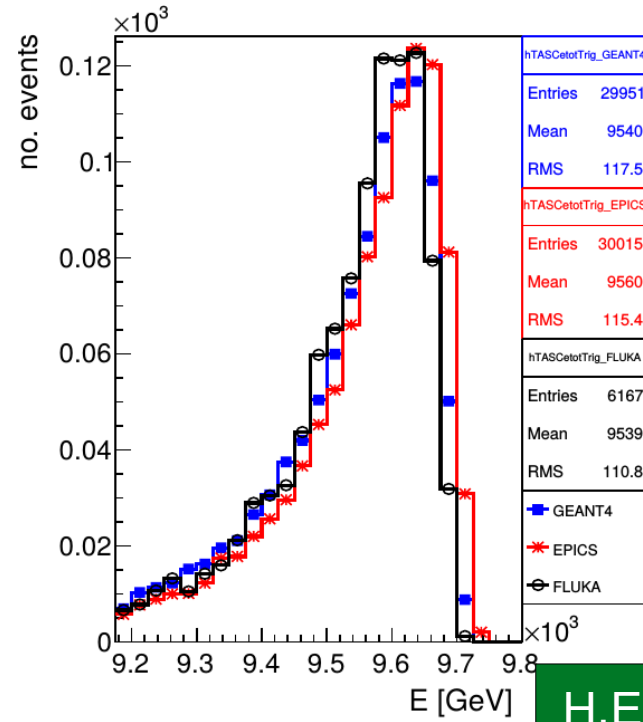
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.02272	0.008622	0.02148	0
EPICS	0.017	0.006434	0.01531	-28.74
FLUKA	0.02292	0.008225	0.0206	-4.088

All electrons @ 10 TeV.
Total energy in TASC.

H.E triggered electrons @ 10 TeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

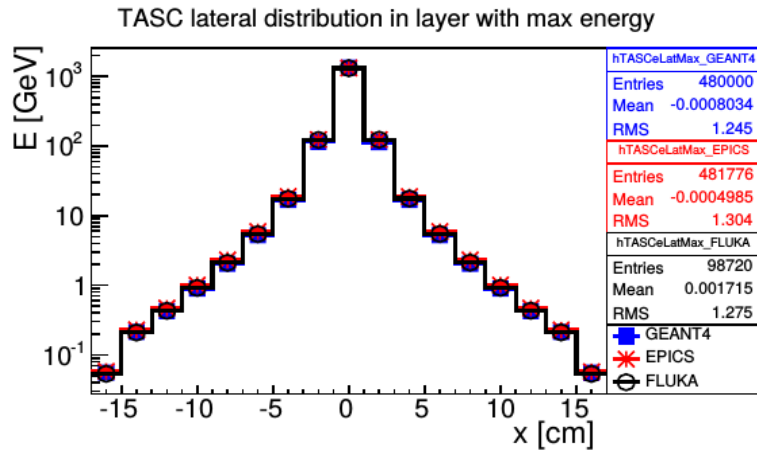


H.E. triggered
particle table:

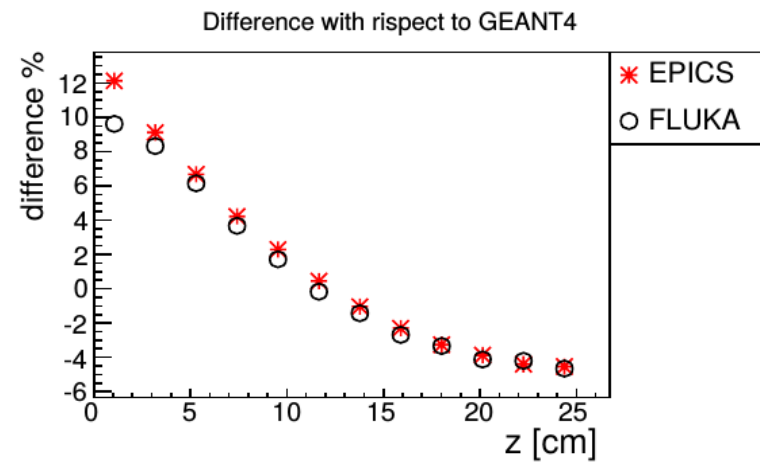
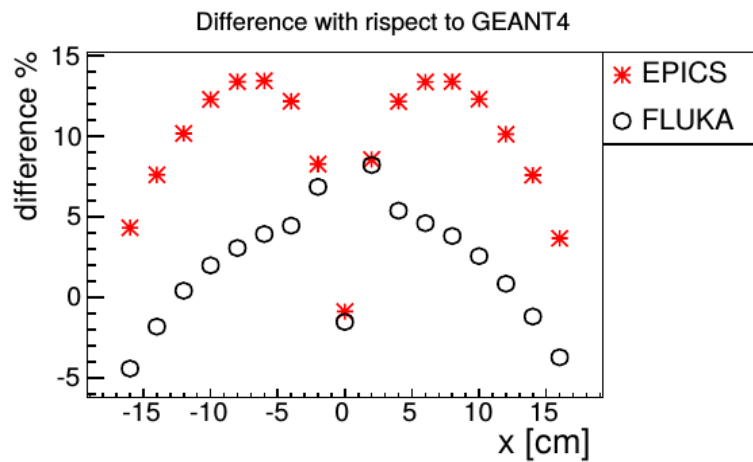
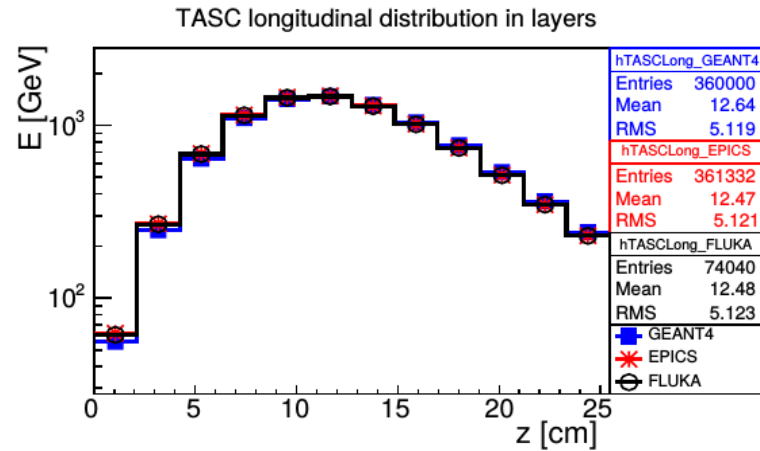
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	9540	117.5	9638	0
EPICS	9560	115.4	9638	0
FLUKA	9539	110.8	9638	0

H.E.trigger
efficiency
GEANT 99.9%
EPICS 99.7%
FLUKA 99.9%

All electrons @ 10 TeV.
TASC lateral distr.



All electrons @ 10 TeV.
TASC longitudinal distr.

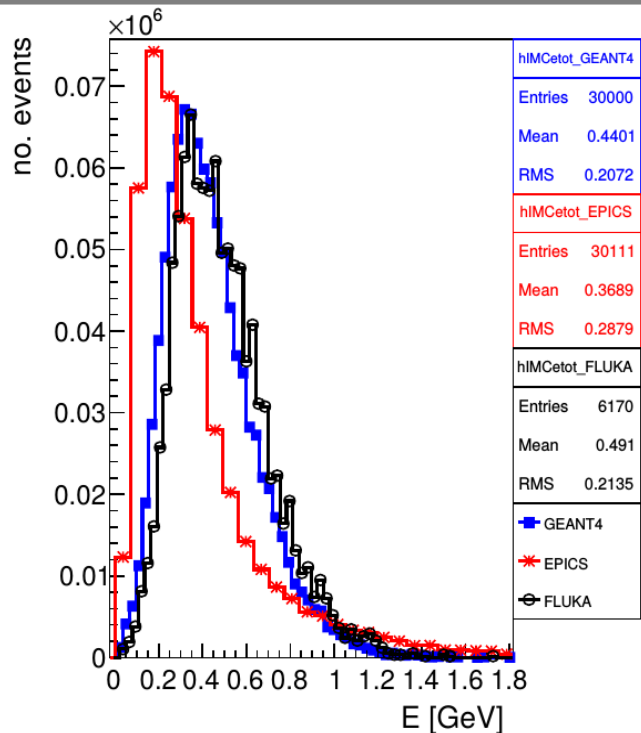


diff = EPICS/GEANT4 - 1 (rosso)

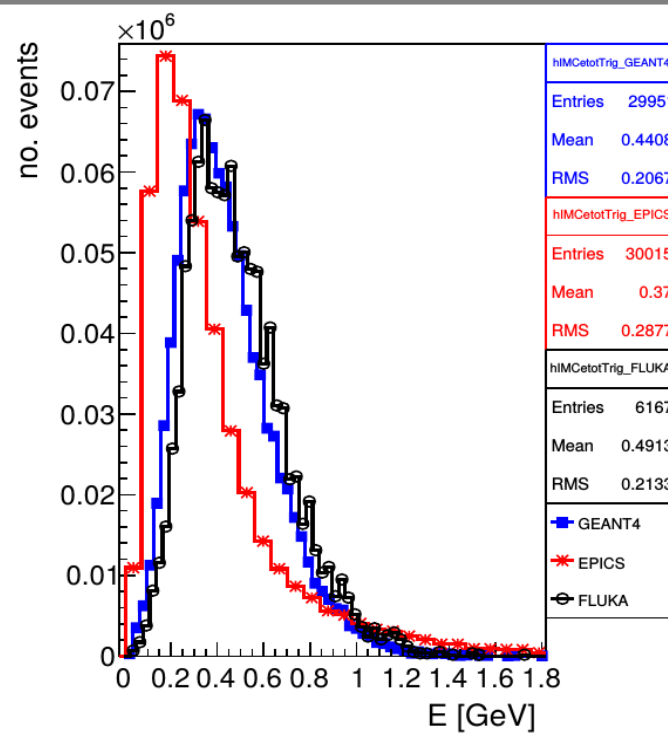
diff = FLUKA/GEANT4 - 1 (nero)

All electrons @ 10 TeV.
Total energy in IMC.

H.E triggered electrons @ 10 TeV.
Total energy in IMC.



GEANT4 blue
EPICS red
FLUKA black

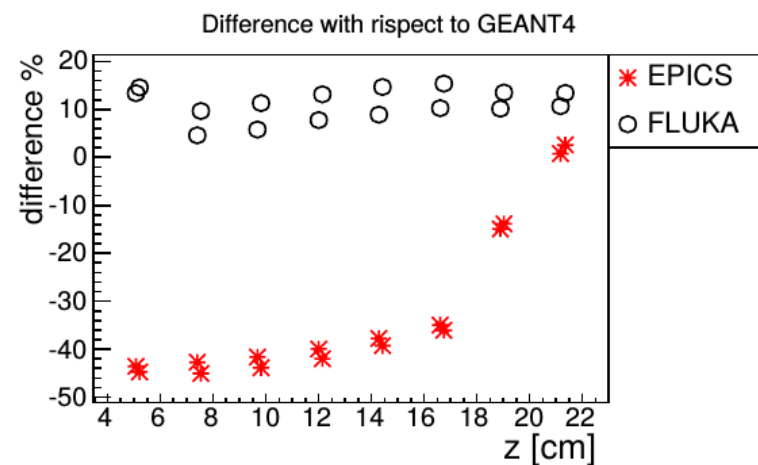
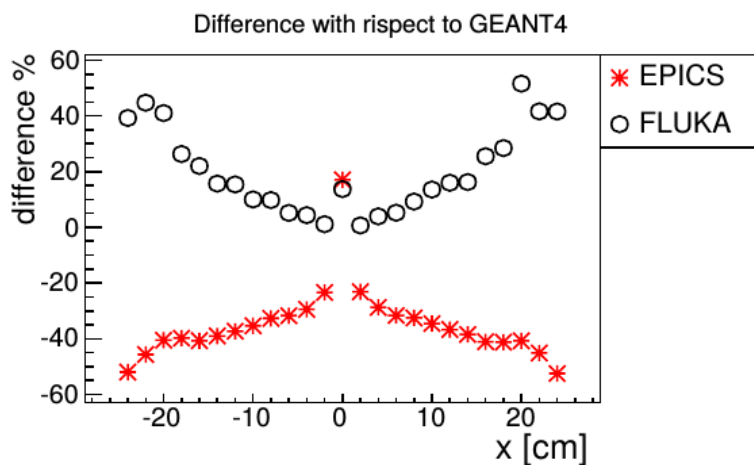
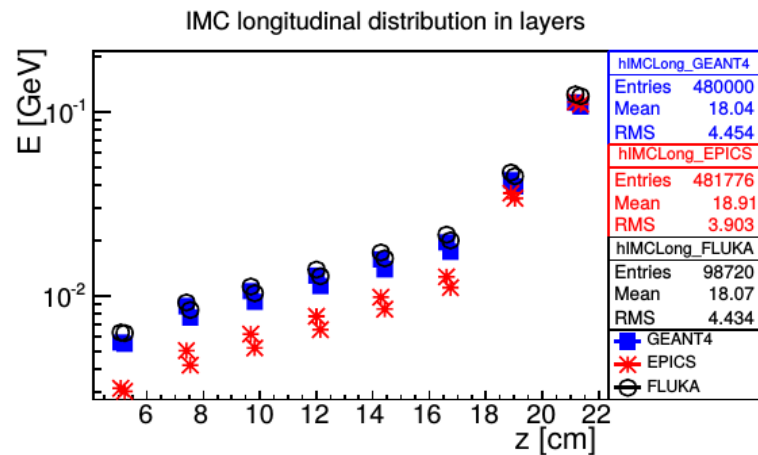
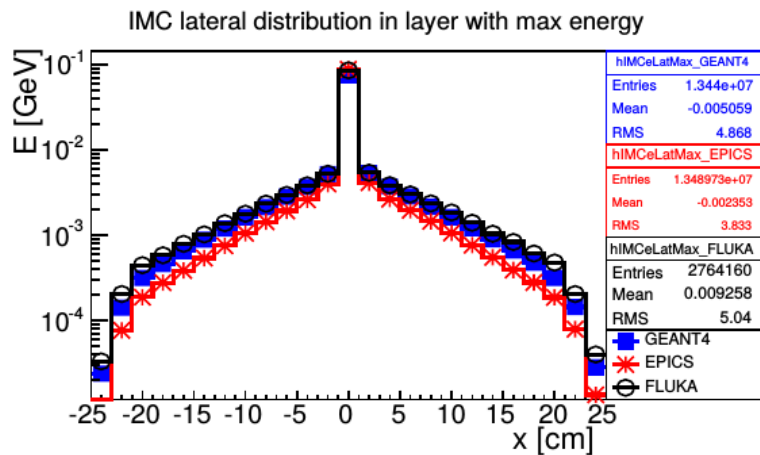


H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.4408	0.2067	0.3182	0
EPICS	0.37	0.2877	0.1777	-44.17
FLUKA	0.4913	0.2133	0.3469	9.024

All electrons @ 10 TeV.
IMC lateral distr.

All electrons @ 10 TeV.
IMC longitudinal distr.

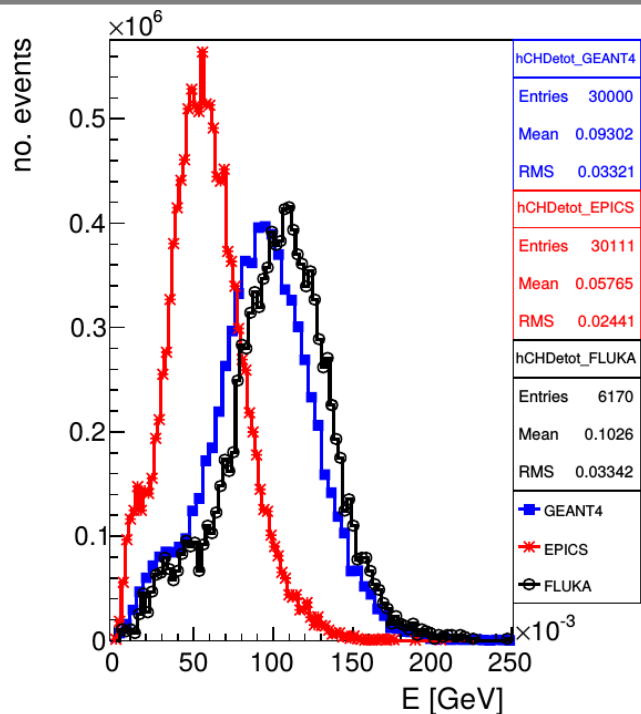


diff = EPICS/GEANT4 - 1 (rosso)

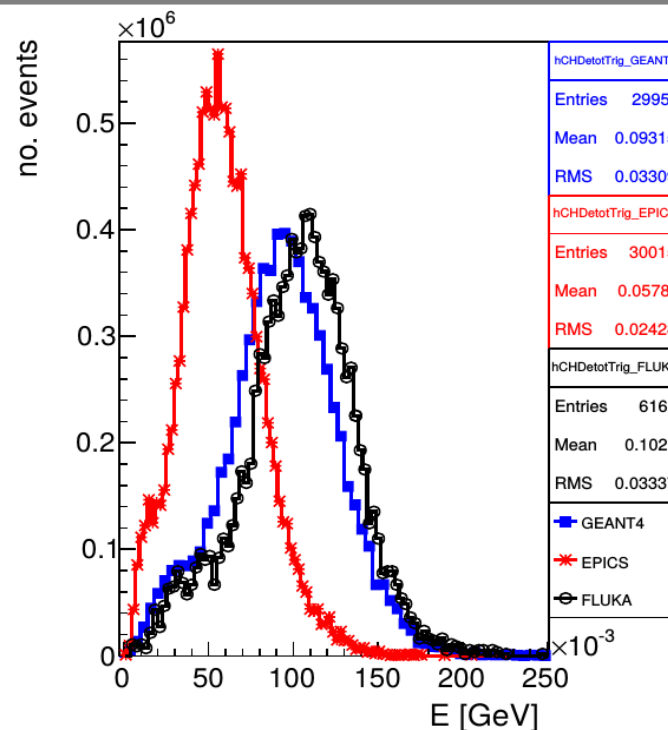
diff = FLUKA/GEANT4 - 1 (nero)

All electrons @ 10 TeV.
Total energy in CHD.

H.E triggered electrons @ 10 TeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black



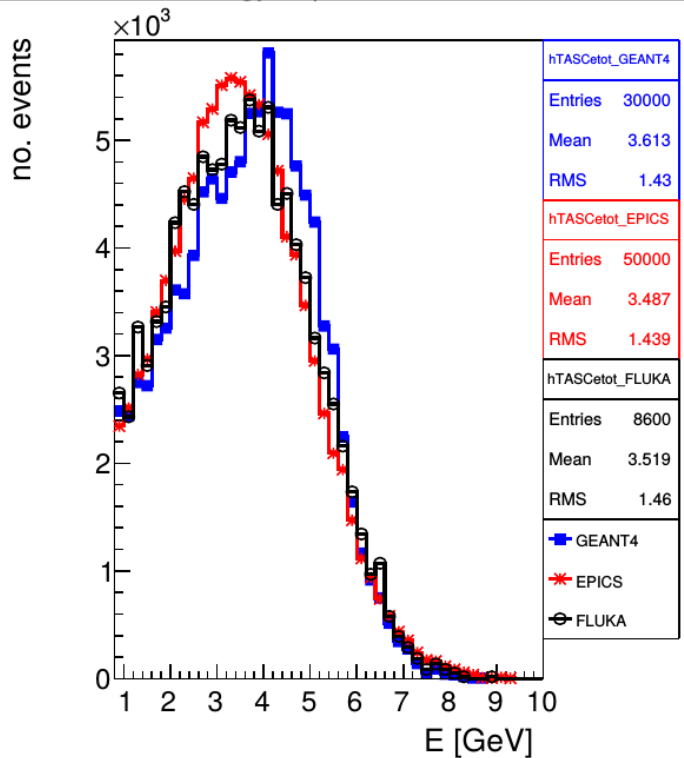
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.09315	0.03309	0.09495	0
EPICS	0.05781	0.02428	0.05555	-41.5
FLUKA	0.1027	0.03337	0.1099	15.76

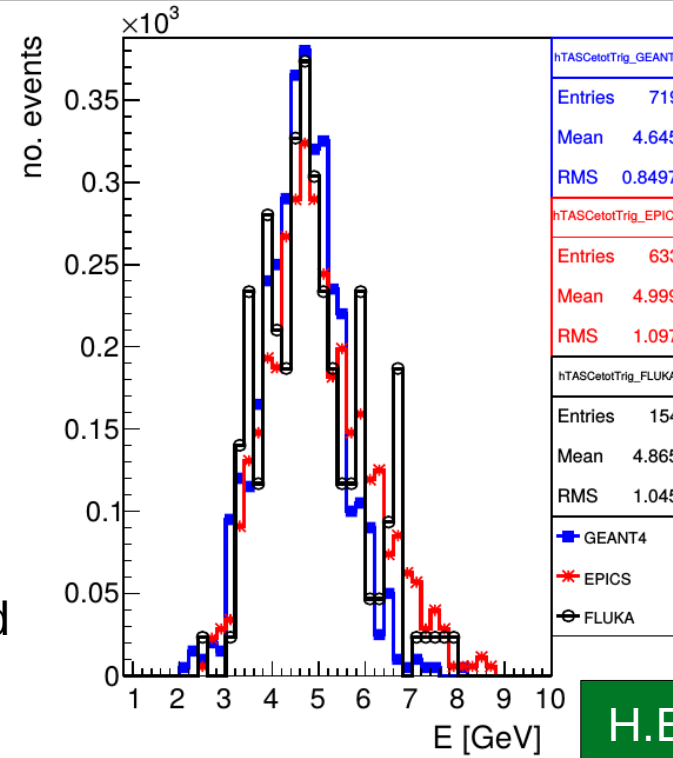
Protons plots and
tables: 10, 100, 1000,
10000 GeV

All protons @ 10 GeV.
Total energy in TASC.

H.E triggered protons @ 10 GeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

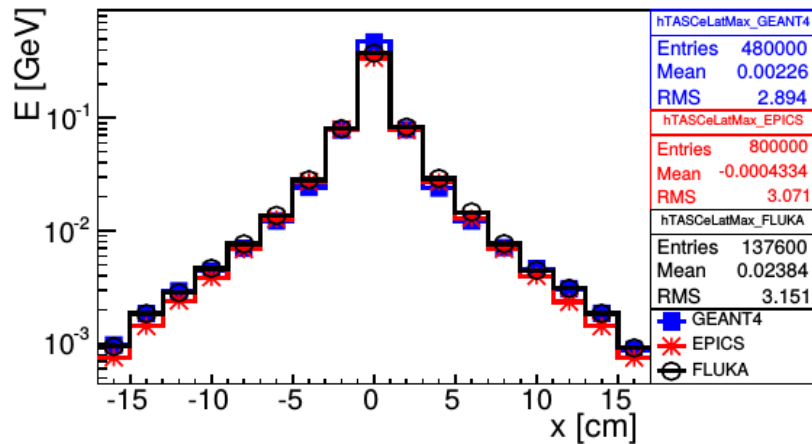


H.E. triggered
particle table:

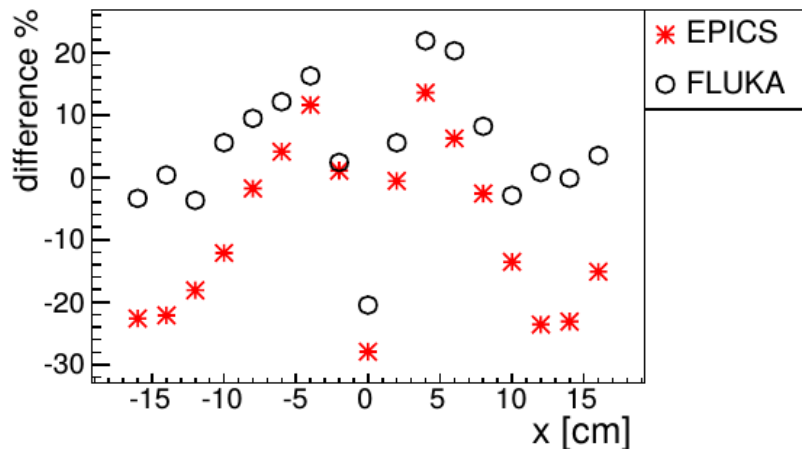
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	4.645	0.8497	4.701	0
EPICS	4.999	1.097	4.701	-0.002489
FLUKA	4.865	1.045	4.701	-0.002489

H.E.trigger
efficiency
GEANT 2.4%
EPICS 1.3%
FLUKA 1.8%

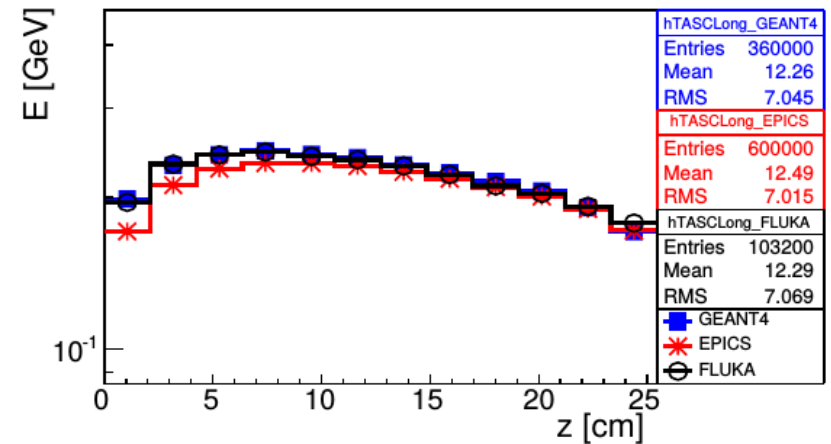
All protons @ 10 GeV.
TASC lateral distr.



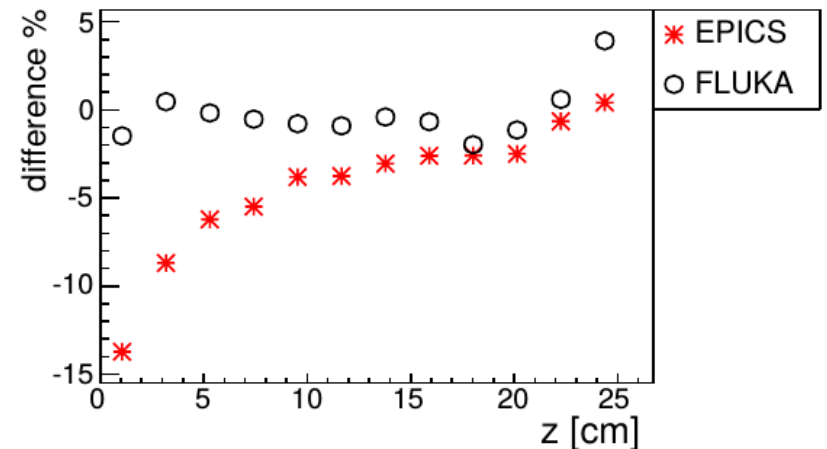
Difference with respect to GEANT4



All protons @ 10 GeV.
TASC longitudinal distr.



Difference with respect to GEANT4

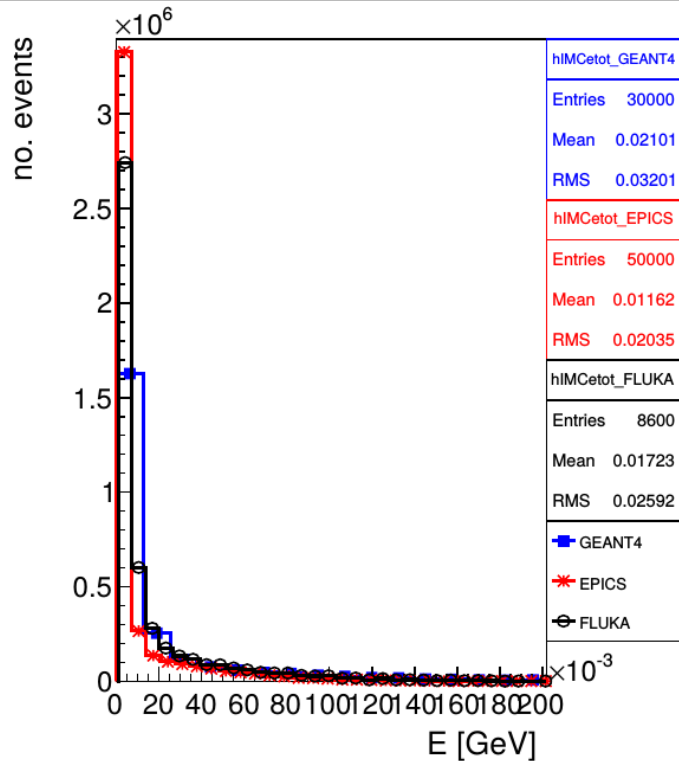


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

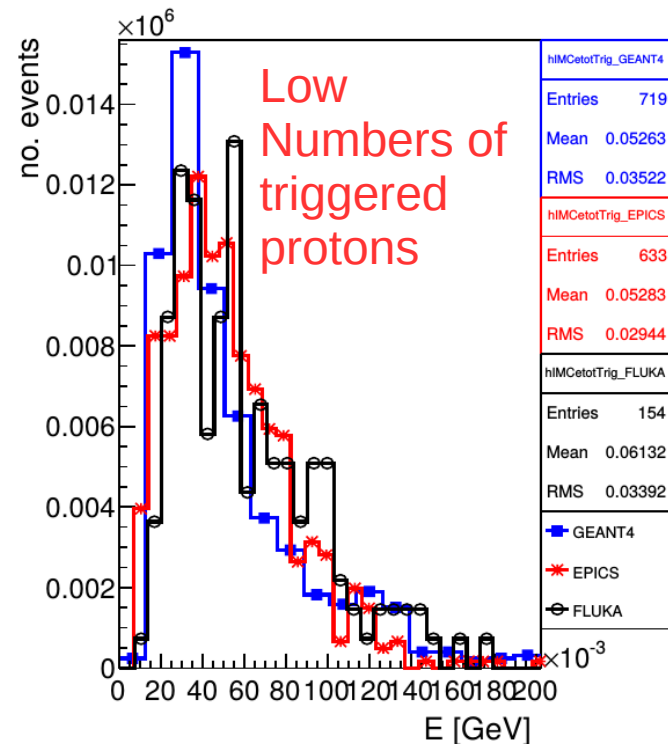
All protons @ 10 GeV.
Total energy in IMC.

H.E triggered protons @ 10 GeV.
Total energy in IMC.



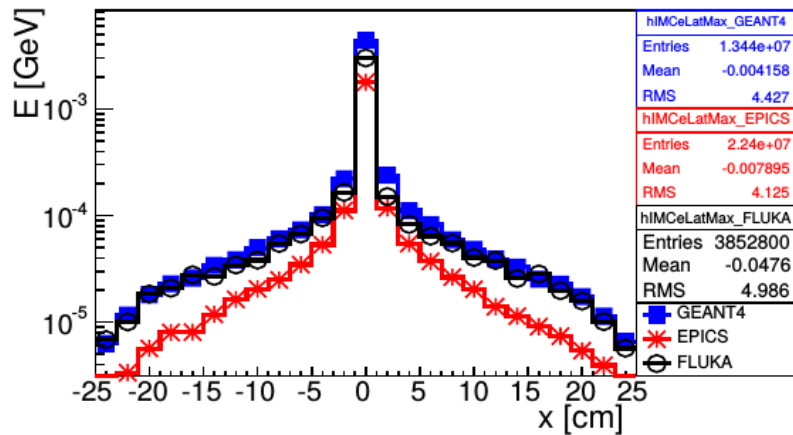
GEANT4 blue
EPICS red
FLUKA black

H.E. triggered particle table:

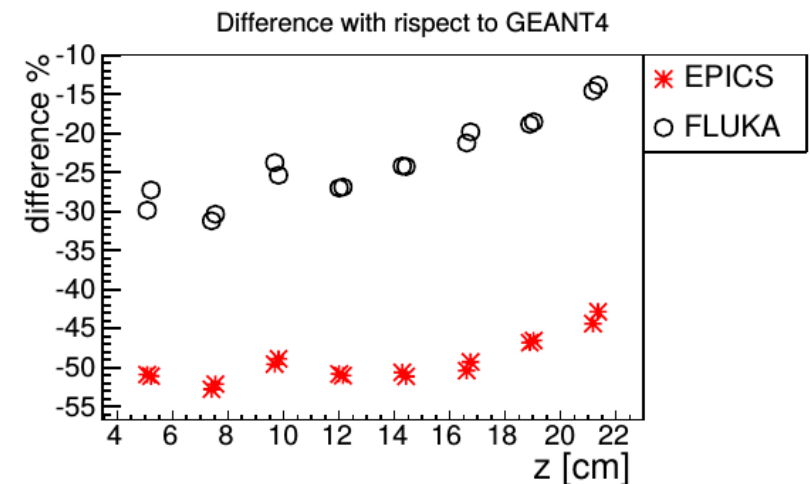
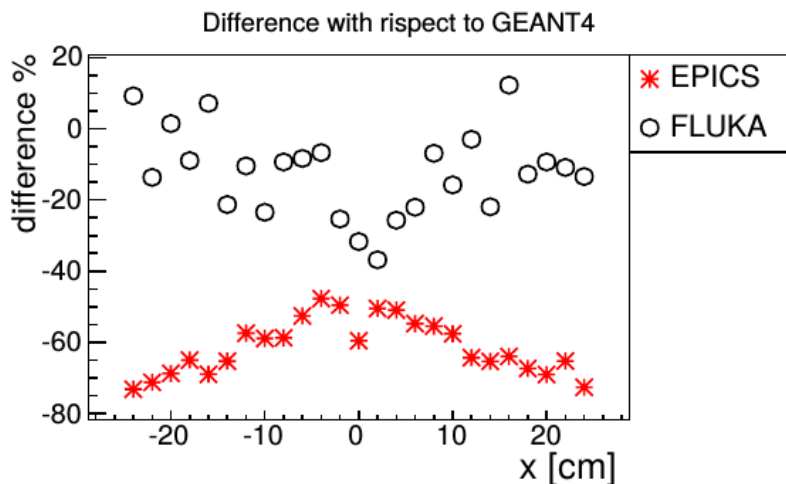
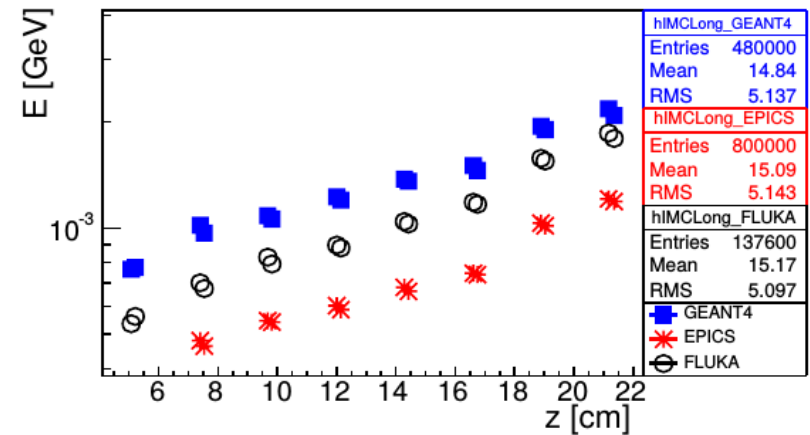


Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.05263	0.03522	0.03156	0
EPICS	0.05283	0.02944	0.0378	19.76
FLUKA	0.06132	0.03392	0.05507	74.49

All protons @ 10 GeV.
IMC lateral distr.



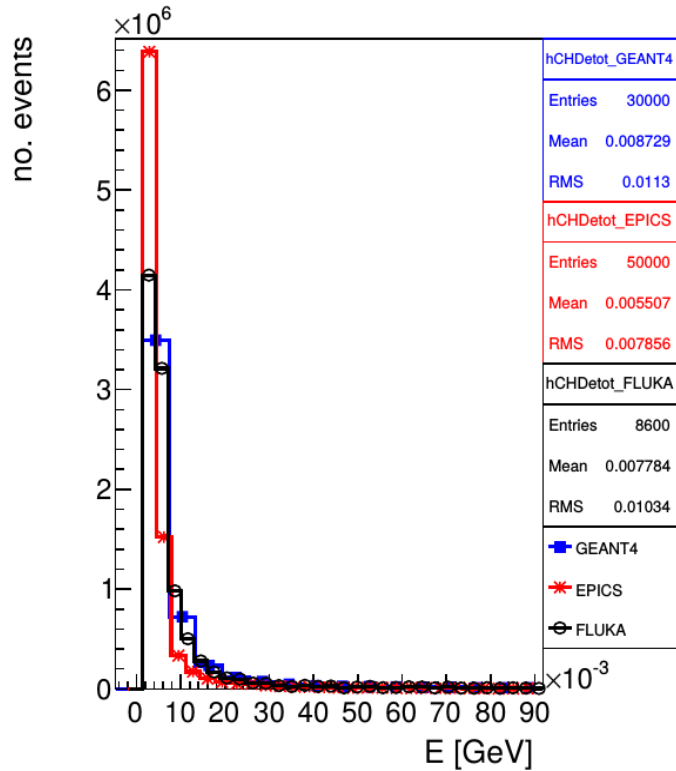
All protons @ 10 GeV.
IMC longitudinal distr.



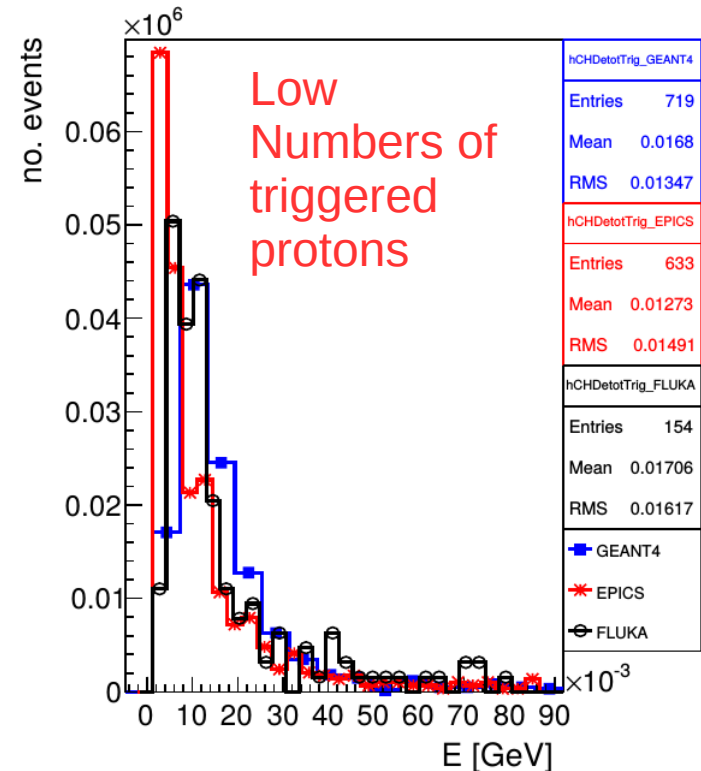
diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 10 GeV.
Total energy in CHD.

H.E triggered protons @ 10 GeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black

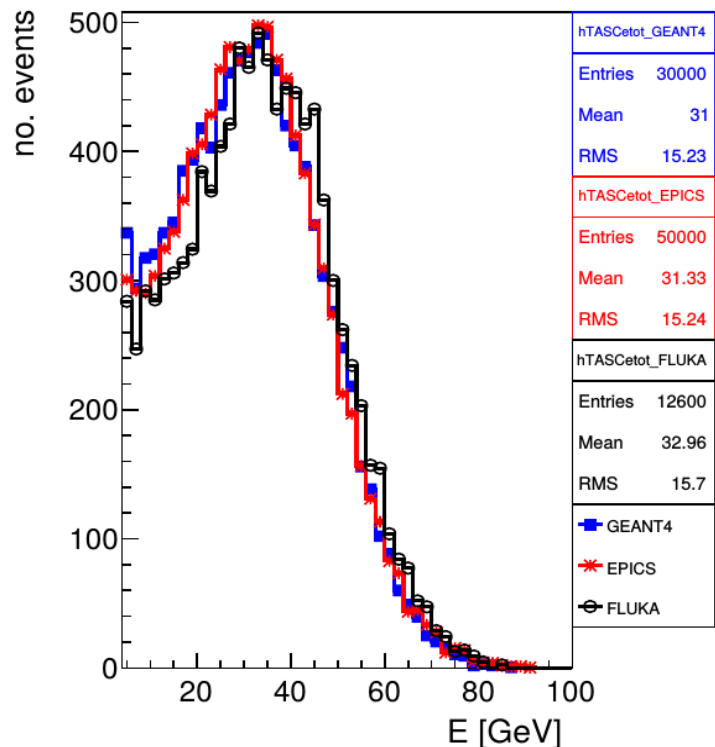


Low
Numbers of
triggered
protons

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.0168	0.01347	0.01034	0
EPICS	0.01273	0.01491	0.002905	-71.89
FLUKA	0.01706	0.01617	0.005719	-44.68

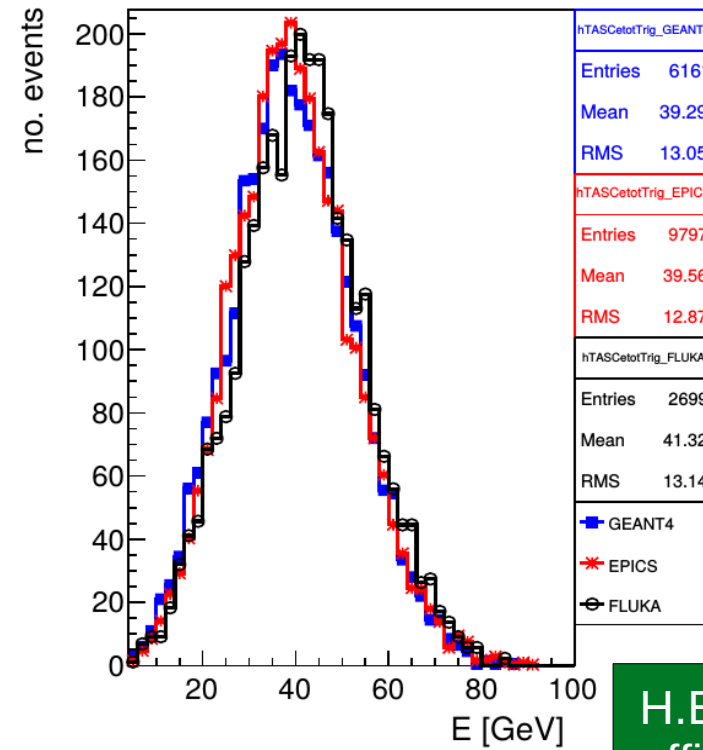
All protons @ 100 GeV.
Total energy in TASC.

H.E triggered protons @ 100 GeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

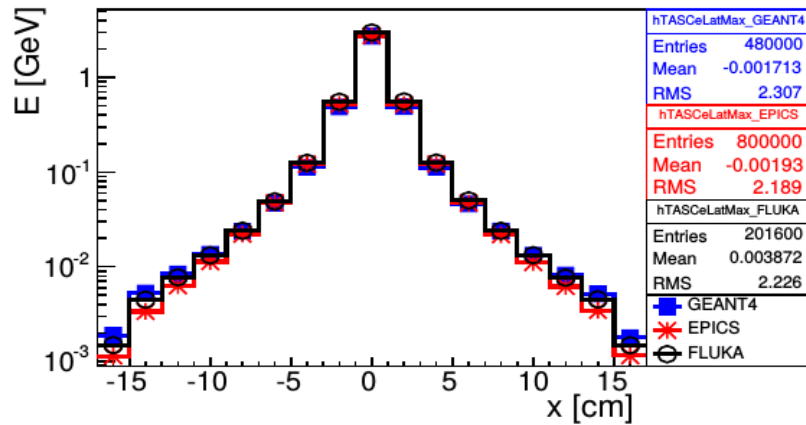
H.E. triggered
particle table:



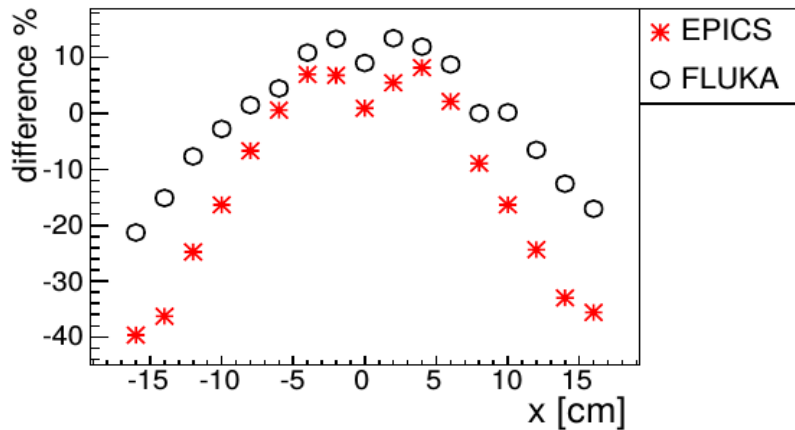
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	39.29	13.05	37.01	0
EPICS	39.56	12.87	39.01	5.404
FLUKA	41.32	13.14	41.01	10.81

H.E.trigger
efficiency
GEANT 25.5%
EPICS 19.4%
FLUKA 21.4%

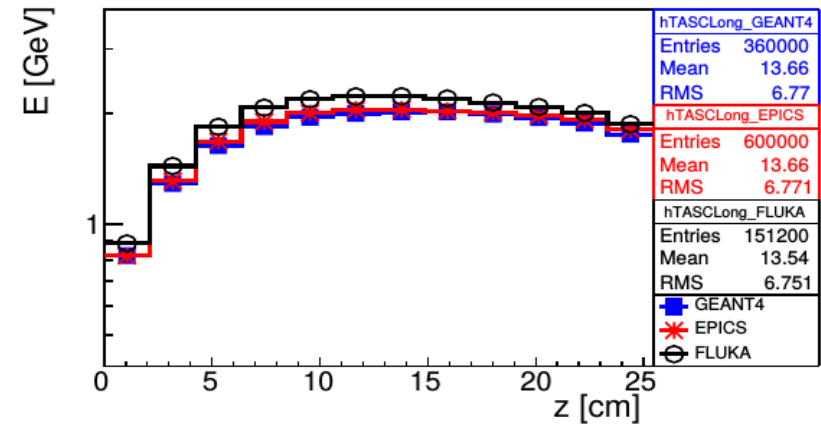
All protons @ 100 GeV.
TASC lateral distr.



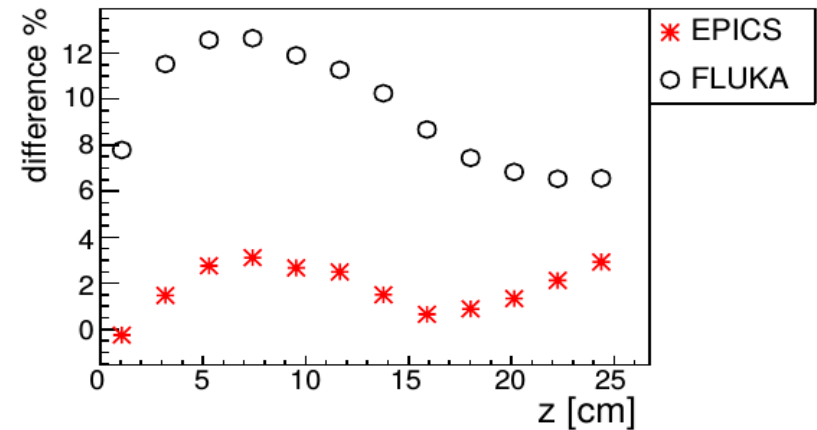
Difference with respect to GEANT4



All protons @ 100 GeV.
TASC longitudinal distr.



Difference with respect to GEANT4

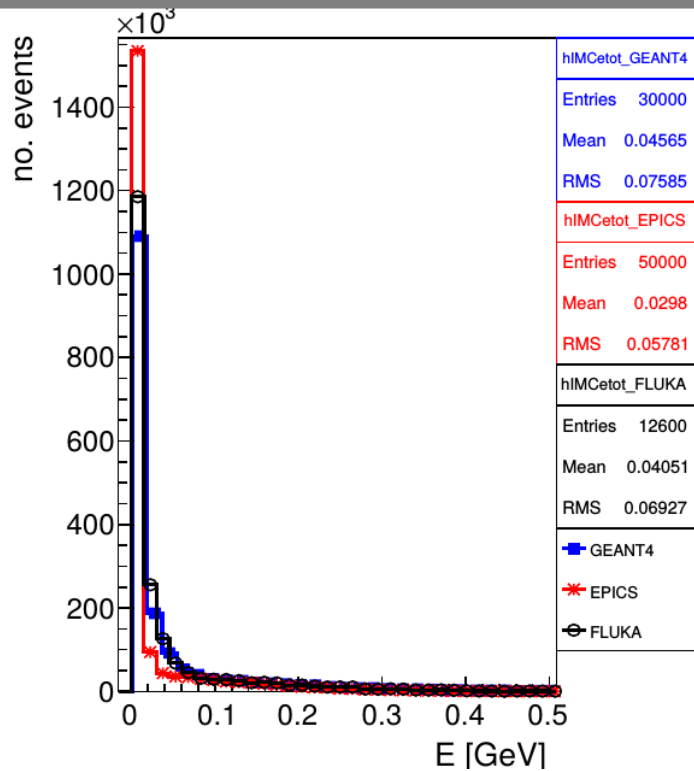


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

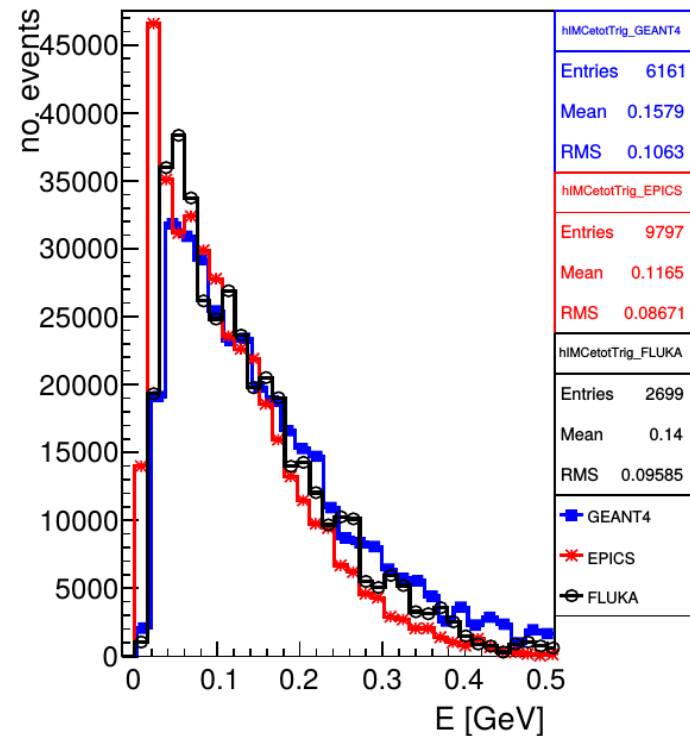
All protons @ 100 GeV.
Total energy in IMC.

H.E triggered protons @ 100 GeV.
Total energy in IMC.



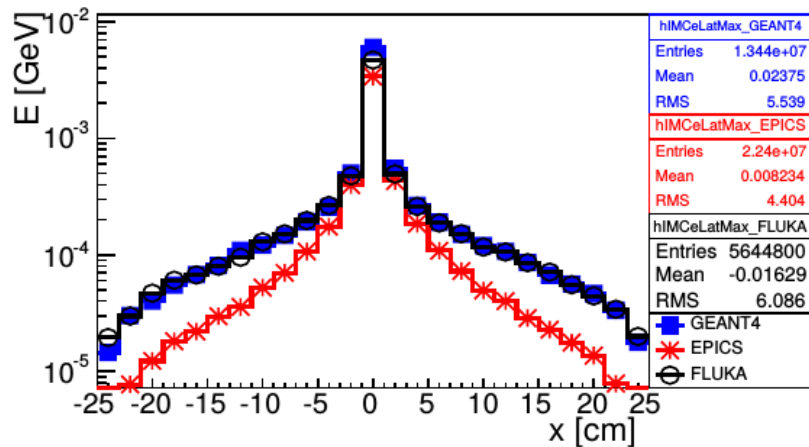
GEANT4 blue
EPICS red
FLUKA black

H.E. triggered
particle table:

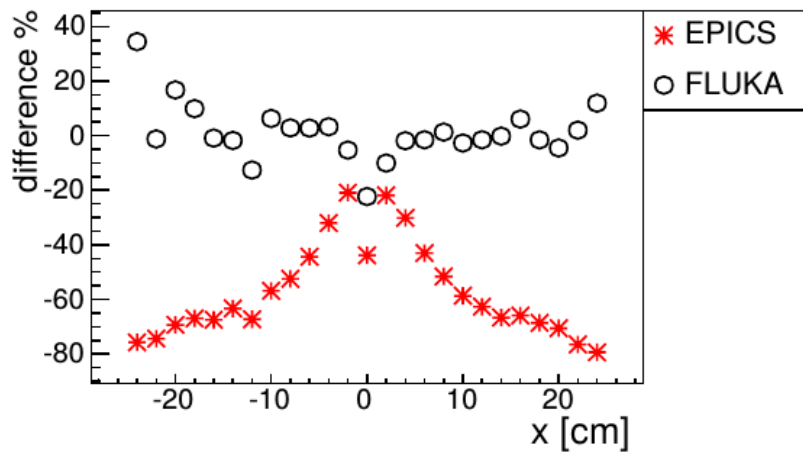


Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.1579	0.1063	0.04561	0
EPICS	0.1165	0.08671	0.02266	-50.32
FLUKA	0.14	0.09585	0.05305	16.3

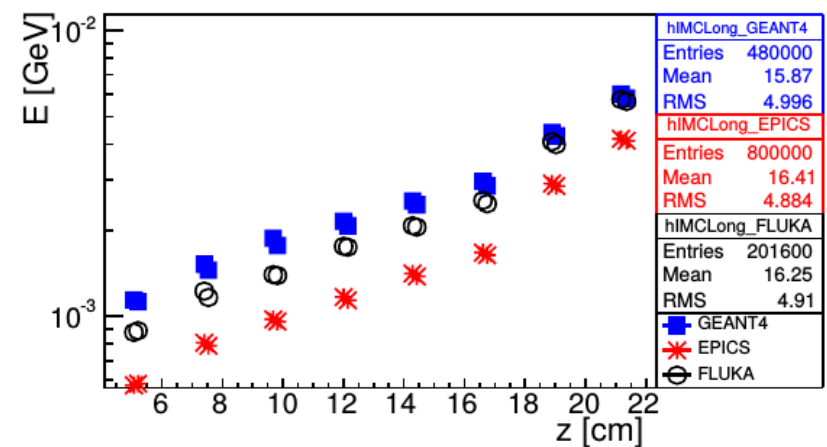
All protons @ 100 GeV.
IMC lateral distr.



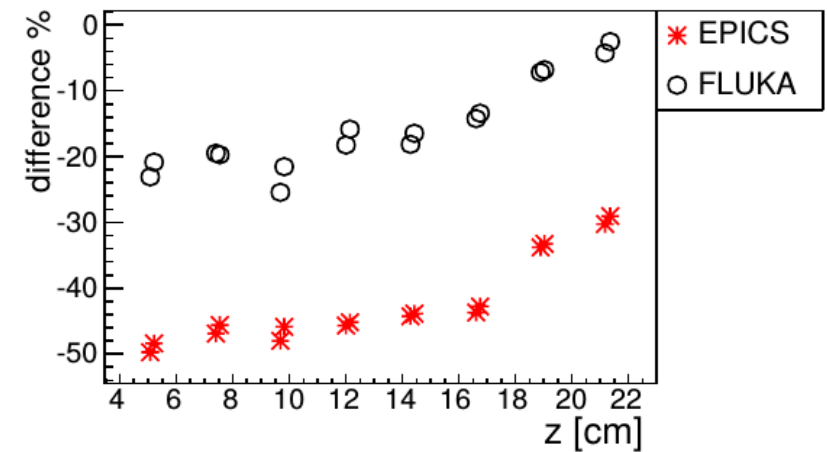
Difference with respect to GEANT4



All protons @ 100 GeV.
IMC longitudinal distr.



Difference with respect to GEANT4

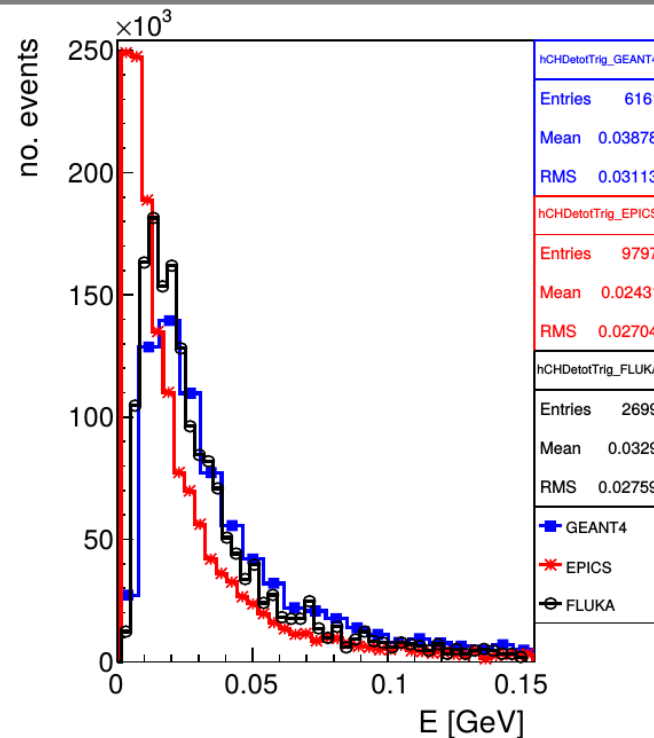
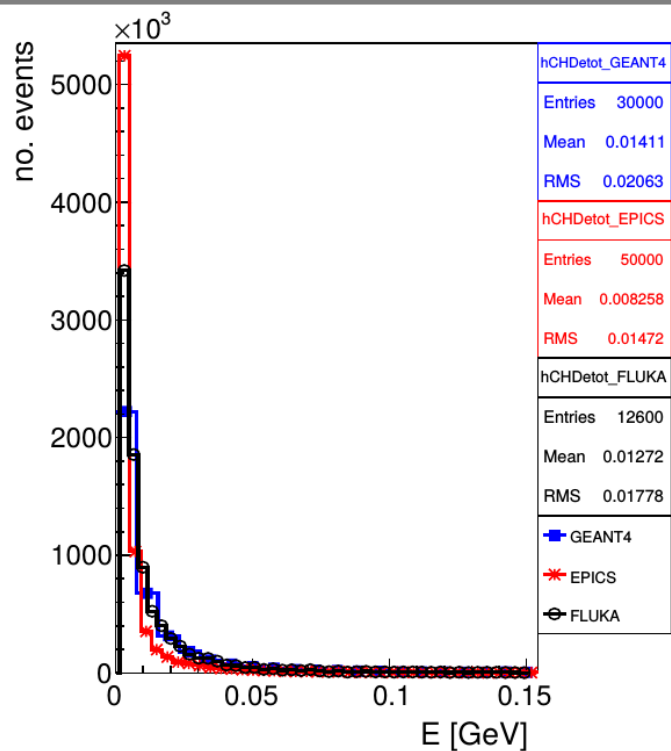


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 100 GeV.
Total energy in CHD.

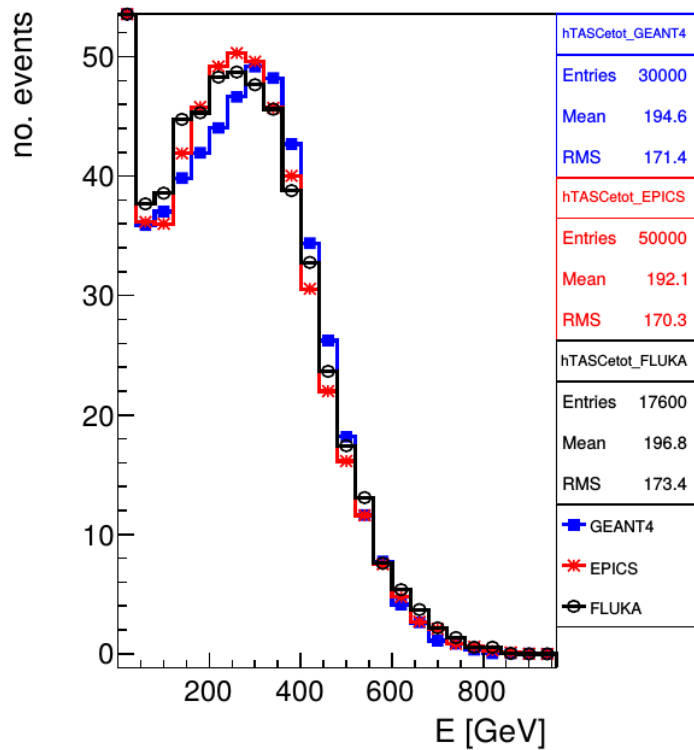
H.E triggered protons @ 100 GeV.
Total energy in CHD.



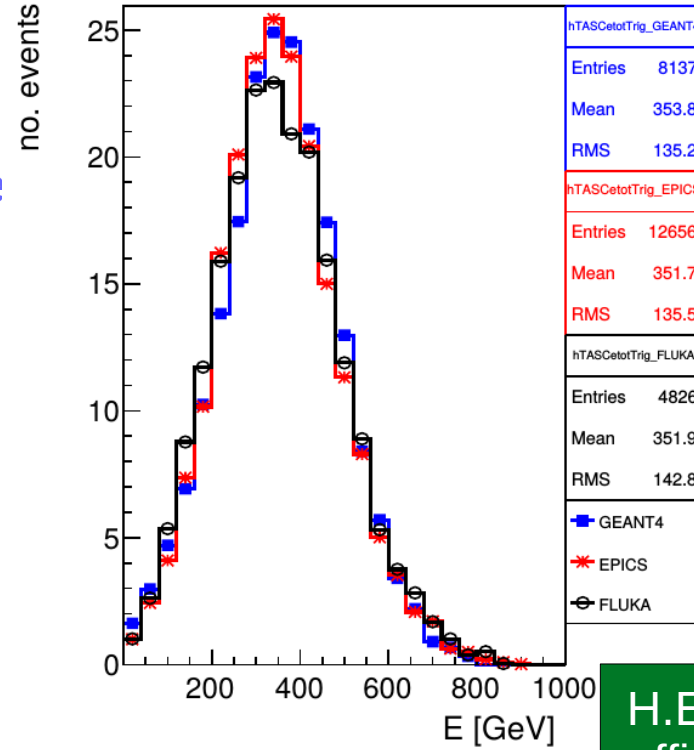
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.03878	0.03113	0.01927	0
EPICS	0.02431	0.02704	0.003234	-83.22
FLUKA	0.0329	0.02759	0.01331	-30.96

All protons @ 1 TeV.
Total energy in TASC.

H.E triggered protons @ 1 TeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

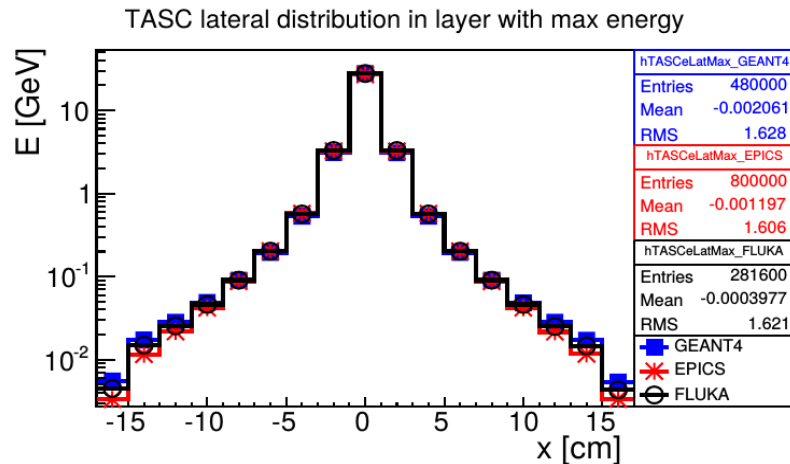


H.E. triggered
particle table:

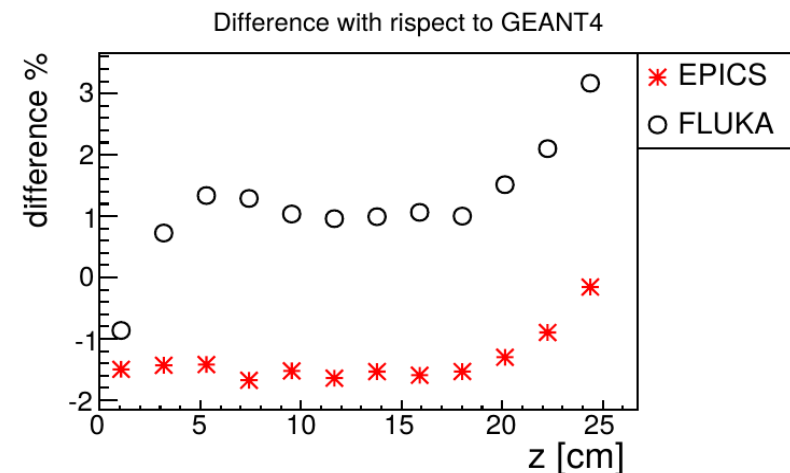
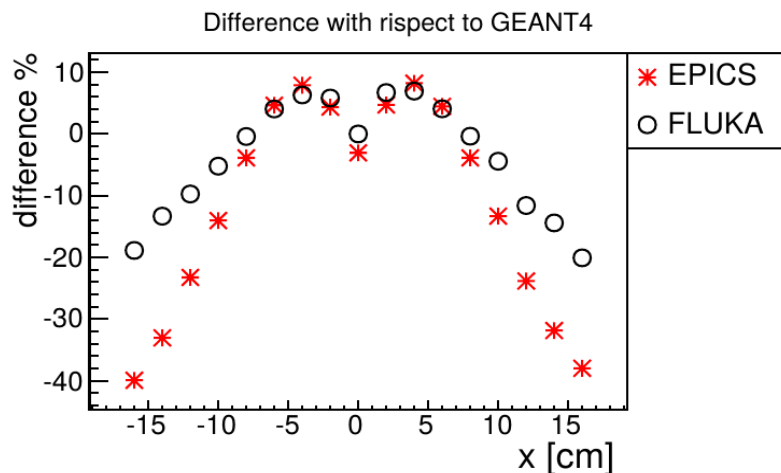
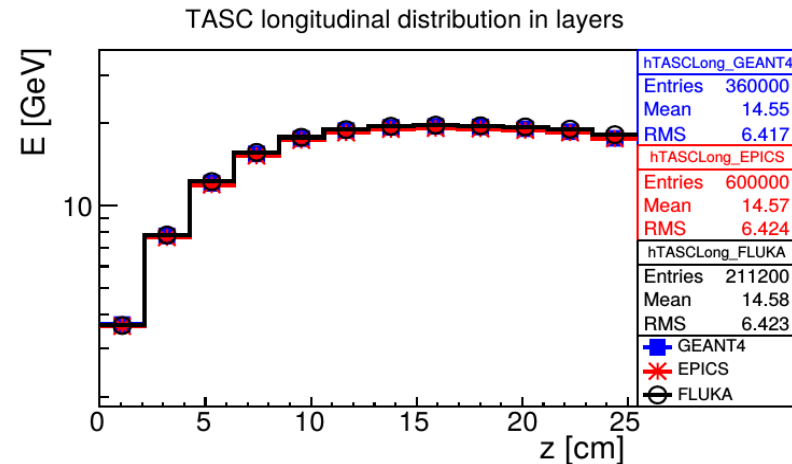
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	354.6	133.6	370.1	0
EPICS	352.3	134.4	330.1	-0.2
FLUKA	352.9	141.5	350.1	-0.2

H.E.trigger
efficiency
GEANT 27.1%
EPICS 24.3%
FLUKA 27.4%

All protons @ 1 TeV.
TASC lateral distr.



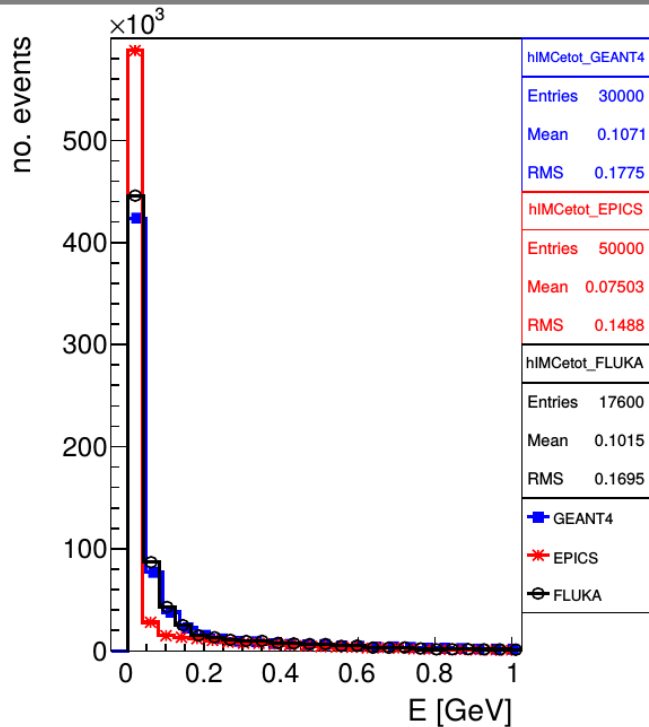
All protons @ 1 TeV.
TASC longitudinal distr.



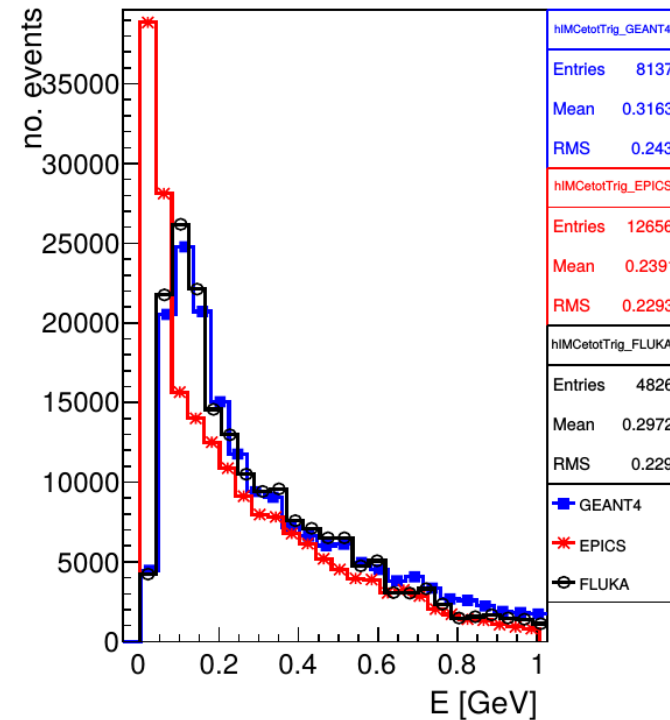
diff = EPICS/GEANT4 - 1 (rosso)
diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 1 TeV.
Total energy in IMC.

H.E triggered protons @ 1 TeV.
Total energy in IMC.



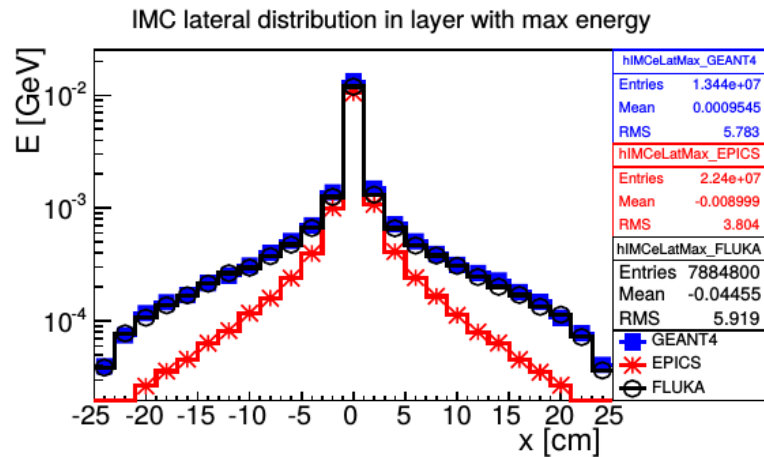
GEANT4 blue
EPICS red
FLUKA black



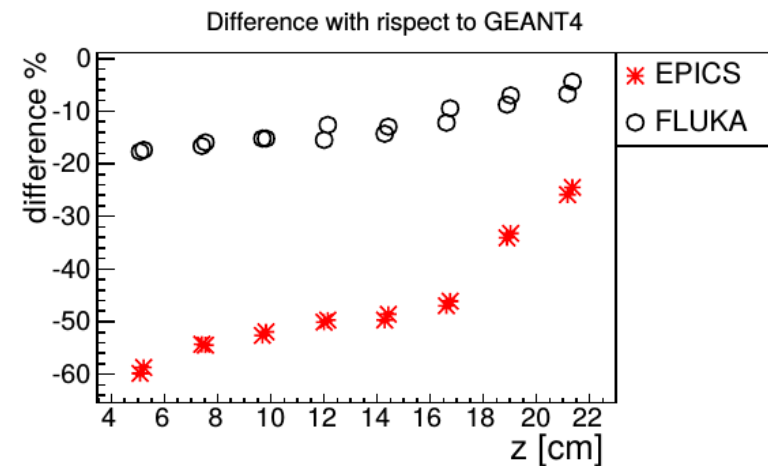
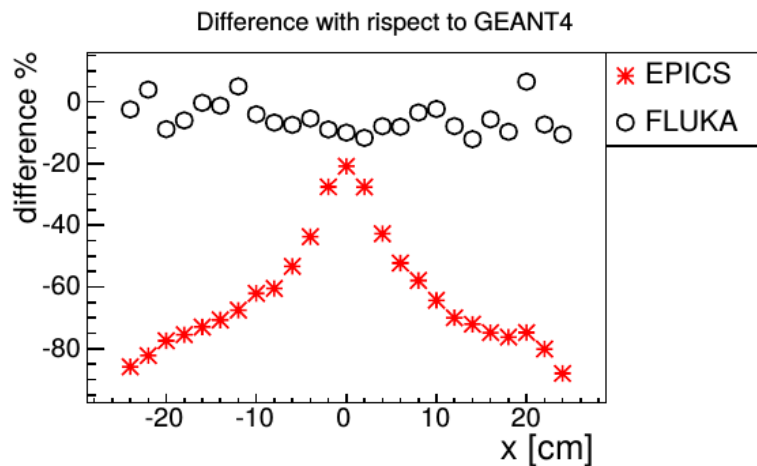
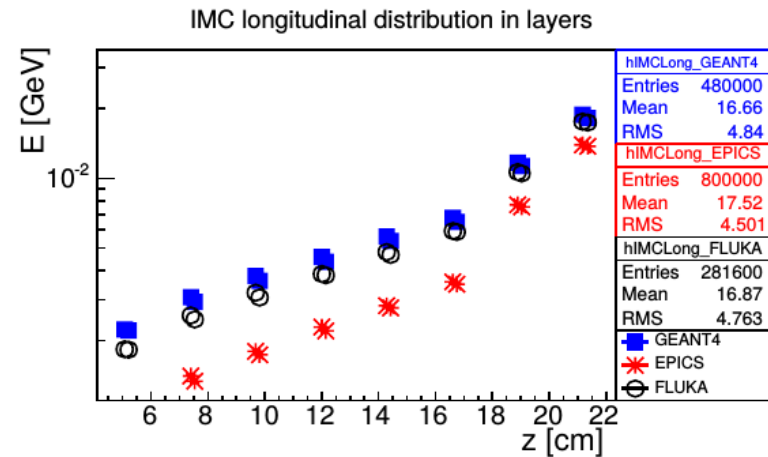
H.E. triggered
particle table:

Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.3163	0.243	0.1133	0
EPICS	0.2391	0.2293	0.02014	-82.23
FLUKA	0.2972	0.229	0.1031	-9.035

All protons @ 1 TeV.
IMC lateral distr.



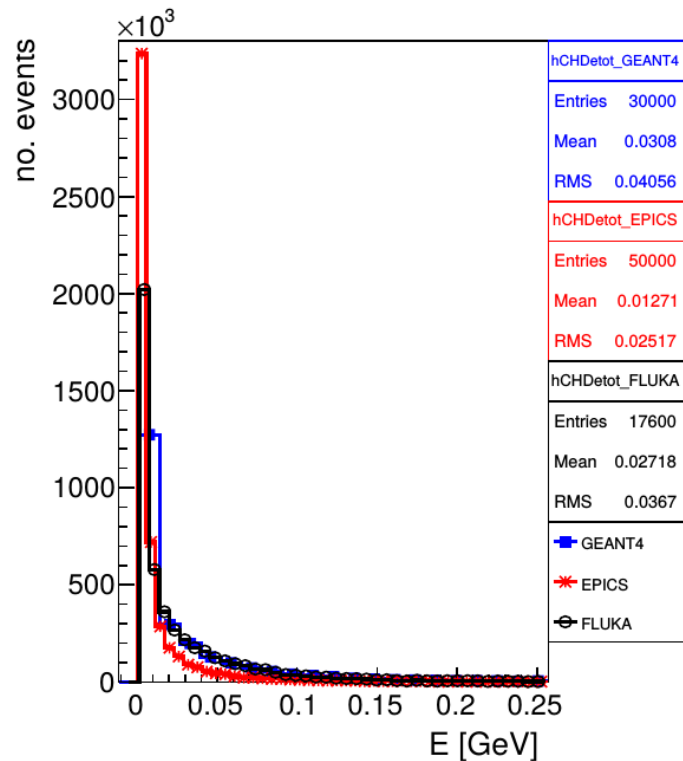
All protons @ 1 TeV.
IMC longitudinal distr.



diff = EPICS/GEANT4 - 1 (rosso)

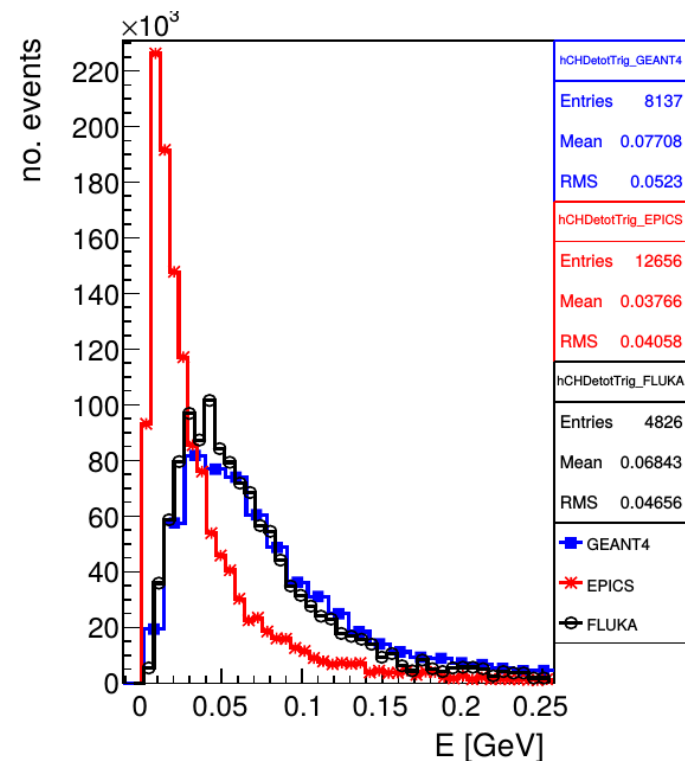
diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 1 TeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black

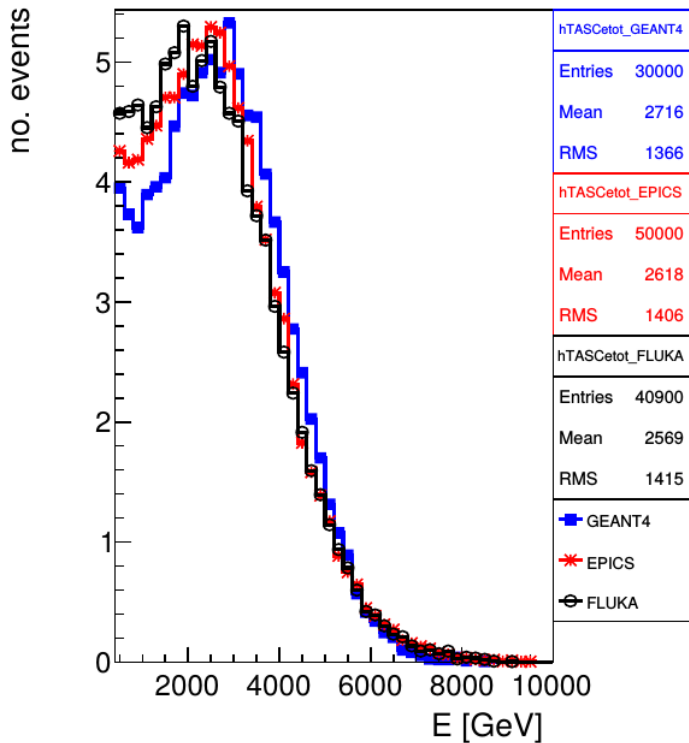
H.E triggered protons @ 1 TeV.
Total energy in CHD.



Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.07708	0.0523	0.03331	0
EPICS	0.03766	0.04058	0.00871	-73.85
FLUKA	0.06843	0.04656	0.04241	27.3

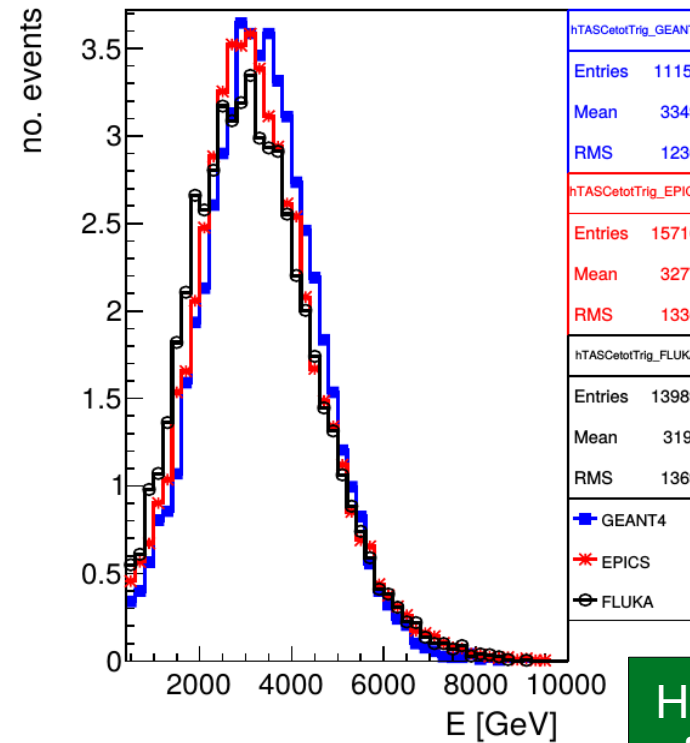
All protons @ 10 TeV.
Total energy in TASC.

H.E triggered protons @ 10 TeV.
Total energy in TASC.



GEANT4 blue
EPICS red
FLUKA black

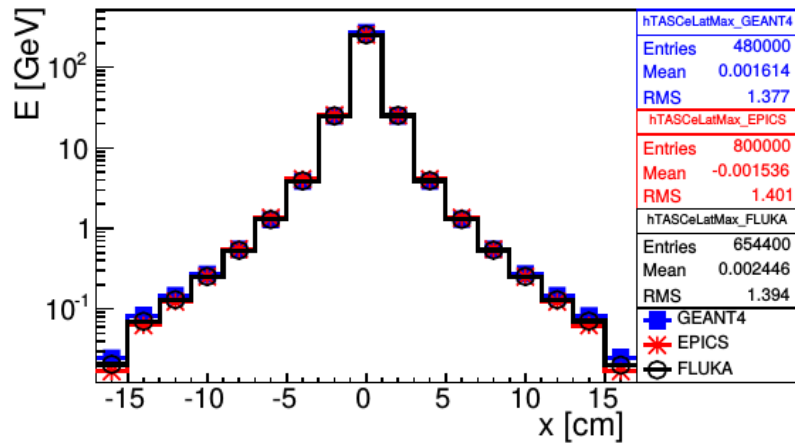
H.E. triggered
particle table:



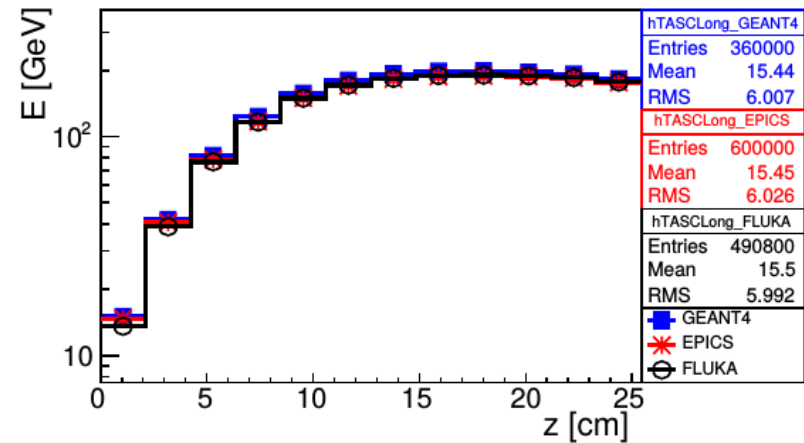
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	3349	1230	2901	0
EPICS	3277	1336	3101	6.894
FLUKA	3191	1369	3101	6.894

H.E.trigger
efficiency
GEANT 37.1%
EPICS 31.4%
FLUKA 34.2%

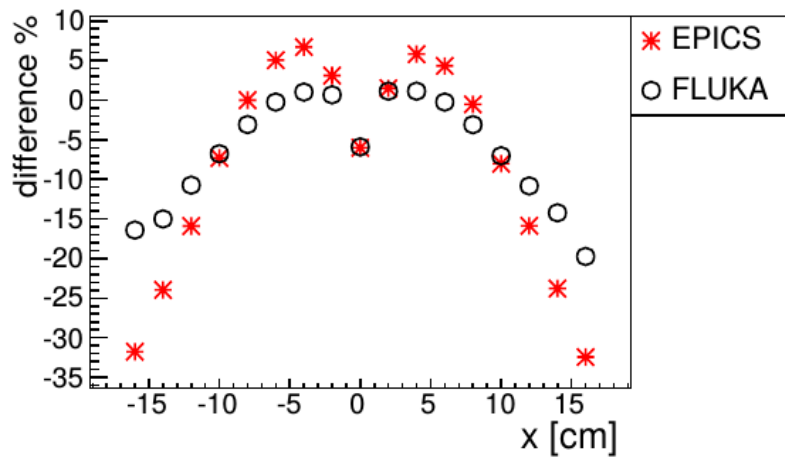
All protons @ 10 TeV.
TASC lateral distr.



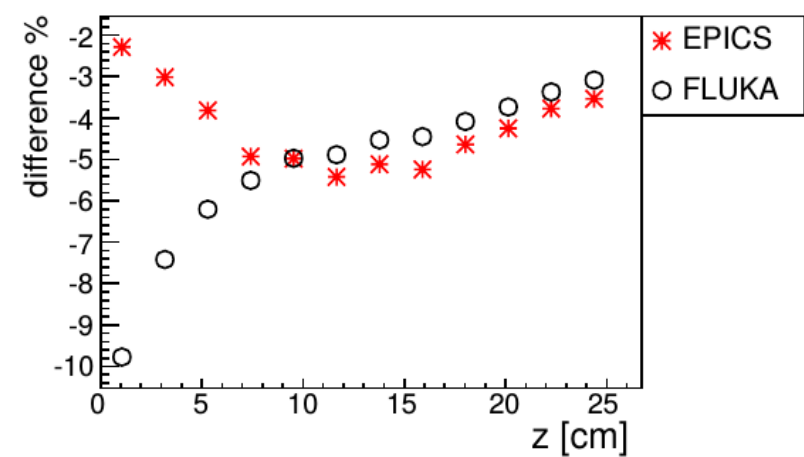
All protons @ 10 TeV.
TASC longitudinal distr.



Difference with respect to GEANT4



Difference with respect to GEANT4

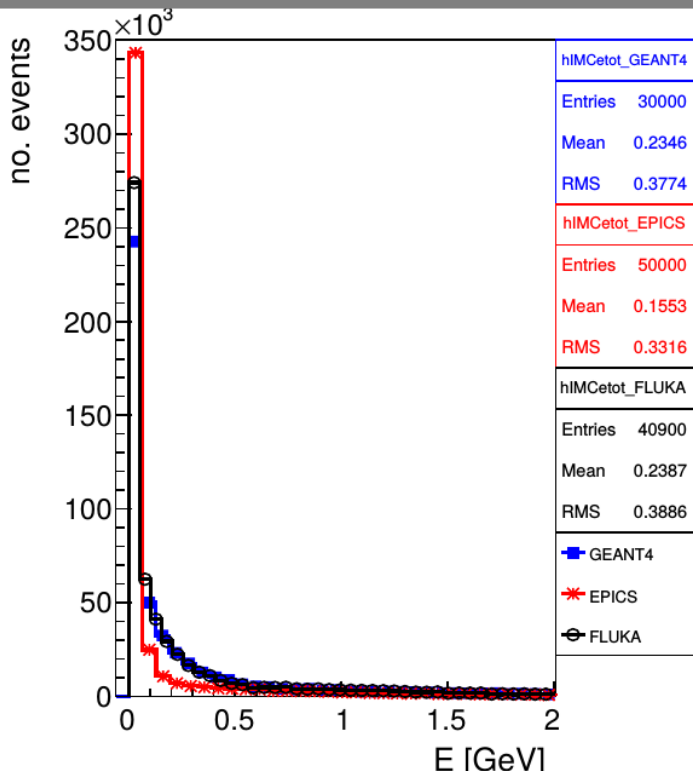


diff = EPICS/GEANT4 - 1 (rosso)

diff = FLUKA/GEANT4 - 1 (nero)

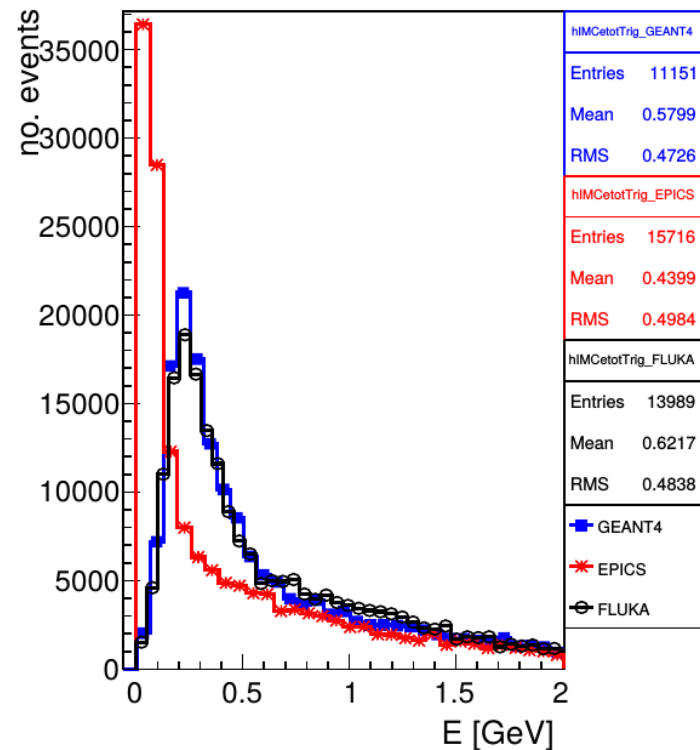
All protons @ 10 TeV.
Total energy in IMC.

H.E triggered protons @ 10 TeV.
Total energy in IMC.



GEANT4 blue
EPICS red
FLUKA black

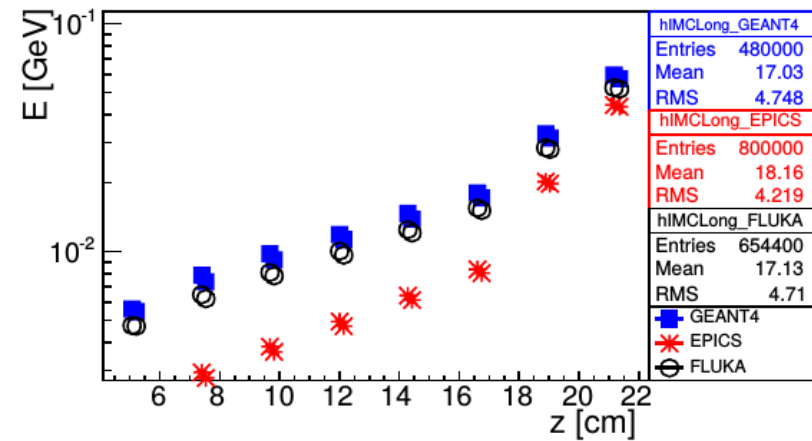
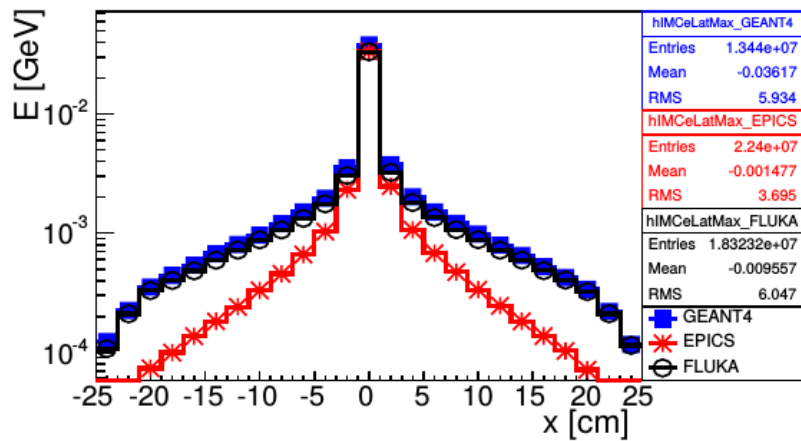
H.E. triggered
particle table:



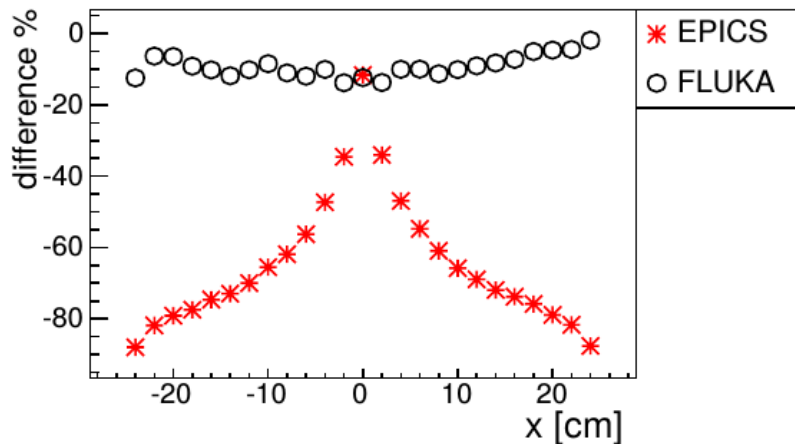
Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.5799	0.4726	0.2214	0
EPICS	0.4399	0.4984	0.03238	-85.37
FLUKA	0.6217	0.4838	0.2293	3.572

All protons @ 10 TeV.
IMC lateral distr.

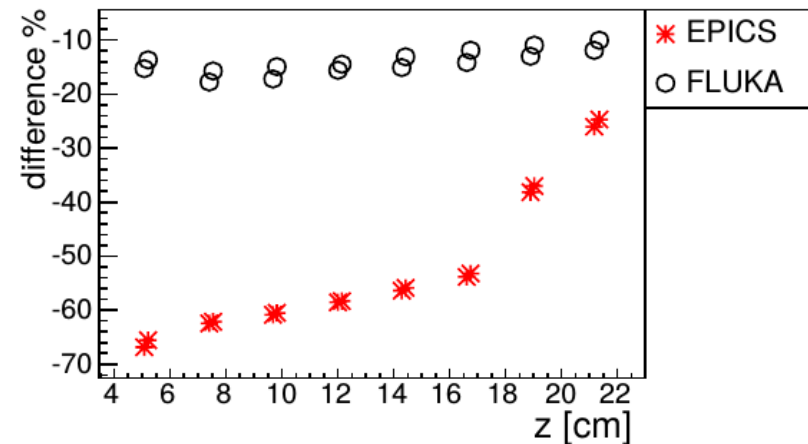
All protons @ 10 TeV.
IMC longitudinal distr.



Difference with respect to GEANT4



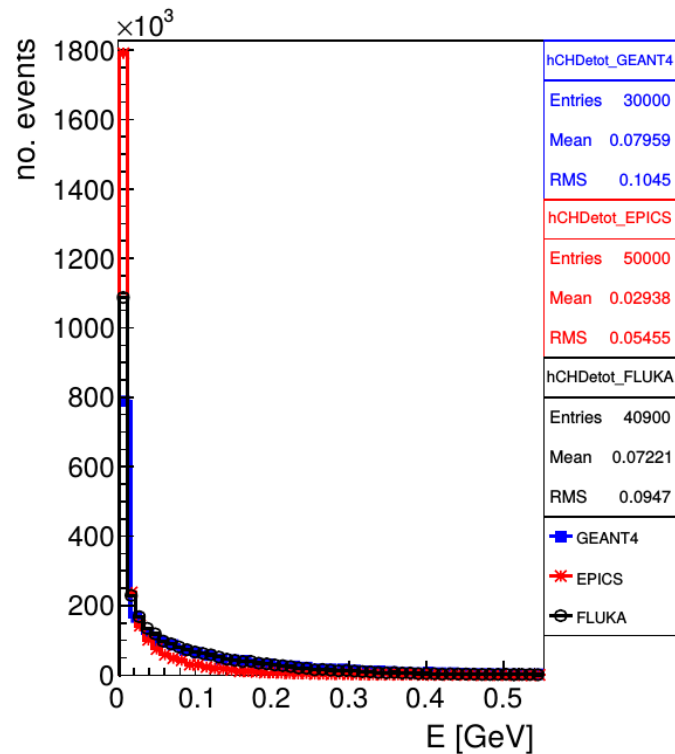
Difference with respect to GEANT4



diff = EPICS/GEANT4 - 1 (rosso)

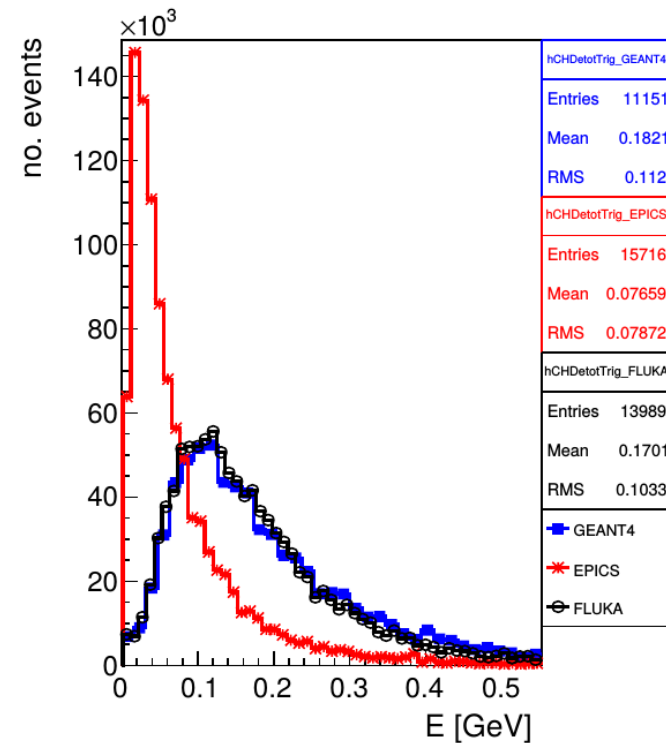
diff = FLUKA/GEANT4 - 1 (nero)

All protons @ 10 TeV.
Total energy in CHD.



GEANT4 blue
EPICS red
FLUKA black

H.E triggered protons @ 10 TeV.
Total energy in CHD.



Simulation	mean[GeV]	RMS[GeV]	BinMax[GeV]	BinMax Diff. (%)
GEANT4	0.1821	0.112	0.1183	0
EPICS	0.07659	0.07872	0.01749	-85.22
FLUKA	0.1701	0.1033	0.1203	1.673