SIMULATION STUDIES
[Accelerator & Detector]

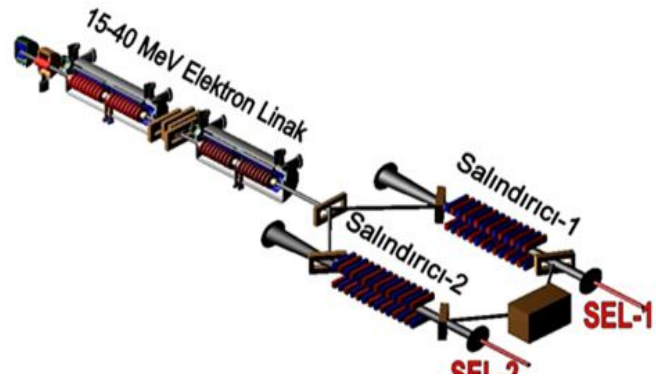
Ercan Piliçer on behalf of
Uludag University Study Group

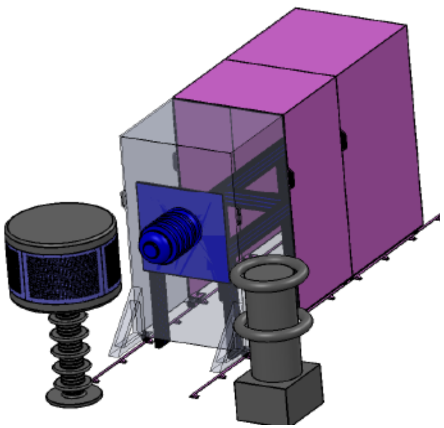
CONTENTS

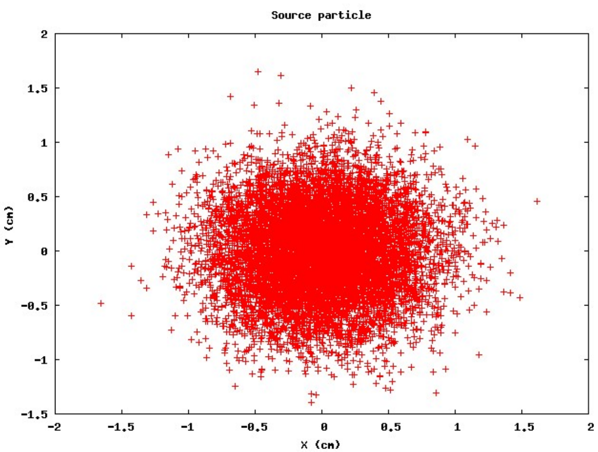
Accelerator & Detector studies for ;

e⁻ Gun & Dump in TARLA

TARLA (**T**urkish **A**cceleration and **R**adiation **L**aboratory at **A**nkara)
Electrons with the energy of 15 – 40 MeV
Free Electrons Lasers with wavelength of 2 – 250 um

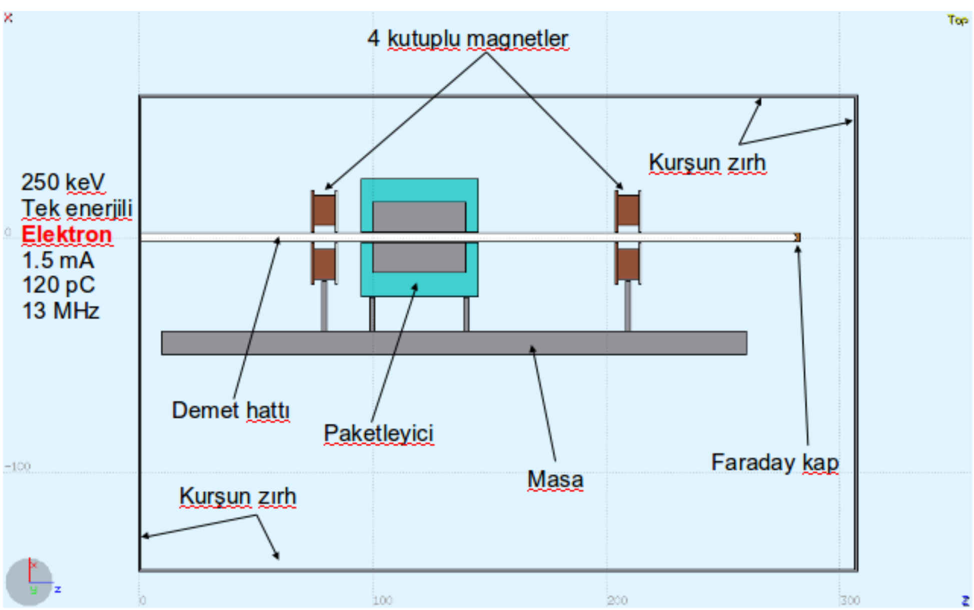


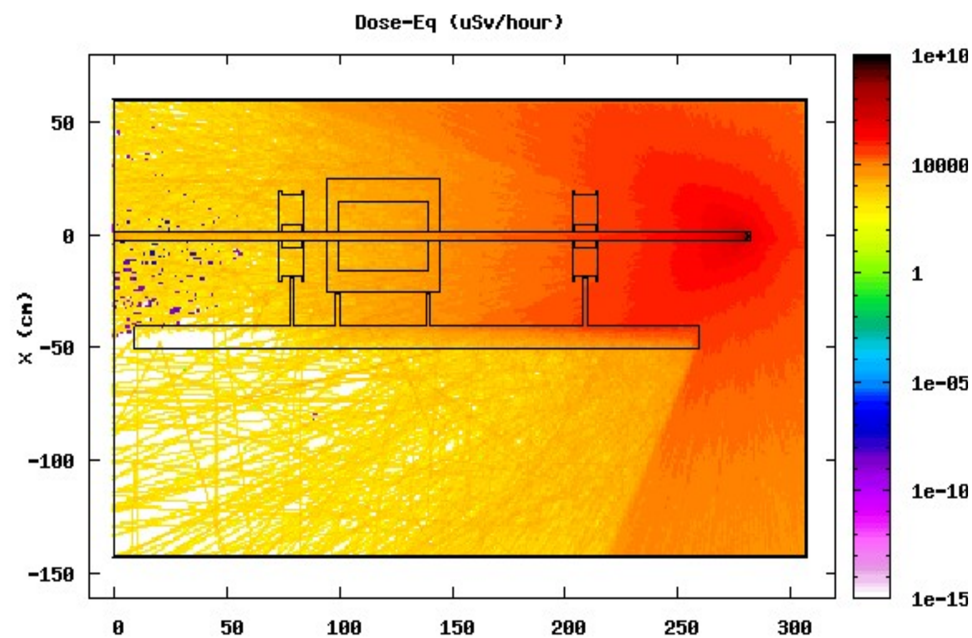




Calculation of radiation levels around thermo ionic electron gun by using **FLUKA**

e-Gun parameters:
250 keV, 1 mA, 80 pC, 13 MHz

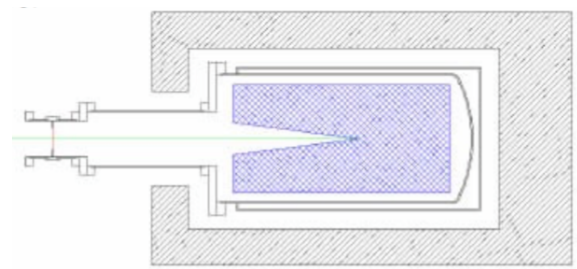




e⁻ Gun & Dump in TARLA

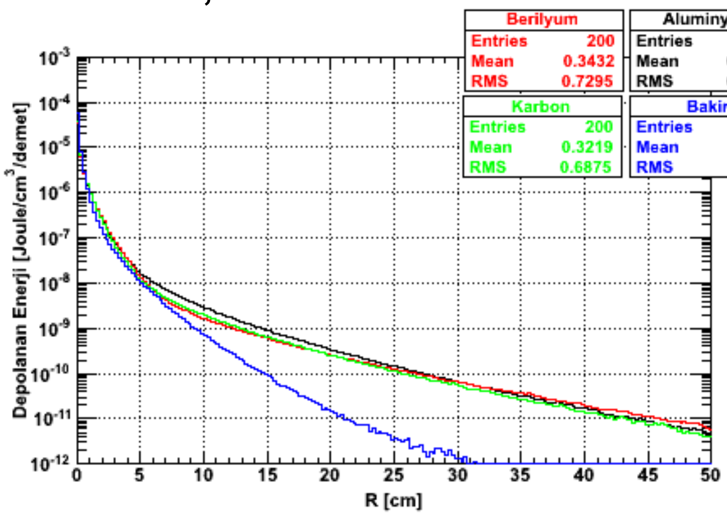
Design studies to dump electrons at the end of linac, by using **FLUKA**

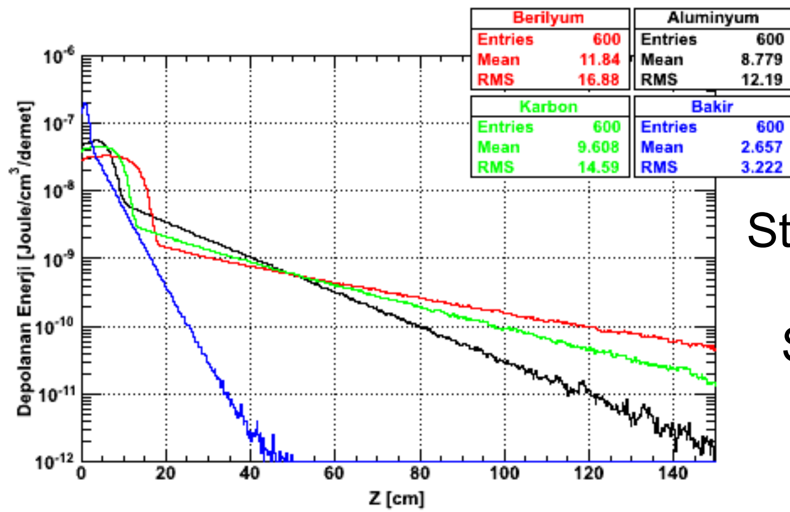
Beam parameters; 50 MeV , 80 pC , 13 MHz , 1 mA , 40 MW , 2-5 mm

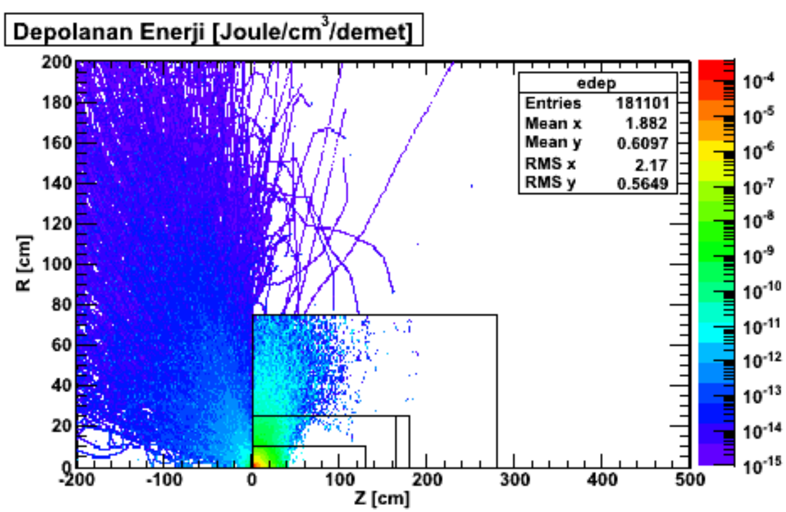


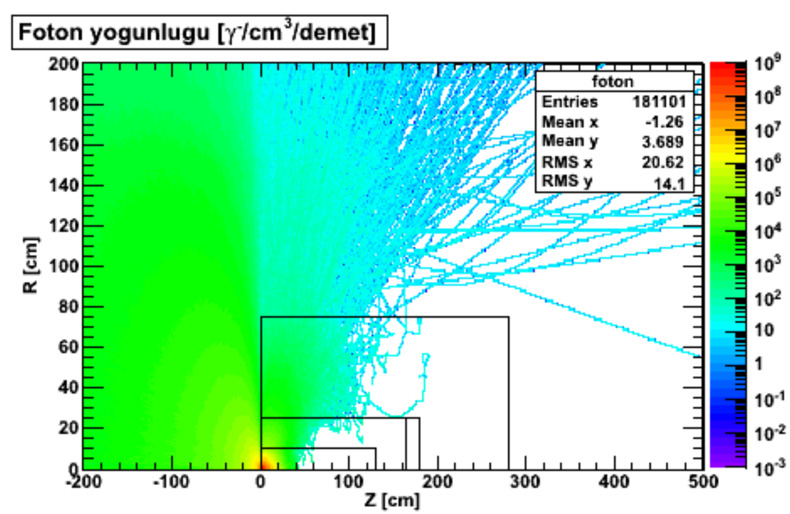
ELBE

Graphit block
Stainless stell vessel
Water cooled
Surrounded by iron









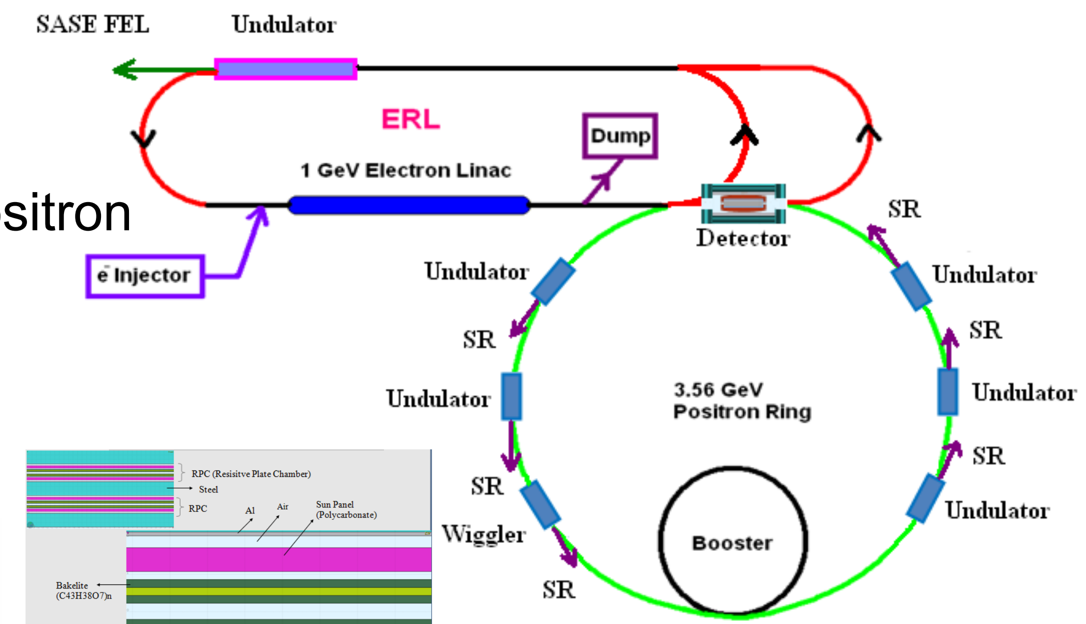
Particle Factory in TAC

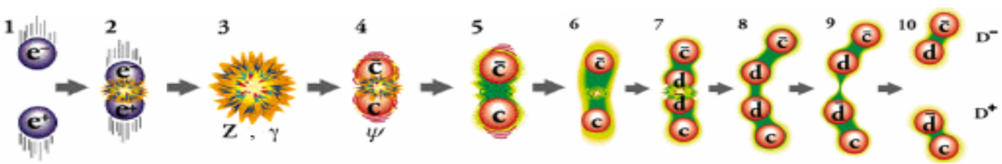
An electron-positron collider as a “super charm factory”

A 1 GeV electron linac and a 3.56 GeV positron ring for linac on ring type collisions and a dedicated detector “**TAC-PF**”

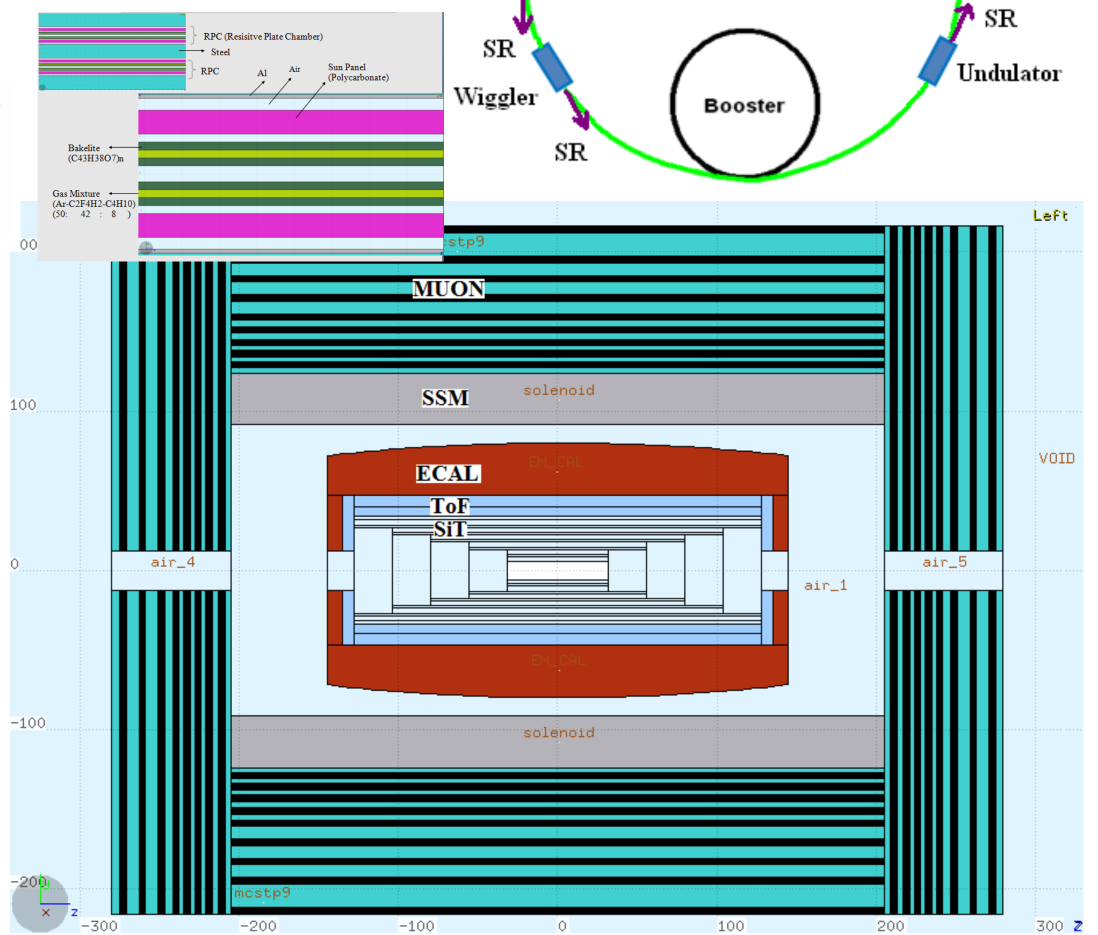
$e^-e^+ \to \Psi \to D^+ D^- / D^0 D^0$bar

$D \sim 10^3$ M/year @ $L \sim 10^{34}$ cm^{-2}s^{-1}

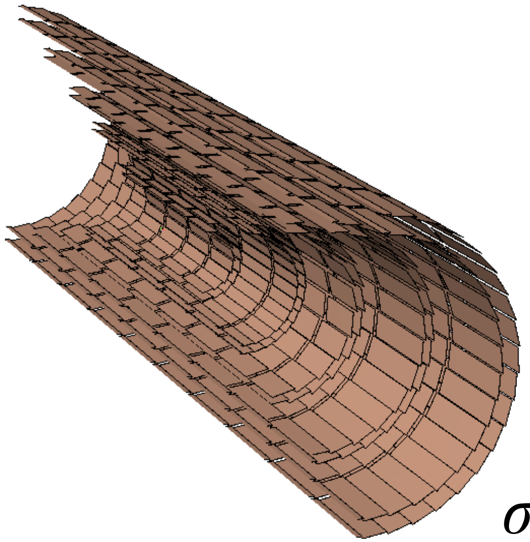




Parameter	Positron ring	Electron ERL
Positron Beam energy (GeV)	3.56	1
Number of positron per bunch (10^{11})	2	0.2
Beta Functions at IP β_x/β_y (mm)	80/5	80/5
Normalized emittance $\varepsilon_x^N/\varepsilon_y^N$ (μm rad)	111/0.36	31/0.1
σ_x/σ_y (μm)	36/0.5	36/0.5
σ_z (mm)	5	5
Beam –beam tune shift (ξ_x/ξ_y)	0.012/0.13	
Energy loss/Turn (MeV)	0.7	
Number of bunches	300	
Circumference (m)	600	
Beam Current (A)	4.8	0.48
Momentum Acceptence (%)	1	
Luminosity (cm^{-2}s^{-1})	1.4x10^{35}	

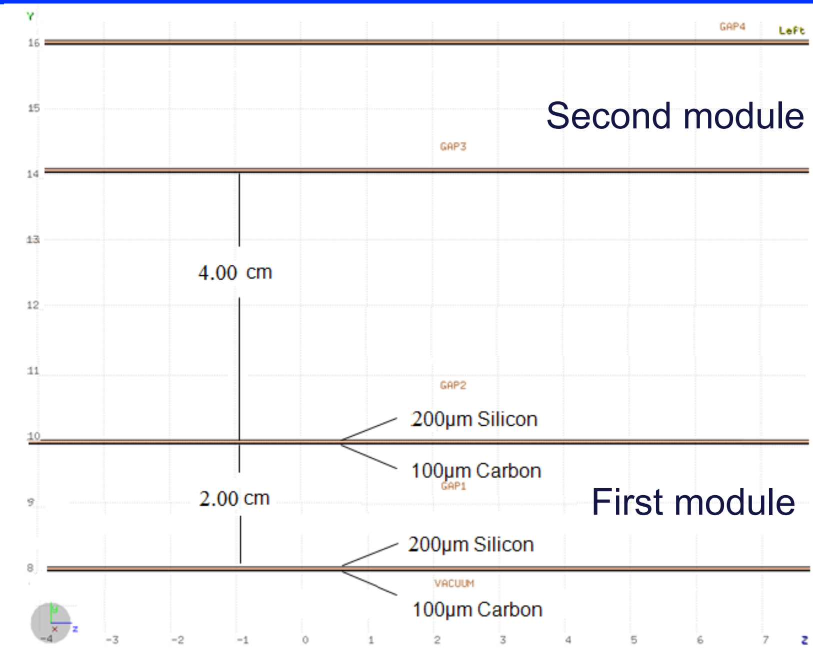


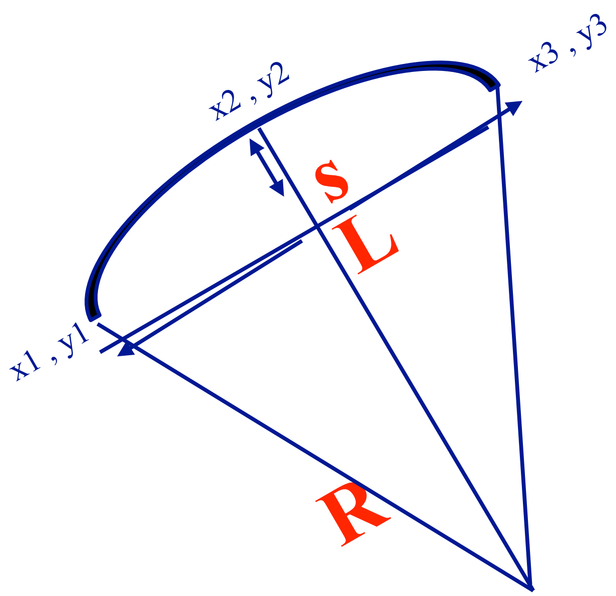
Particle Factory in TAC [Tracker]



Momentum resolution of Silicon Tracker were calculated by using **FLUKA**

$$\frac{\sigma p_T}{p_T} = \frac{8\sigma s p_T}{0.3BL^2} \oplus \frac{0.05}{BL}\sqrt{\left(\frac{x}{X_0}\right)}$$





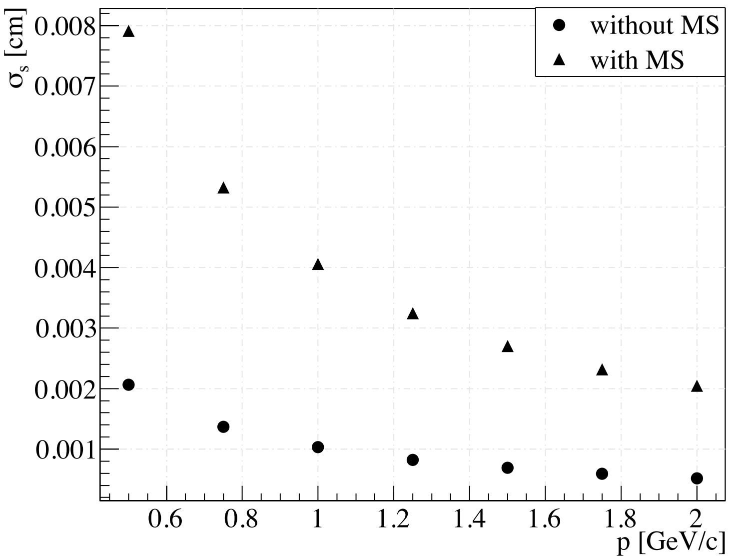
Two main parameters contribute on transverse momentum resolution;

First term , contribution from measurement error by means of trajectory uncertainties define "**Sagitta**", thus depends on tracker geometry

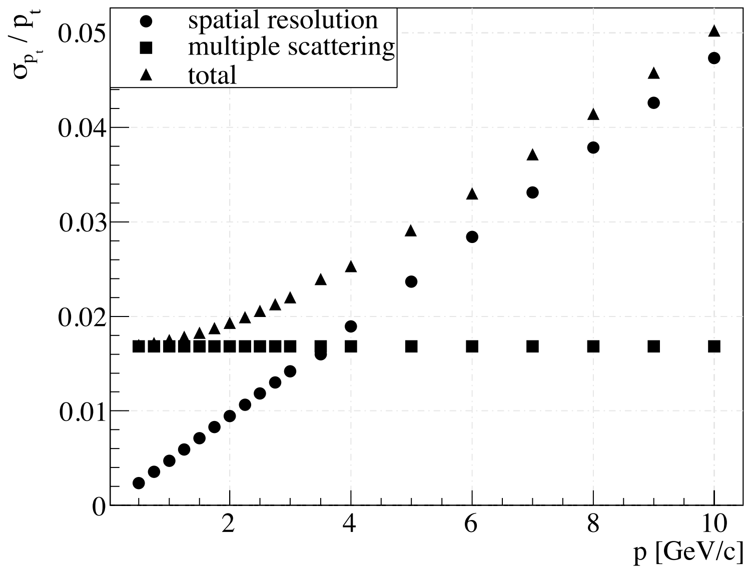
Second term, multiple scattering contribution to momentum uncertainty, thus material dependence

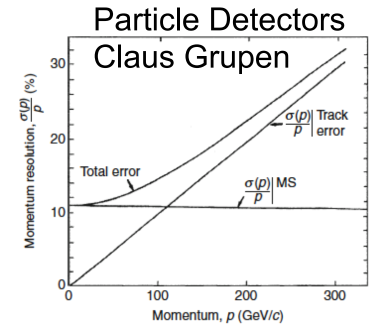
Particle Factory in TAC [Tracker]

Sagitta measurement error variation with momentum



Relative momentum resolution variation with momentum



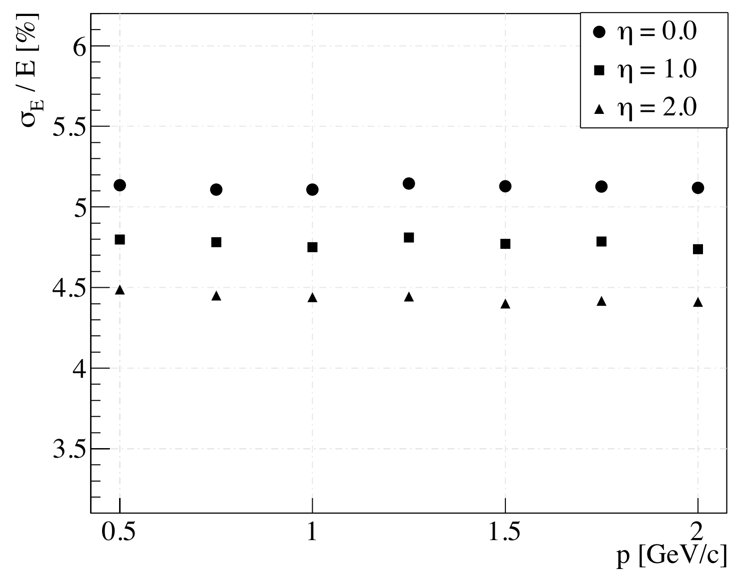


At low momentum, momentum resolution limited by MS in tracker material.

I.Tapan and B.Pilicer, Published in NIMA 765 (2014) 240-243

	Spatial resolution (%)	MS (%)	σ_{pt}/p_t
e^+	0.46	1.67	1.74
π^+	0.47	1.50	1.57
K^+	0.53	1.69	1.77

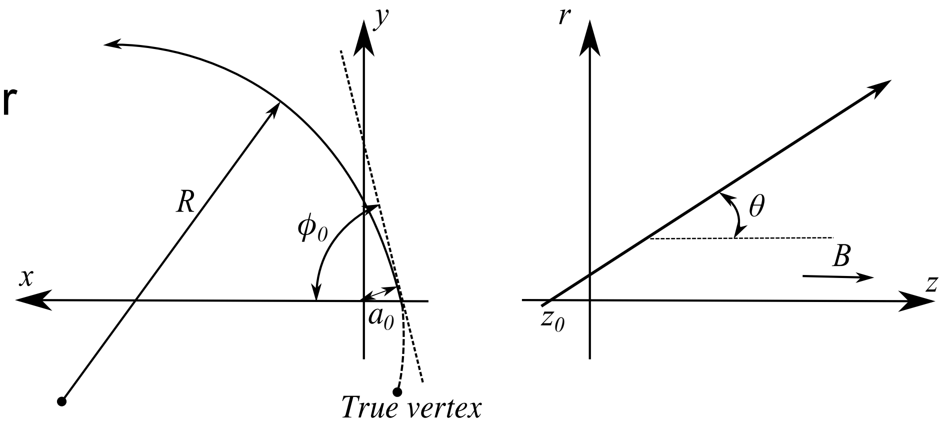
Energy resolution is about 5%, improving with eta

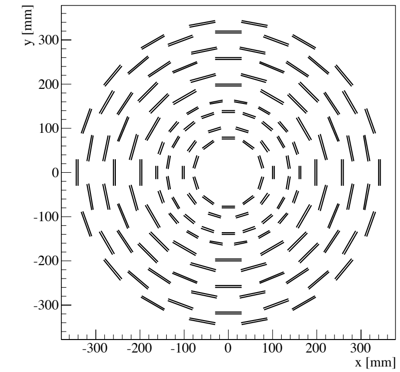


Particle Factory in TAC [Tracker]

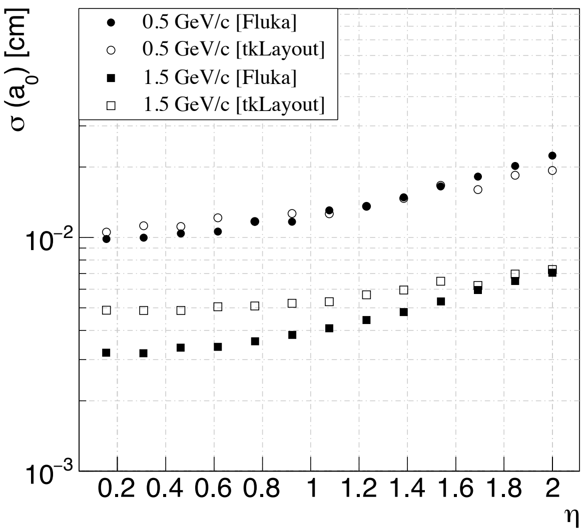
Calculation of "Impact parameters resolutions" with **FLUKA** and **tkLayout** (software package for tracker layouts developed by CMS group)

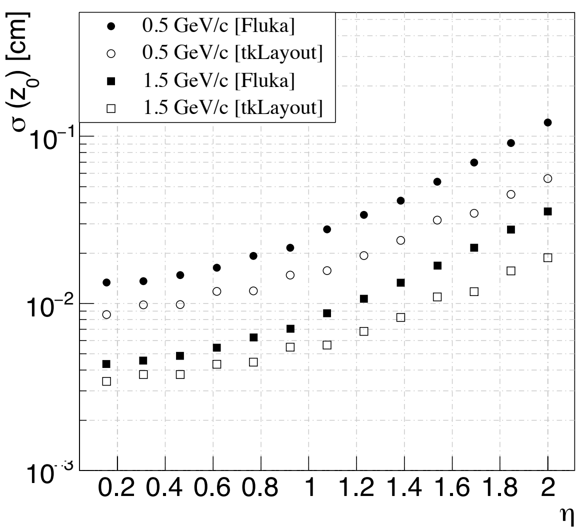
- a_0 Transverse impact parameter
- z_0 Longitudinal impact parameter
- Φ_0 Azimuth angle
- Θ Polar angle

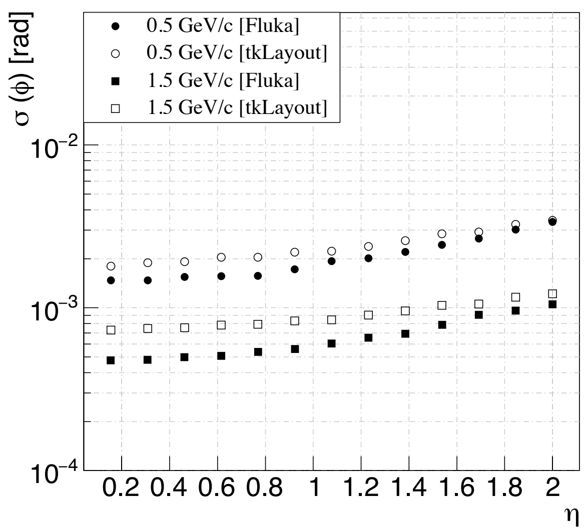


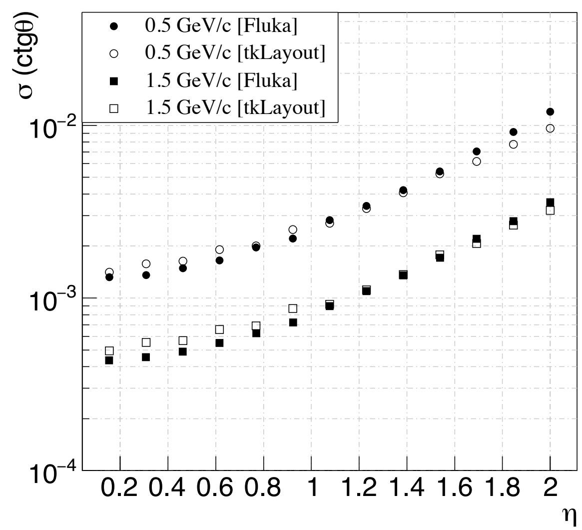


tkLayout geometry









Particle Factory in TAC [Calorimeter]

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

$$a = \sqrt{a_{lateral}^{\;2} + a_{pe}^{\;2}} \qquad a_{pe} = \sqrt{\frac{F}{N_{pe}}}$$

$$N_{pe} = N_{ph} \times QE$$

a : stochastic term (photoelectron statistics, shower fluctuations, lateral leakage)

b : constant term (non-uniformities, longitudinal leakage)

c : electronic noise term

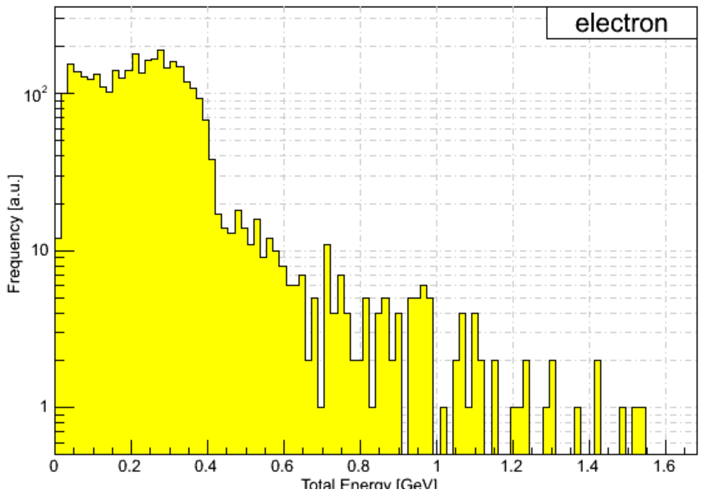
E : the energy of the incident particle

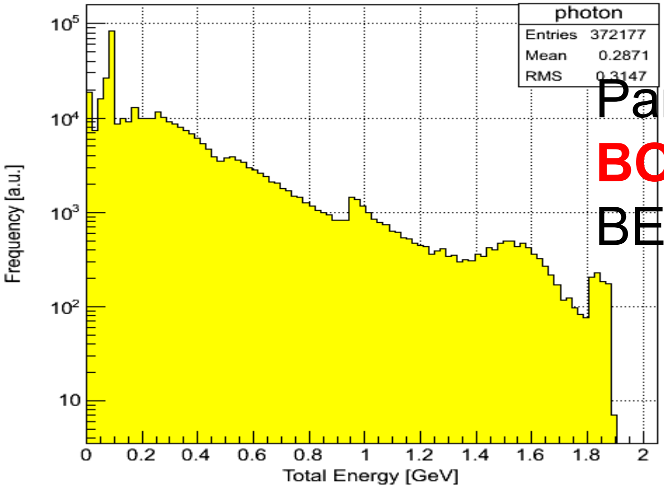
$a_{lateral}$: Event to event fluctuations in the lateral shower containment

a_{pe} : Photoelectron statistics contribution from photodetector

F : Excess noise, avalanche gain fluctutation in APD

N_{ph} : Number of the incident photons collected by the PD

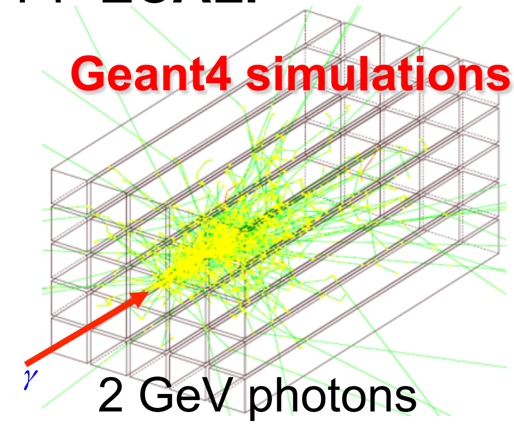


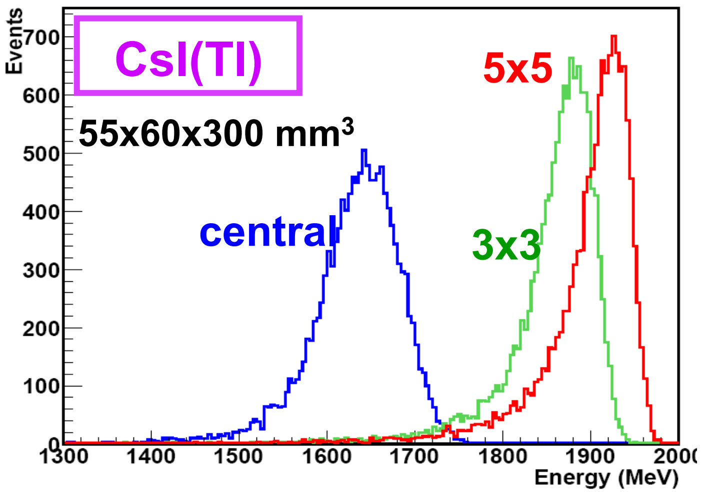


Particle distributions from;
BOSS 6.6.3
BES Offline Software System

Particle Factory in TAC [Calorimeter]

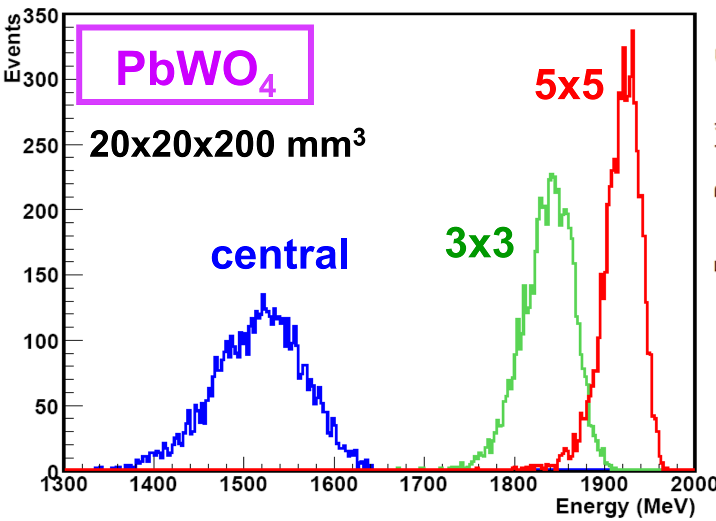
Crystals, **$PbWO_4$** ~$22.5X_0$ and **CsI(Tl)** ~$16.2X_0$, studied for TAC-PF **ECAL.**
Photodiodes, Hamamatsu S8664-55 **APD** and S2744 **PD**.

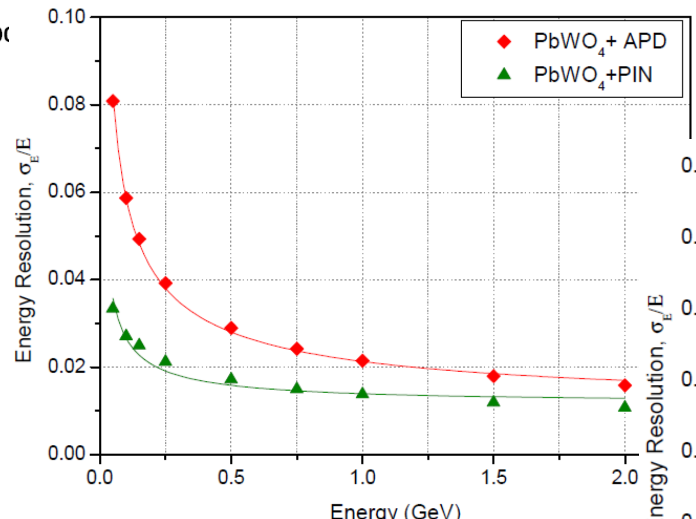


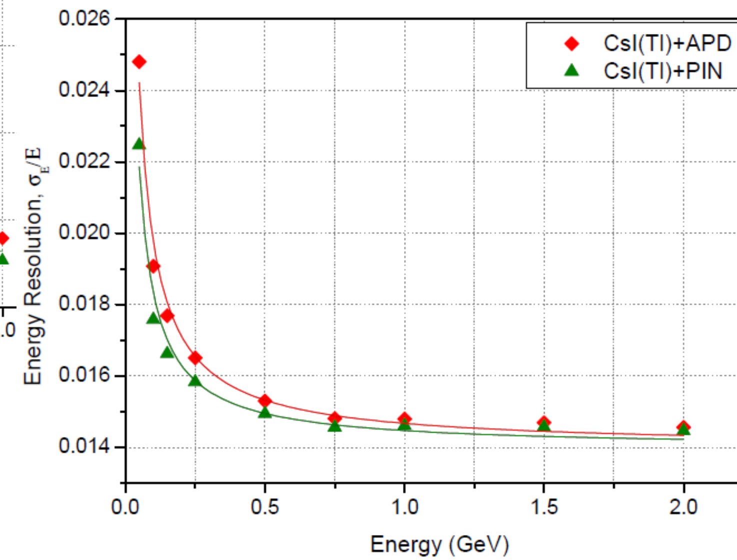


Energy deposition spectra is a Novosibirsk function having a tail towards lower energies

$$f(x) = A \cdot exp\left[-0.5 \cdot \left(\frac{ln^2[1 + \Lambda \cdot \tau \cdot (E - E_0)]}{\tau^2} + \tau^2\right)\right]$$



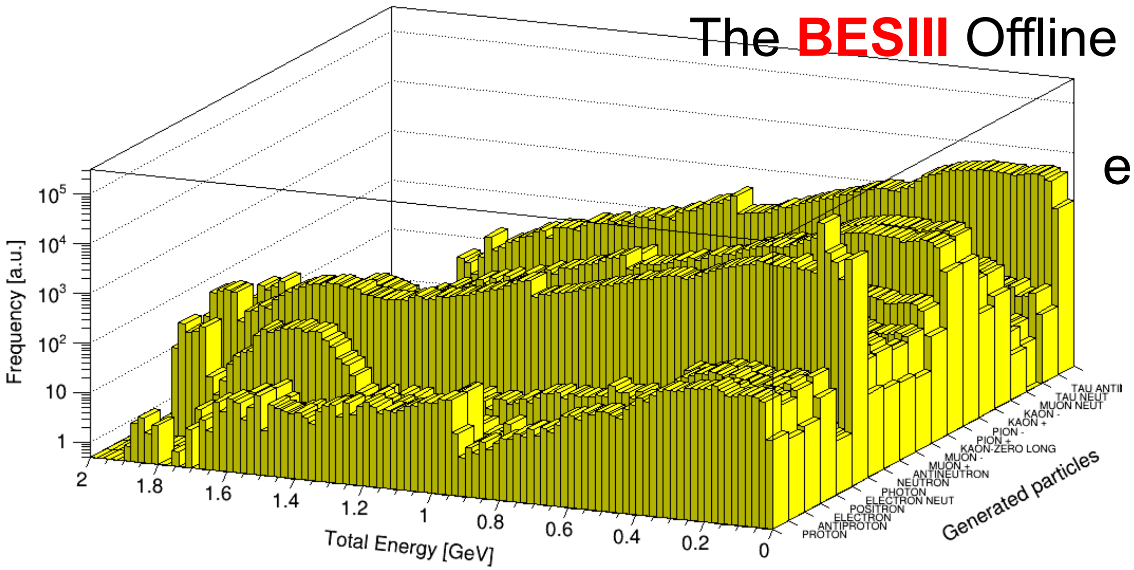




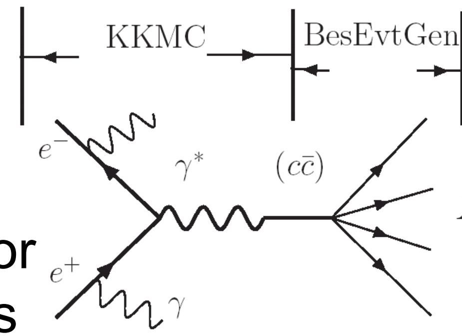
F.Kocak, Published in NIMA 787 (2015) 144-147

Particle Factory in TAC [Full Simulation]

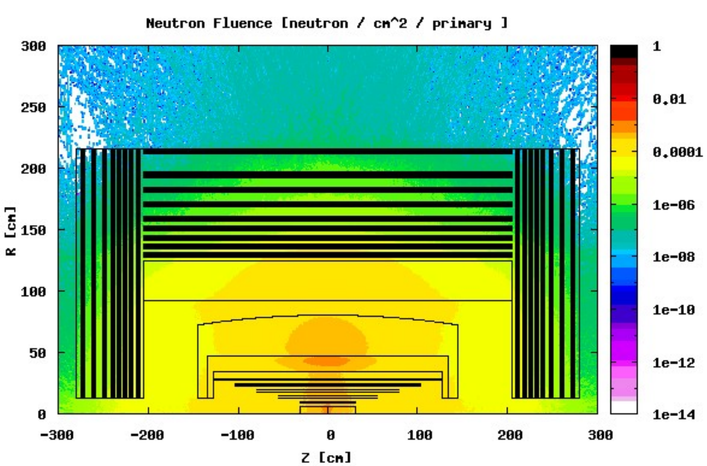
The **BESIII** Offline Software System (BOSS version 6.6.2)



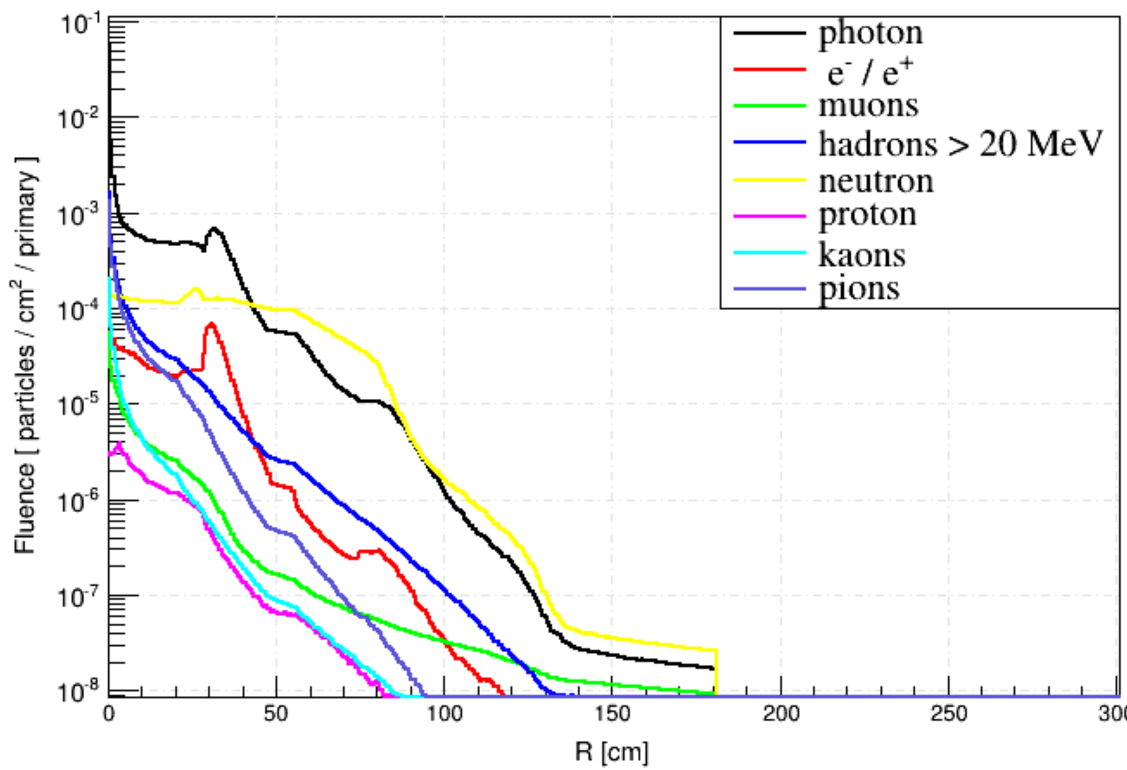
e- e+ → 3.77 GeV



BesEvtGen is the event generator for tau-charm physics

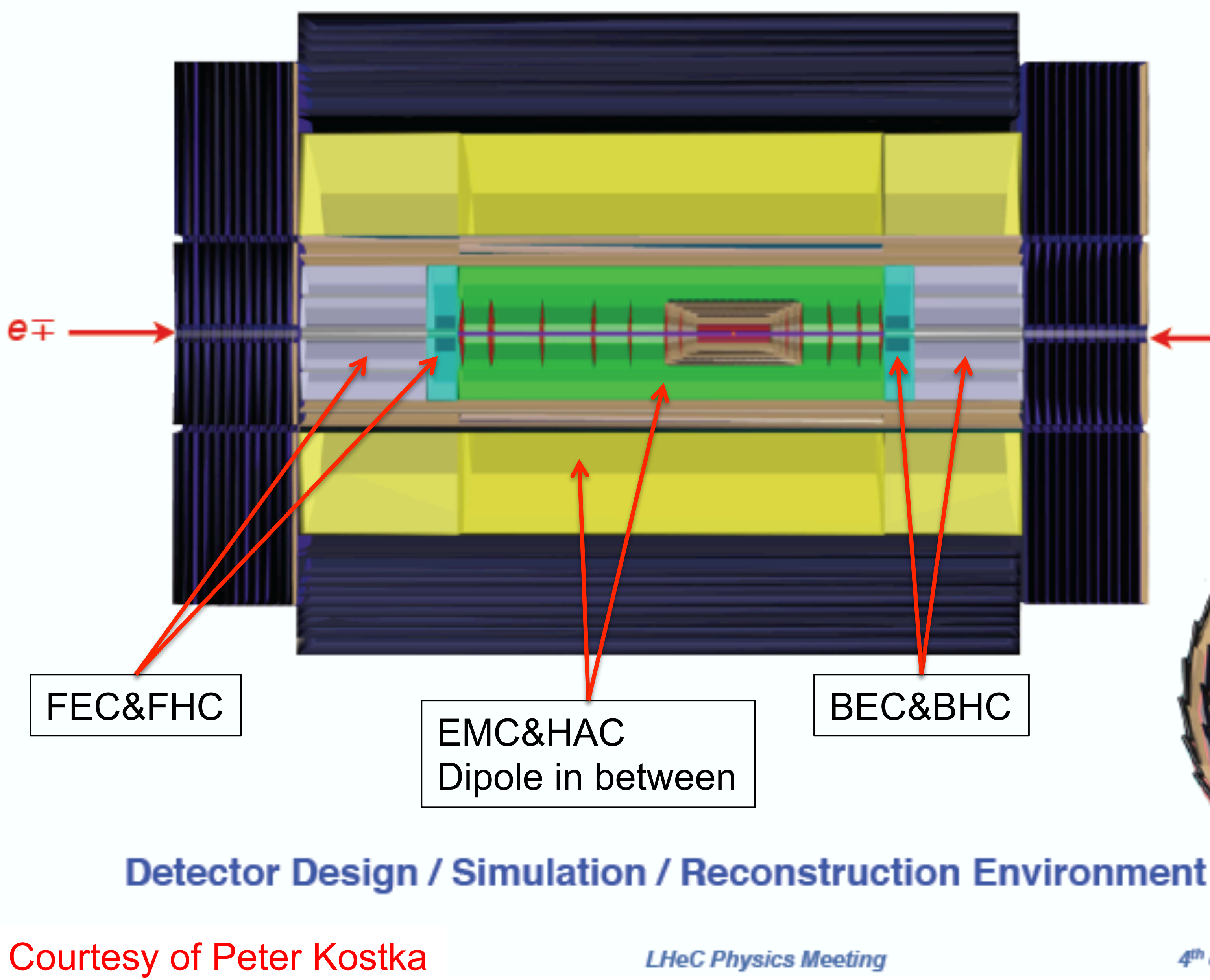


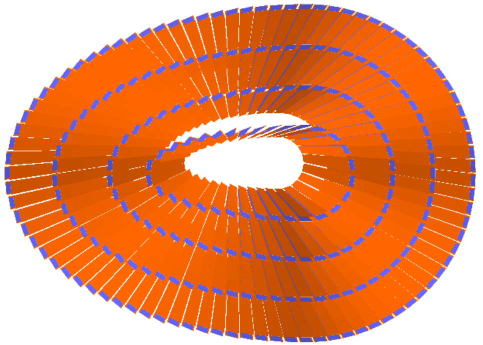
Particle fluences as a function of detector radius



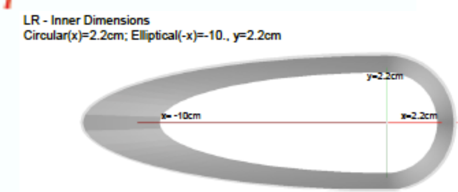
LHeC Detector

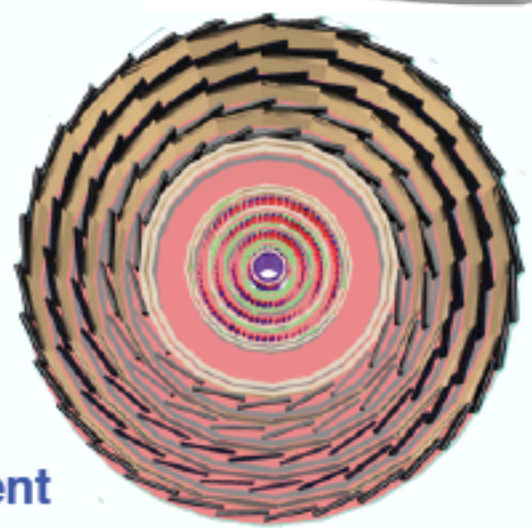
DD4hep, (Detector Description for HEP). full detector simulation





Elliptical tracker (Si+C)
Elliptical beam-pipe

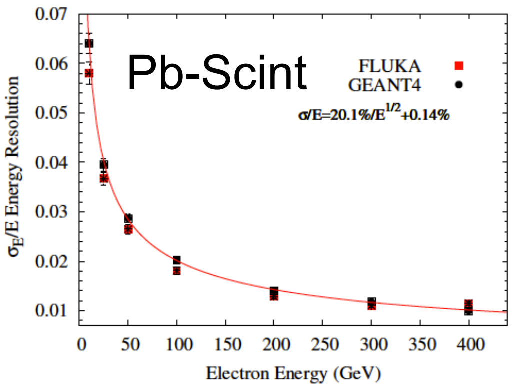


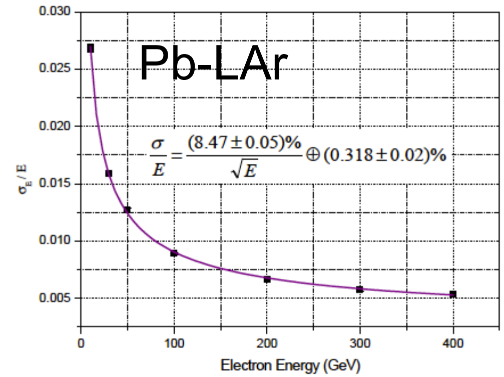


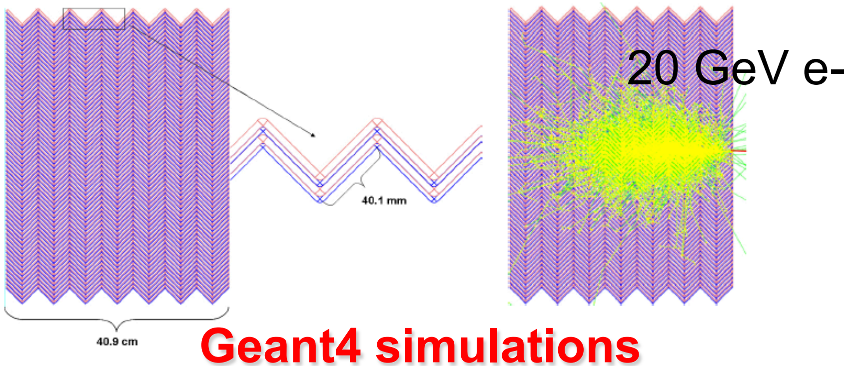
Courtesy of Peter Kostka

LHeC Detector [Barrel Calorimeter]

EMC, Pb-LAr (2.2+3.8 mm thick, like ATLAS)
Pb-Scint (8.5+4mm mm thick), no cryogenics



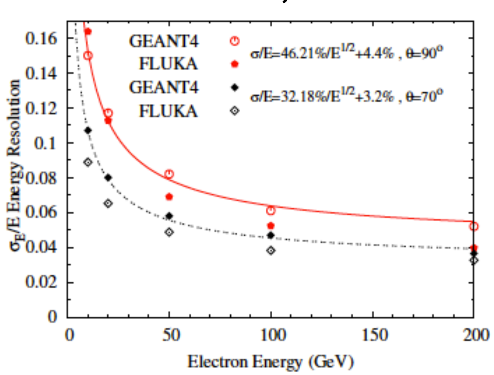


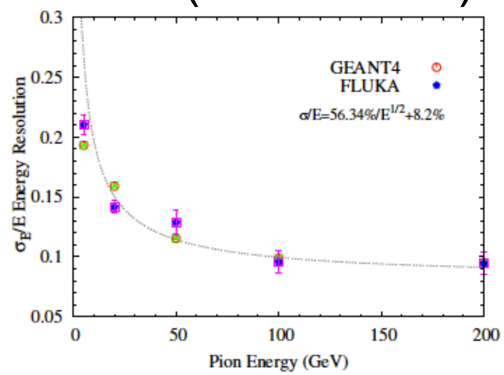


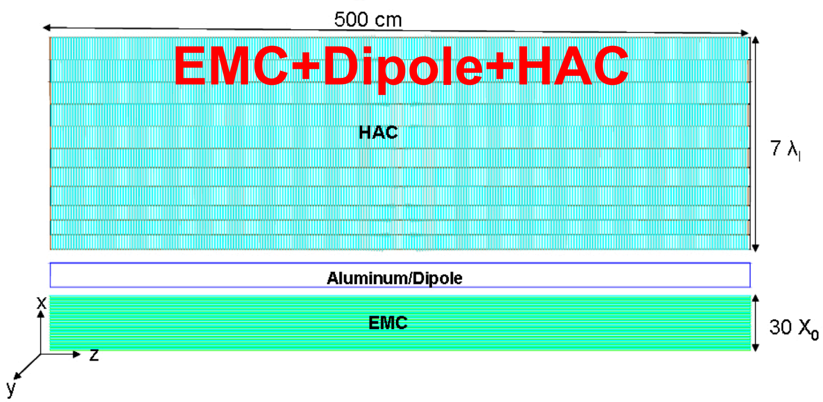
Geant4 simulations

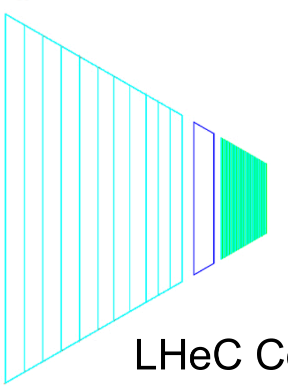
HAC, Tile calorimeter (like ATLAS)

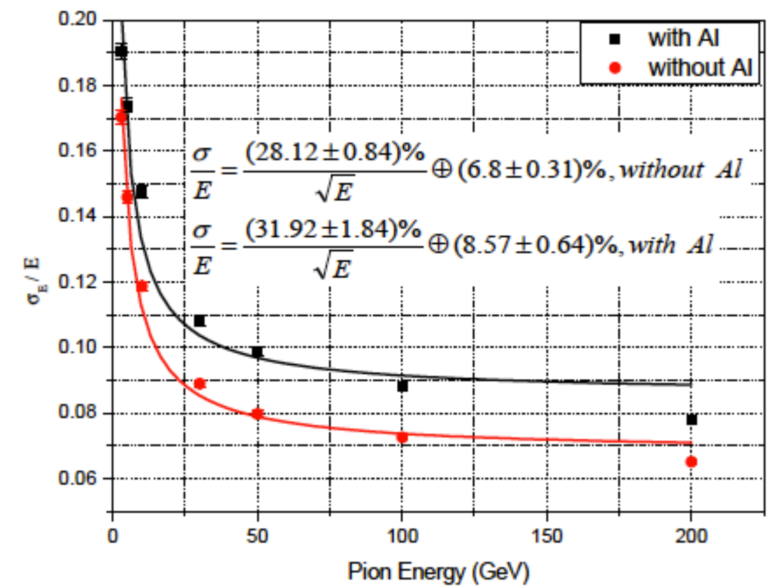
Tile Rows	Height of Tiles in Radial Direction	Scintillator Thickness
1-3	97 mm	3 mm
4-6	127 mm	3 mm
7-11	147 mm	3 mm
x-depth	1407 mm	





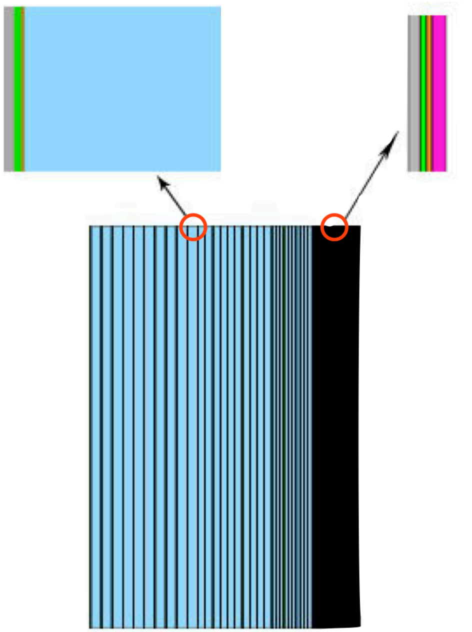






LHeC Collaboration Published in JPG Vol:39 No:7 (2012)

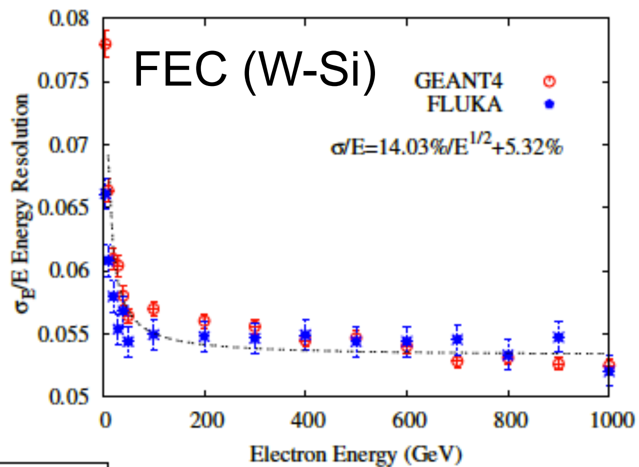
LHeC Detector [Endcap Calorimeters]

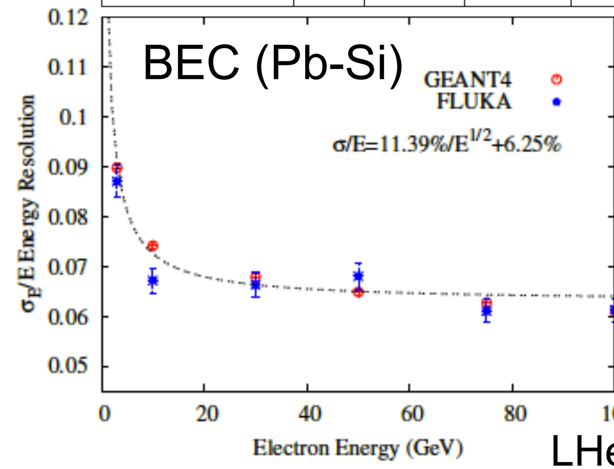


FHC & FEC composite Calorimeter

Forward and **Backward** calorimeter components defined in the simulations

Calorimeter Module	Layer	Absorber	Thickness	Instrumented Gap	Total Depth
$FEC_{(W-Si)}$ $30X_0$	1-25 26-50	1.4 mm 2.8 mm	16 cm 19.5 cm	5 mm	35.5 cm
$FHC_{(W-Si)}$ $10\lambda_I$	1-15 16-31 32-46	1.2 cm 1.6 cm 3.8 cm	39 cm 48 cm 78 cm	14 mm	165 cm
$FHC_{(Cu-Si)}$ $10\lambda_I$	1-10 11-20 21-30	2.5 cm 5 cm 7.5 cm	30 cm 55 cm 80 cm	5 mm	165 cm
$BEC_{(Pb-Si)}$ $25X_0$	1-25 26-50	1.8 mm 3.8 mm	17 cm 22 cm	5 mm	39 cm
$BHC_{(Cu-Si)}$ $7.9\lambda_I$	1-15 16-27 28-39	2.0 cm 3.5 cm 4.0 cm	39.75 cm 49.8 cm 55.8 cm	6.5 mm	145.35 cm





LHeC Collaboration
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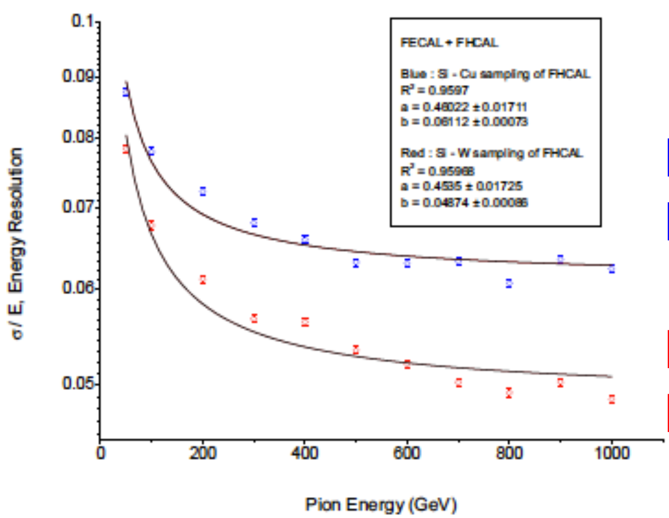
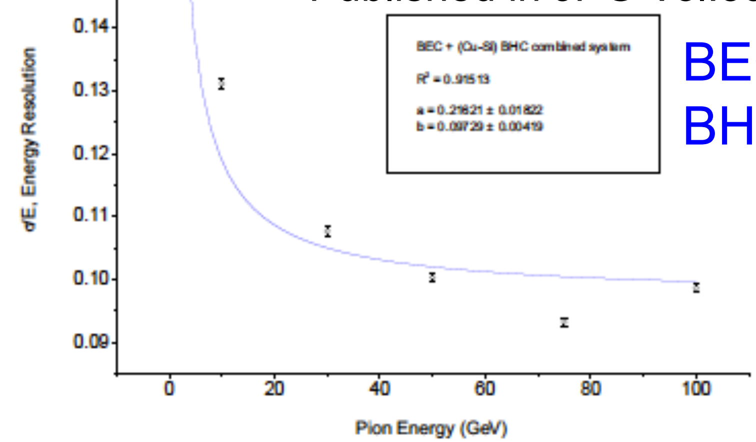


FEC (W-Si)
FHC (Cu-Si)

FEC (W-Si)
FHC (W-Si)

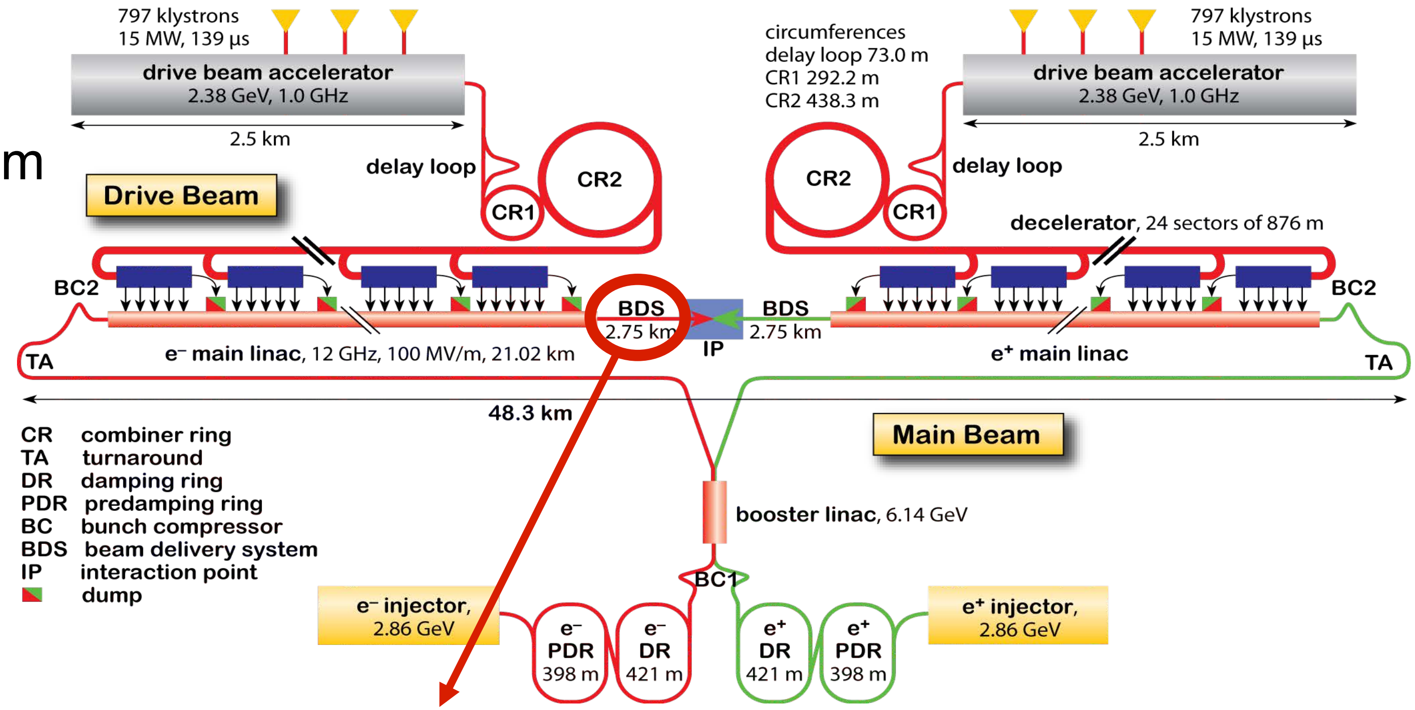


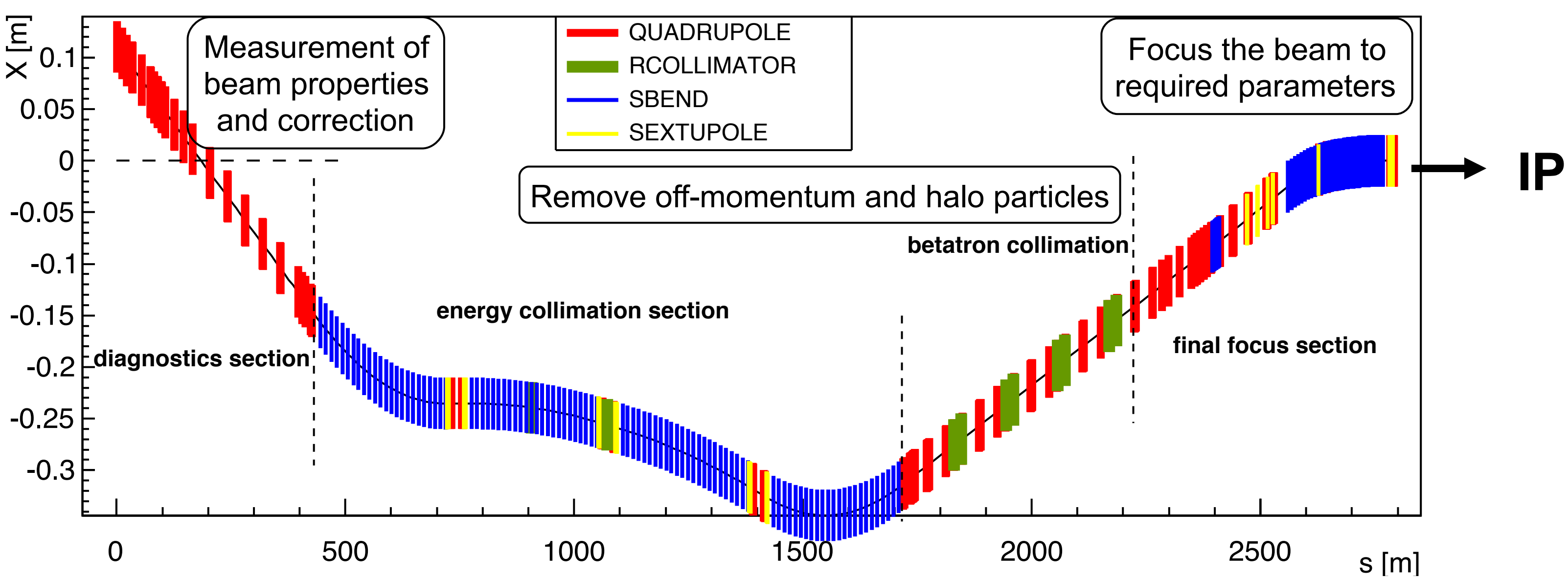
BEC (Pb-Si)
BHC (Cu-Si)

CLIC BDS

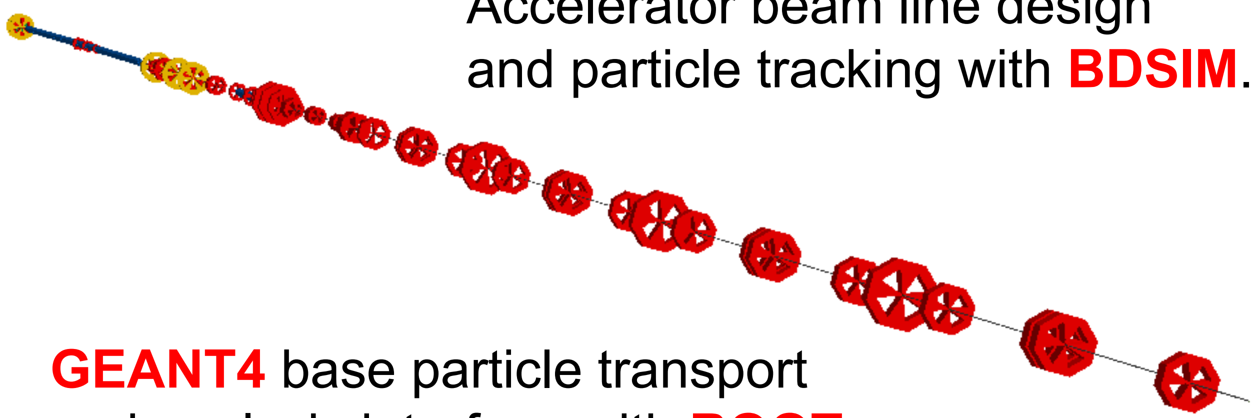
CLIC Beam Delivery System

Beam transfer line from main linac to IR (interaction region).

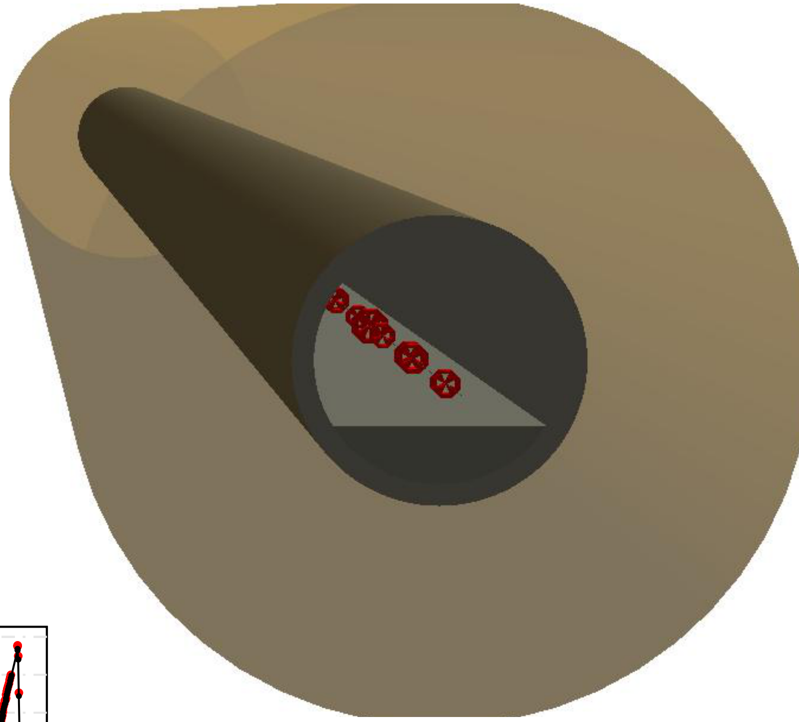




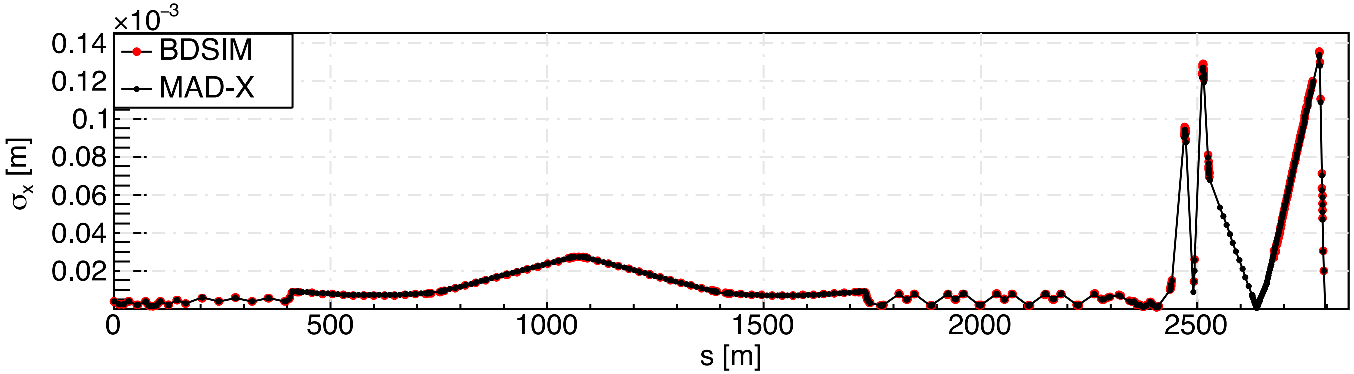
Muon Background in CLIC BDS



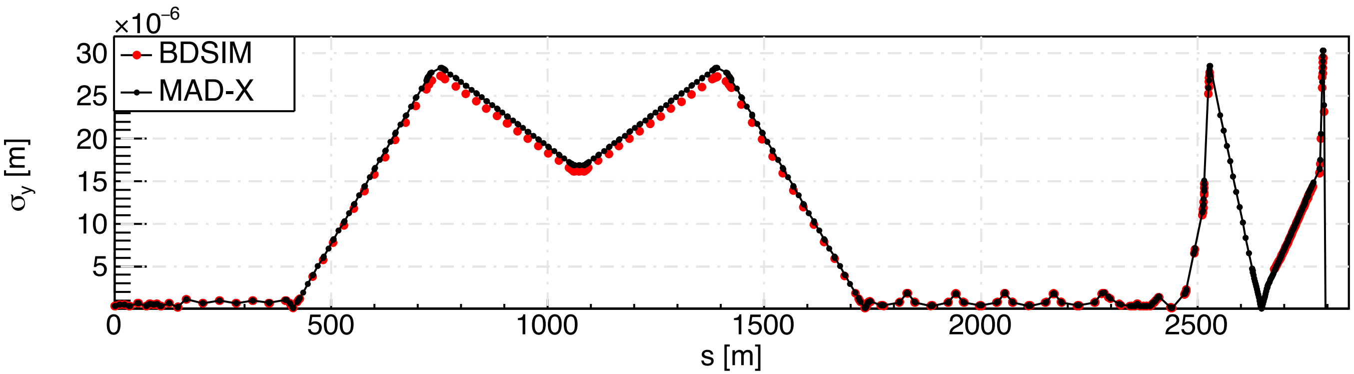
Accelerator beam line design and particle tracking with **BDSIM**.



GEANT4 base particle transport and analysis interface with **ROOT**.

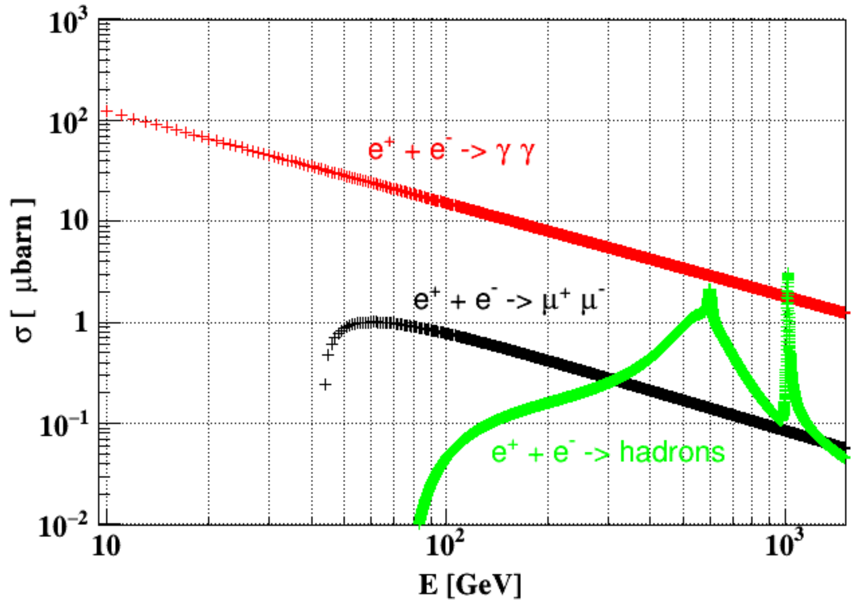


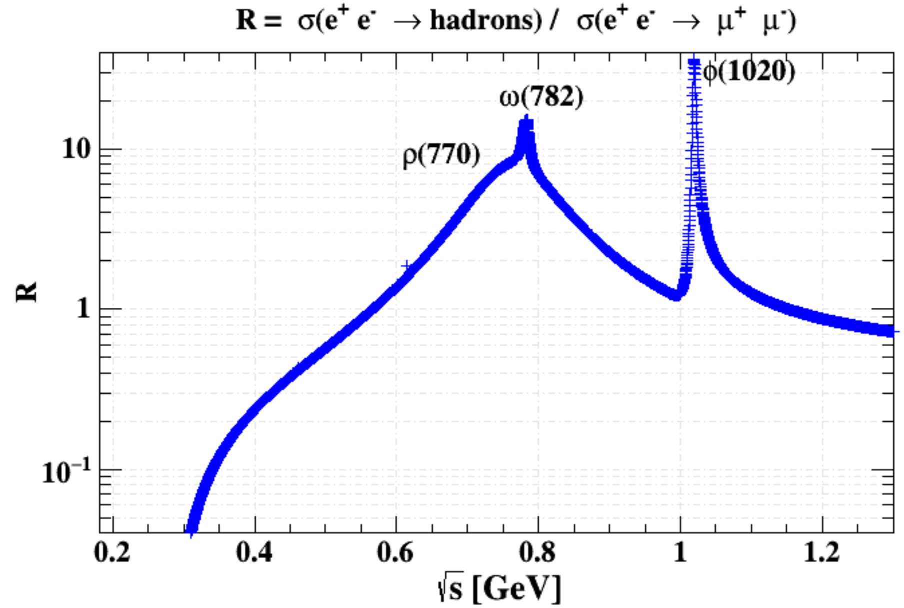
Beam sizes for each elements

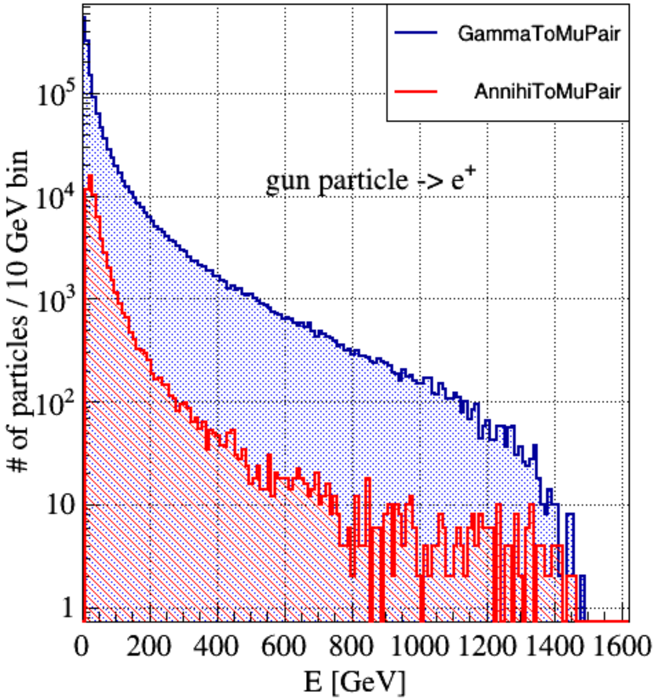


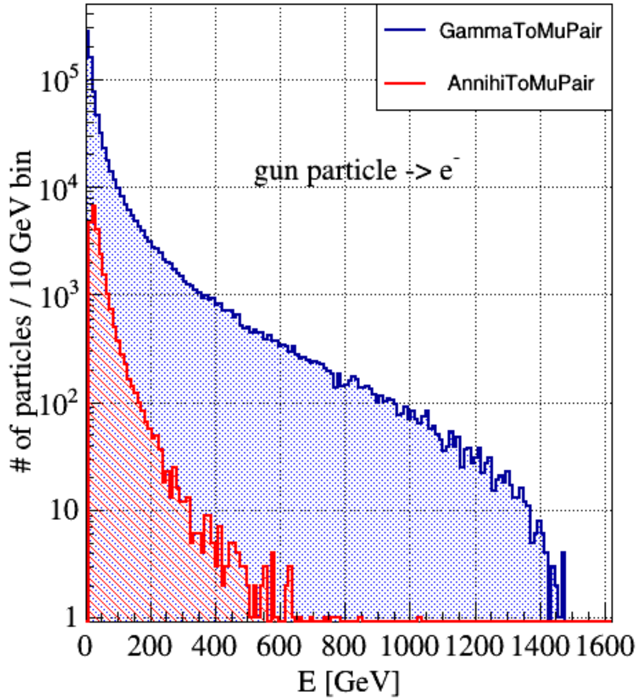
Good agreement between **BDSIM** and **MAD-X**.

Muon Background in CLIC BDS









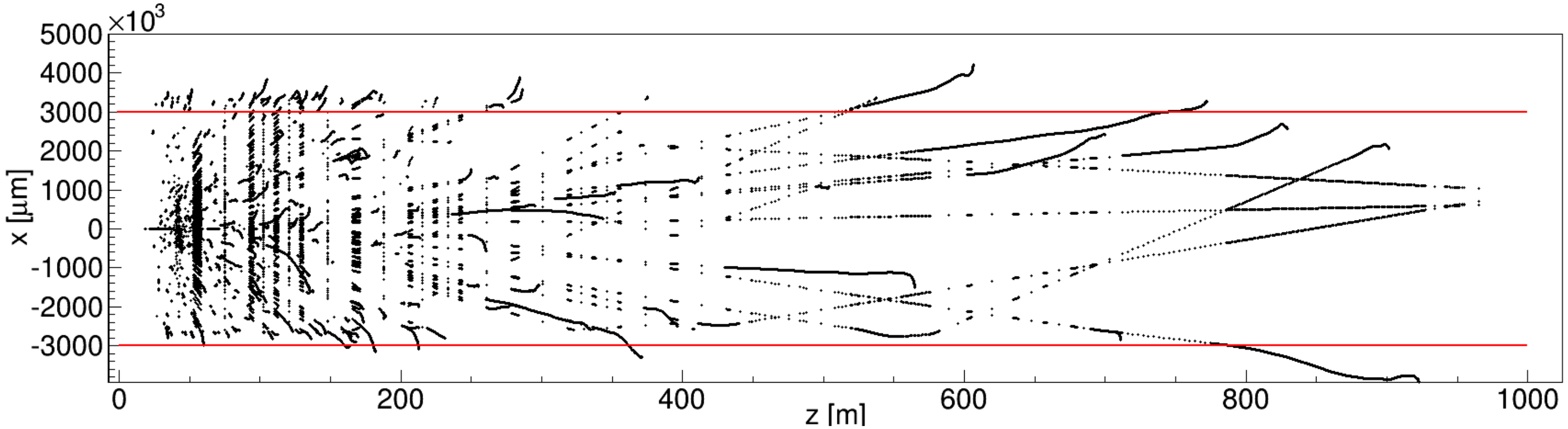
Background muons → while removing of halo particles

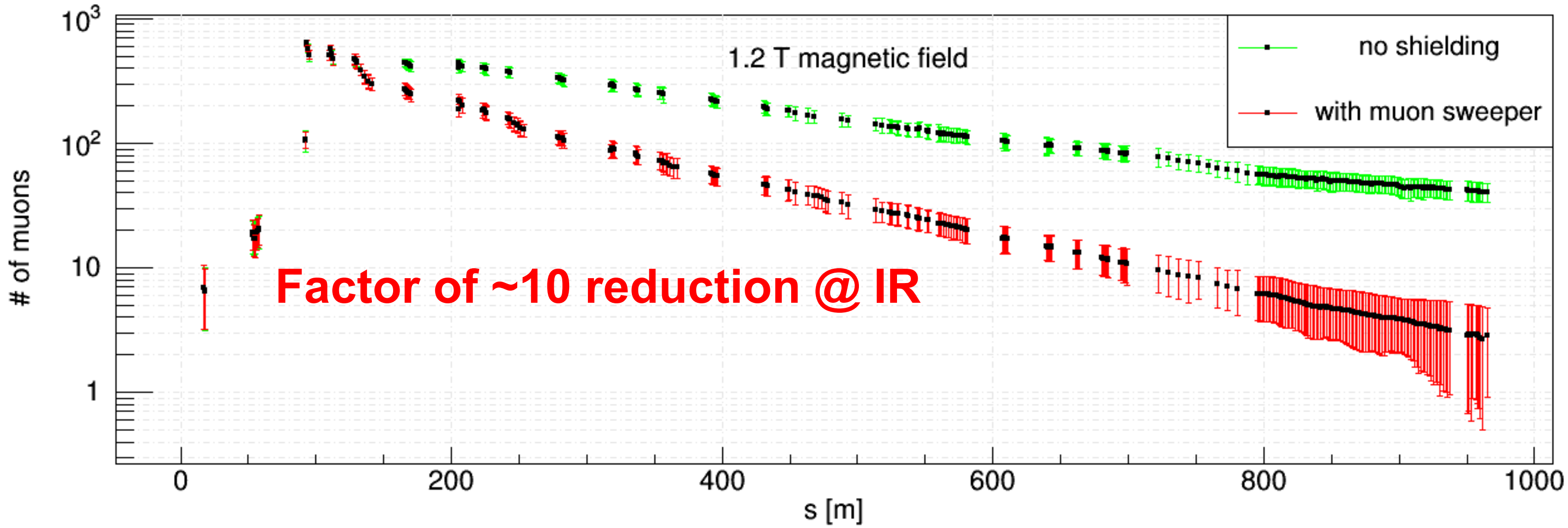
- **Direct** muon production
  - $\gamma\gamma \to \mu^+\mu^-$
  - $e^+e^- \to \mu^+\mu^-$
- **Indirect** contribution
  - $e^+e^- \to$ hadrons

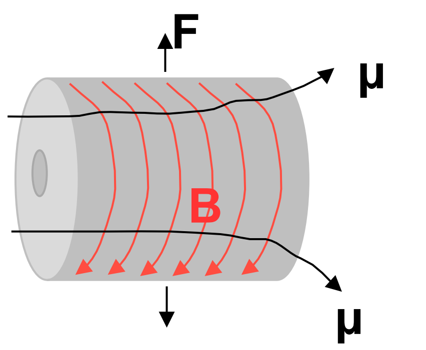
Contribution from decay of hadrons to muons and energetic photons.

Muon Background in CLIC BDS

Muon trajectories in the tunnel through the IR







Magnetized muon sweeper/shielding to prevent muons reaching to IR (as background)

They have been placed available drift space in betatron collimation section

B. Pilicer et al., Published in IPAC 2015
B. Pilicer et. al. Published in LCWS15

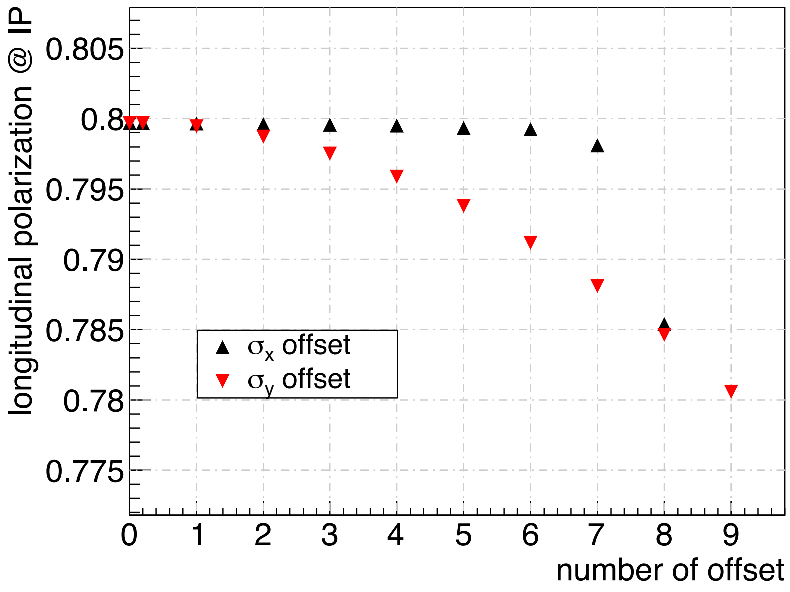
Spin Transport in CLIC BDS

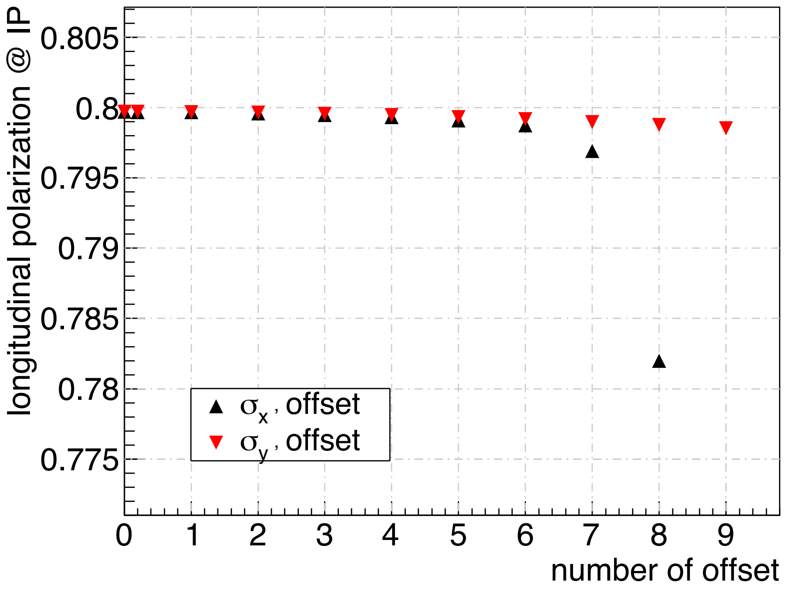
Numerical spin tracking through BDS done with **BMAD** to have particle dynamics.

Longitudinal electron beam polarization values @ IP were estimated 80% polarized electron beam.

The electron beam was sent with different misalignment values to the BDS.

The beam sizes (σ_x , σ_y) and the tilt values on axes ($\sigma_{x'}$, $\sigma_{y'}$) were calculated.

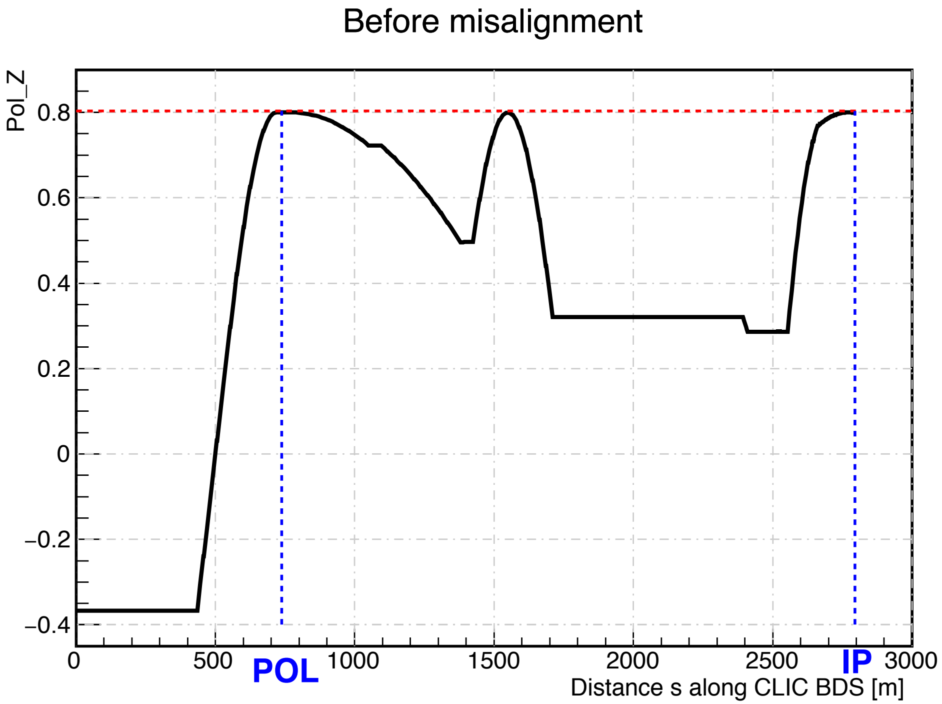


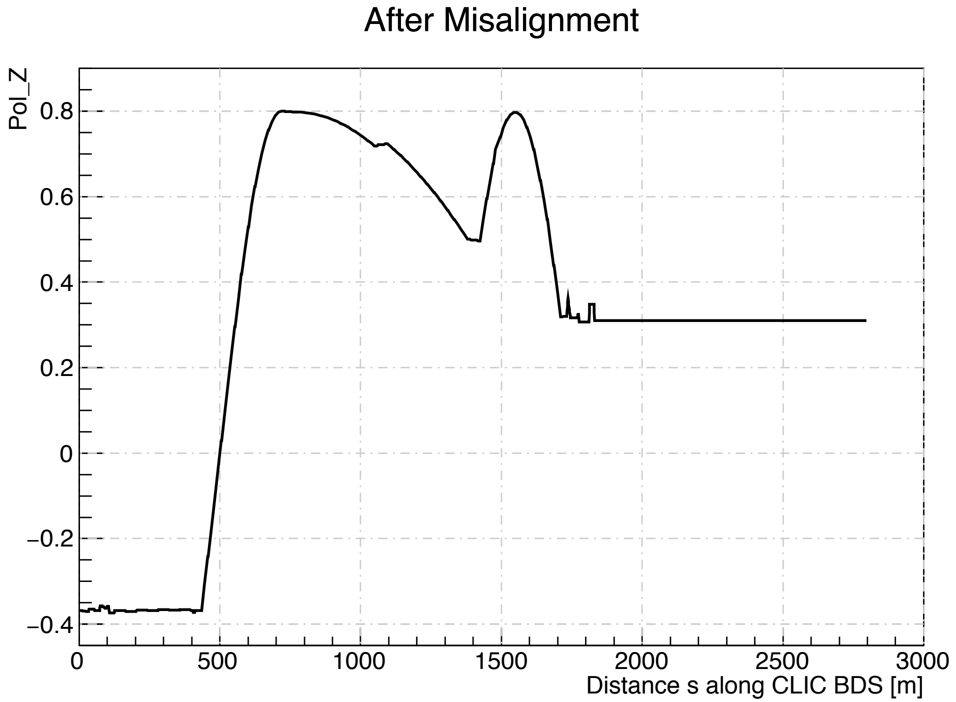


The polarization values at the IP were decreased up to 0.1% with applied misalignments of **$7\sigma_x$** and **$2\sigma_y$ $6\sigma_{x'}$** and **$7\sigma_{y'}$**

Spin Transport in CLIC BDS

The misalignment effect on polarization was also investigated for the quadrupole magnets. The **70 quadrupoles** on the beamline were misaligned randomly at around **10 um** and the beam was sent to the BDS without any misalignment.

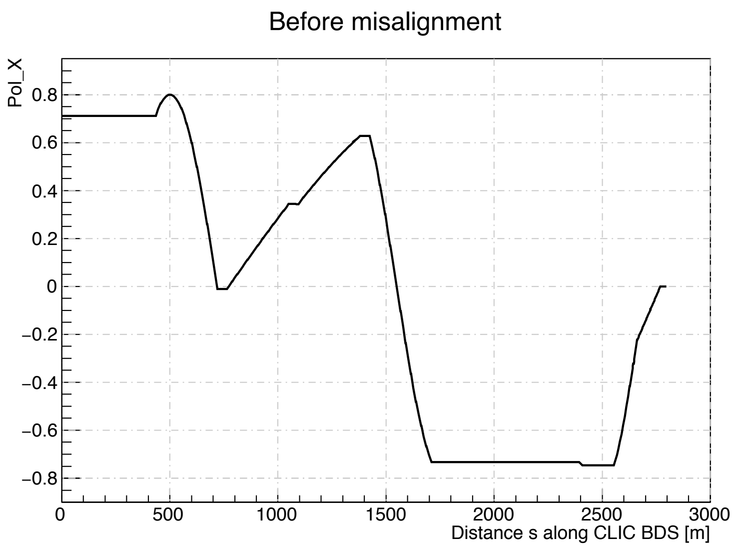


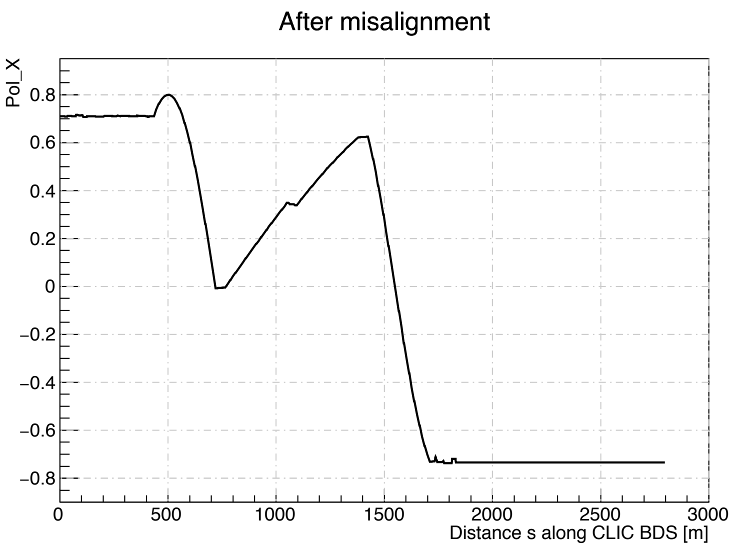


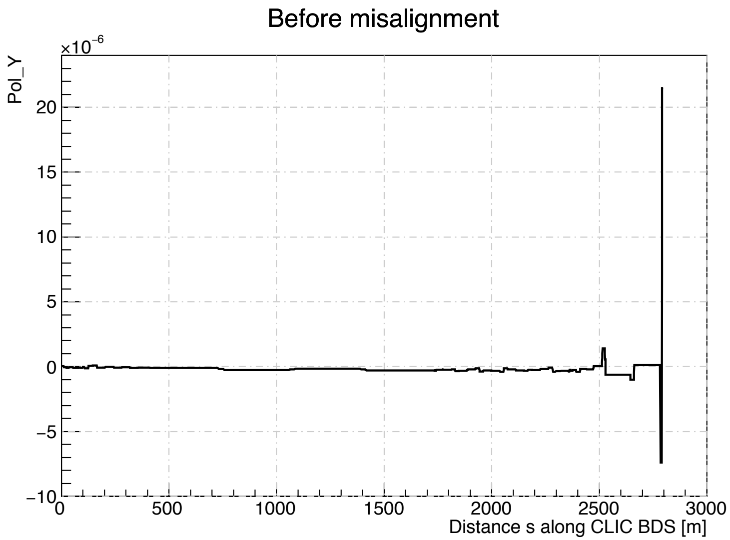
The changes of longitudinal polarization without applied misalignment and after applied misalignment on all quadrupoles in CLIC BDS

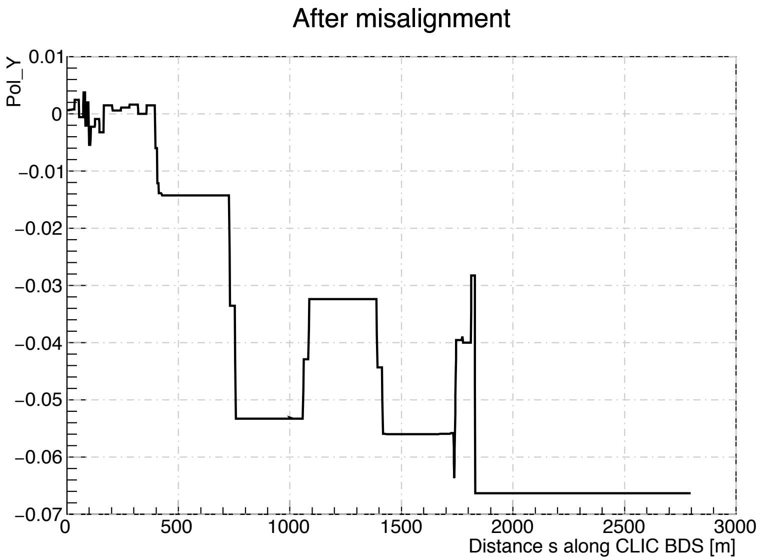
Spin Transport in CLIC BDS

The changes of x and y components of polarization before and after applied misalignment to the quadrupoles



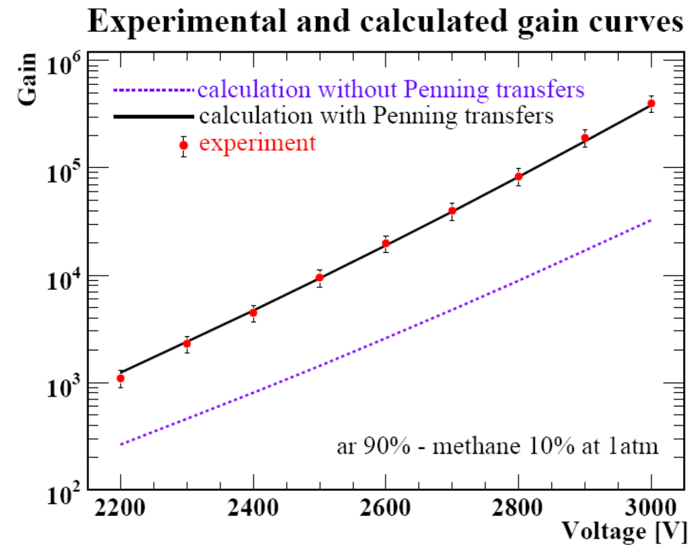


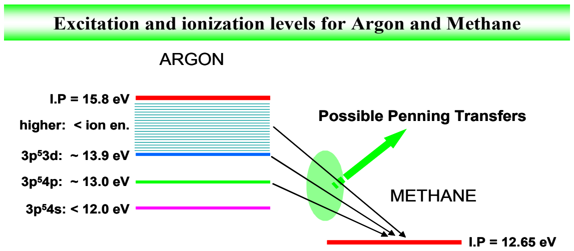




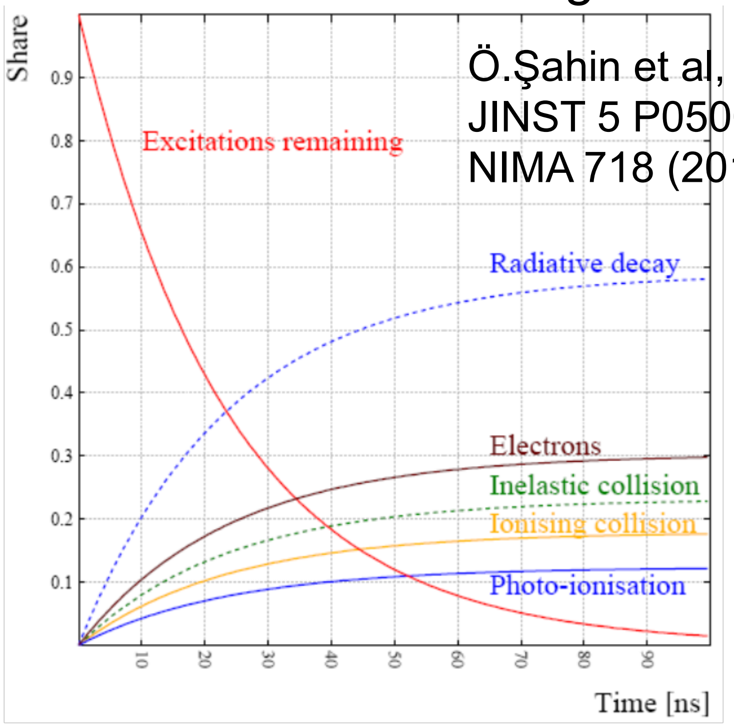
Penning Transfer Simulations for RD51

In addition to direct ionising collisions, there may be many non–ionising interactions in which some fraction of the energy is spent on the creation of short or long lived excited states. If the energy stored in excited noble gas atoms is used efficiently for additional ionisations.



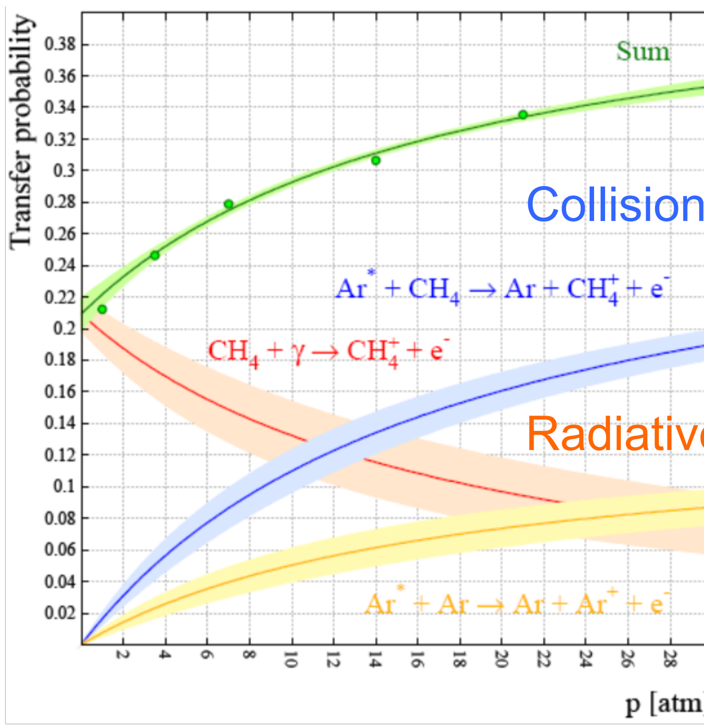


Time evolution of Penning transfer



Ö.Şahin et al, Published in JINST 5 P05002 (2010) NIMA 718 (2013) 432-433

Contributions to the transfer rates



Collisional ionisation

Radiative ionisation

Summary & Remarks

- Our group's experiences on the simulations of both accelerator and detector sides have been presented
- Different aspects of accelerator, like machine detector interface, are of interests
- Different aspects of detector, like tracker and calorimeter resolutions, are of interests
- Many papers, talks and notes relevant to those studies are present
- Two relevant PhD thesis are on the way of finalizing
- An ambitious group of experienced researchers ready to take part in **FCC studies**