SUMMARY OF SOFTWARE SESSION

Thursday morning

Patrizia Azzi - INFN PD

A FULL AND VERY VARIED AGENDA + DISCUSSION

- ➤Covering: technical general issues, full simulation, reconstruction, fast simulation, performance
- ➤Active participation rom the audience and constructive discussion

09:10 **FCC Software Framework & vision for the future**
Speaker: Javier Cervantes Villanueva (CERN)
FCCSW-FCC-ee-Wor...

09:30 **MDI and background studies with IDEA tracker**
Speaker: Niloufar Alipour Tehrani (CERN)
nalipour_FCCee201...

09:50 **Tracking in the IDEA chamber**
Speaker: Giovanni F. Tassielli (INFN Lecce / Università del Salento)
IDEA-Tracking-Sftw_... IDEA-Tracking-Sftw_...

10:10 **Dual Readout Calorimeter Full Simulation Status**
Speaker: Lorenzo Pezzotti (Universita and INFN (IT))
FCC_Pezzotti.pdf

11:00 **CEPC simulations and tools**
Speaker: Manqi Ruan (Chinese Academy of Sciences (CN))
Simulation-tool-CEP...

11:25 **Delphes Fast Simulation status for the IDEA detector**
Speaker: Elisa Fontanesi (Universita e INFN, Bologna (IT))
Delphes Fast simula...

11:45 **CLIC/CLD Software for simulation and event reconstruction**
Speakers: Andre Sailer (CERN), Marko Petric (CERN)
190110_FCC_sailer...

12:05 **General Discussion and next steps**
FCC-ee SW discussi...

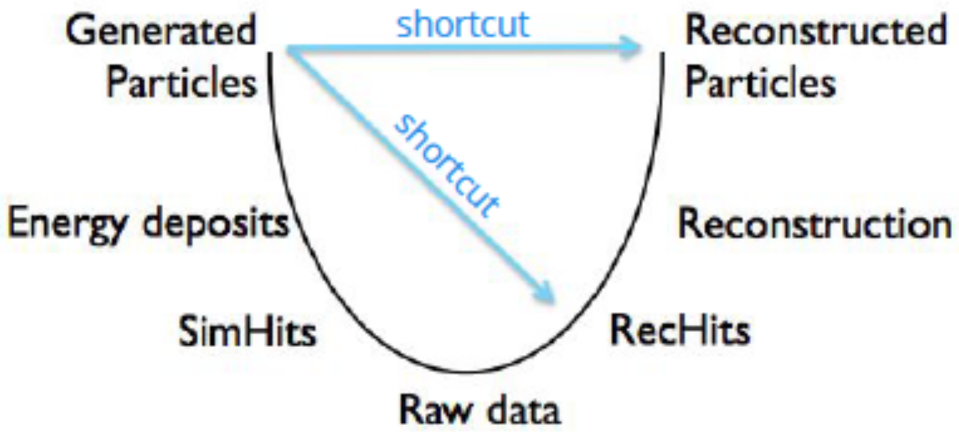
LOOK TO THE FUTURE

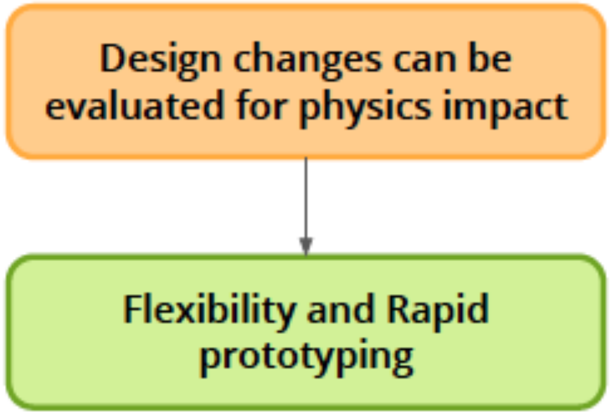
Javier Cervantes

Introduction

- Support experiments for all collider options: ee, eh & hh
- Support physics and multiple detector studies
- Collaborative approach:
  - Extract and adapt from the LHC experiments if possible
  - Invest into new solutions where necessary
  - Benefit from AIDA and HSF efforts
- One software stack:

  Support all experiments from *event generation* to *physics analysis*





TOWARD A SUSTAINABLE STRATEGY

Javier Cervantes

SFT Group Mandate

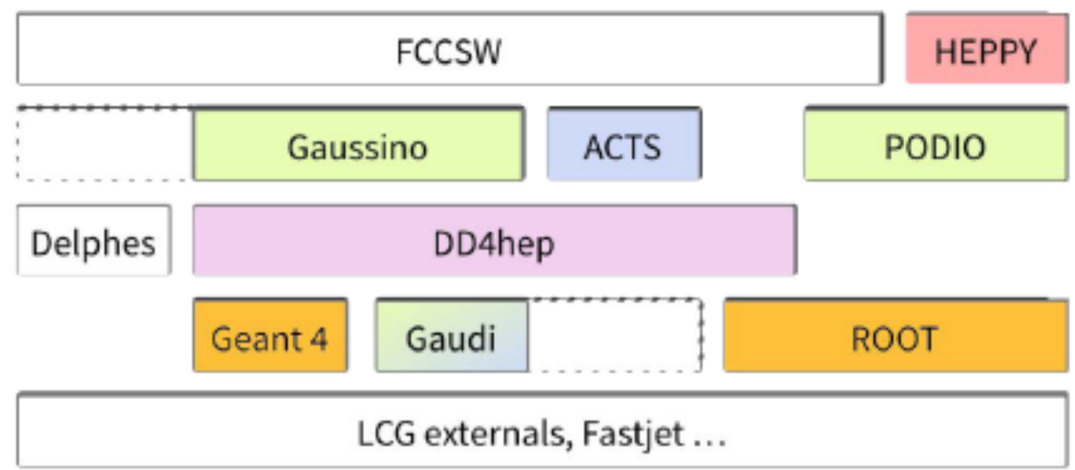
- The group **develops and maintains common scientific software** for the physics experiments in close collaboration with the EP experimental groups, the IT department and collaborating HEP institutes
  - Geant4, ROOT, Gaudi, CernVM, ...
- The group provides **common infrastructure and expertise** to the experiments
  - select & maintain tools used in the development process
  - manage stack of >300 external software packages
  - provides people to the experiments to fill key roles
  - training (CSC, GridKa, CERN Technical Training, ...)
- The group leads and participates actively to **community initiatives** such as HEP Software Foundation (HSF)

TURNKEY SOFTWARE STACK PROPOSAL

Javier Cervantes

FCC Software components and collaborations

- Event Data Model - **PODIO**
- Detector Description - **DD4HEP**
- Simulation - **Geant4, PAPAS**
- Reconstruction - **Acts, TrickTrack**
- Physics Analysis - **HEPPY**



LHCb ATLAS CMS CLIC/ILC EP-SFT

Strong candidates to become part of the **Turnkey Software Stack**

More details about the current workflow adopted by FCC on [Joschka's talk]

FCC Software, Javier Cervantes 10/01/2019 12

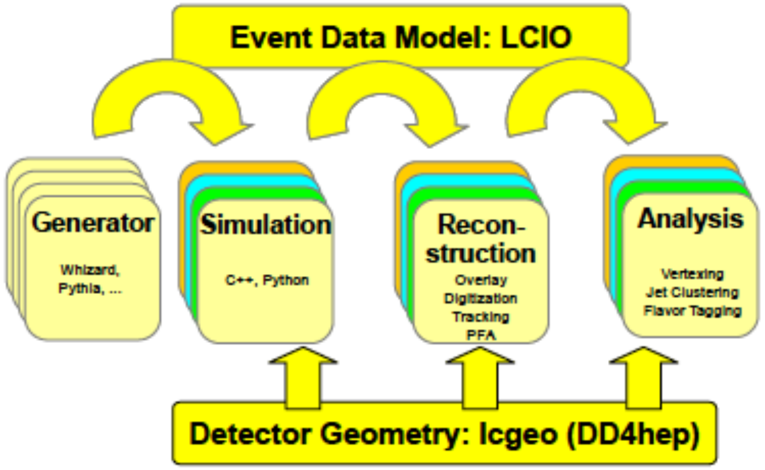
CLIC SOFTWARE EXAMPLE

Andre Sailer

➤Experience and development over a long period of time. Stable and understood software and framework. Useful for studies and performance right now.

Linear Collider Software

- Linear collider community has used and developed **common software** for many years
  - Event data model (EDM) and persistency: LCIO
    - ⋆ podIO is being investigated in AIDA2020
  - Particle flow reconstruction: PandoraPFA
- Adopted DD4Hep geometry description to develop more common software this geometry information
- Interface generic reconstruction packages via thin wrappers to linear collider framework

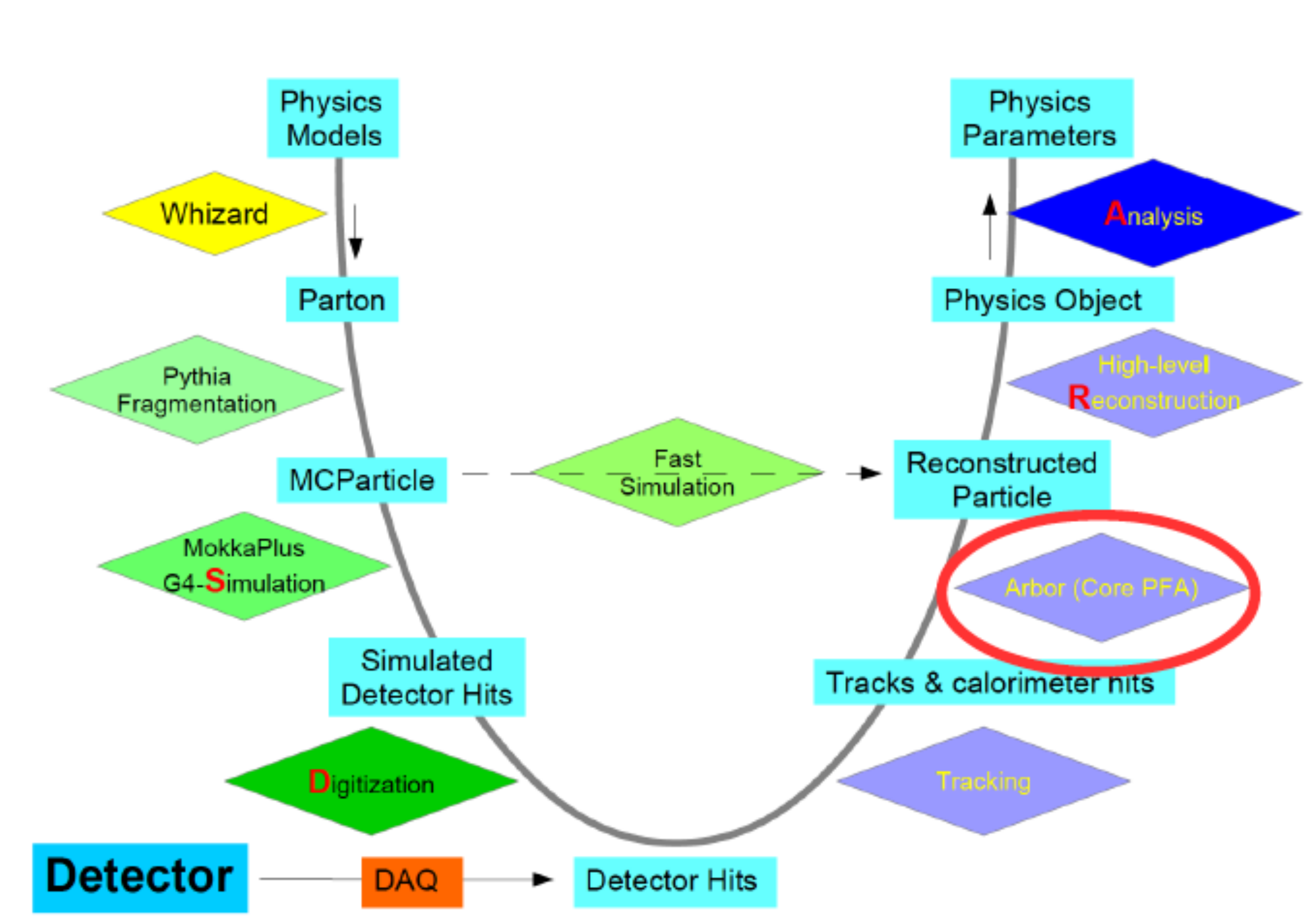


CEPC EXPERIENCE WITH ILC SOFTWARE

Manqi Ruan

➤CEPC choice to base development on ILCSoft. Also modular approach. Stable and validated used for FullSimulation of Physics Studies for CDR.

CEPC Baseline Software



Generators (Whizard & Pythia)
Data format & management (LCIO & Marlin)
Simulation (MokkaC)
Digitizations
Tracking
PFA (Arbor)
Single Particle Physics Objects Finder (LICH)
Composed object finder (Coral)
Tau finder
Jet Clustering (FastJet)
Jet Flavor Tagging (LCFIPLus)
Event Display (Druid)
General Analysis Framework (FSClasser)
Fast Simulation (Delphes + FSClasser)

CEPC-SIMU-2017-001,
CEPC-SIMU-2017-002,
(DocDB id-167, 168, 173)

General Software | ILCSoft | ILCSoft + Development | Developments

WHAT NEXT

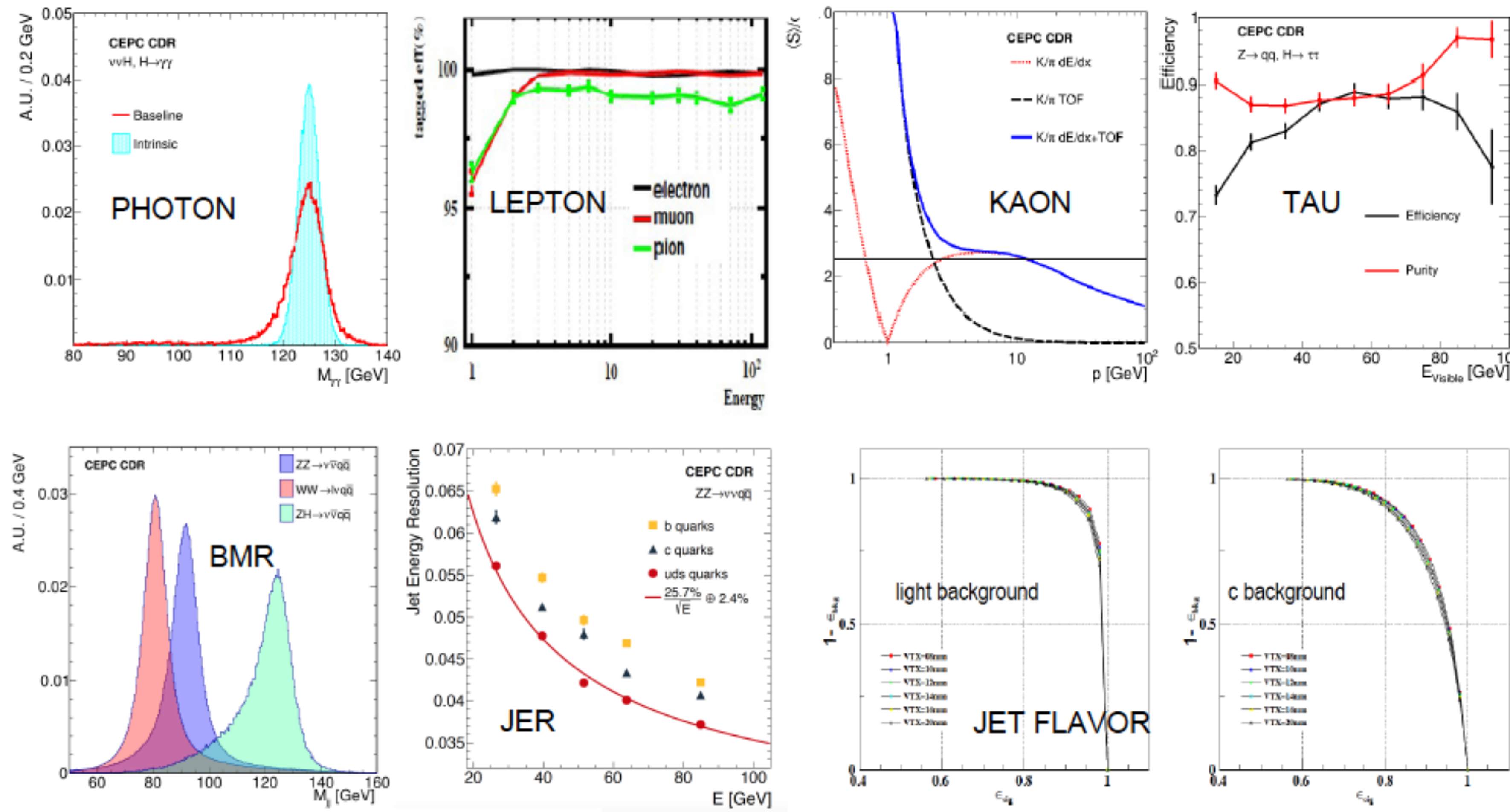
- ➤Lots of detailed studies. CDR published
- ➤Evolution?

Physics Objects

CEPC CDR

Eur. Phys. J. C (2017) 77: 591

Eur. Phys. J. C (2018) 78:464



Eur. Phys. J. C (2018) 78: 426

10/01/19 FCC WS@CERN 7

- Wishlist & Perspective for future collaboration
  - Common software: simulation framework and reconstruction algorithm/toolkits
  - Common samples: start from generator samples
  - Common toolkits/repositories to other tech. Challenges: integration, cooling, etc

Manqi Ruan

CLIC SOFTWARE TOWARD THE FUTURE

Andre Sailer

➤Modular structure with plug-and-play approach. Some components are already part of the new strategy for a CSF. Some new components can be (more or less easily) ported or replaced to mantain evolution for the future.

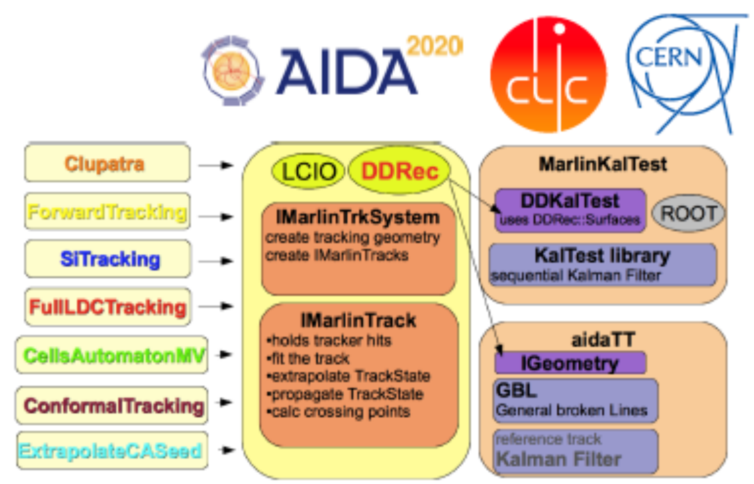
➤Here example fo tracking algorithm: many different ones relying only on standard hit format

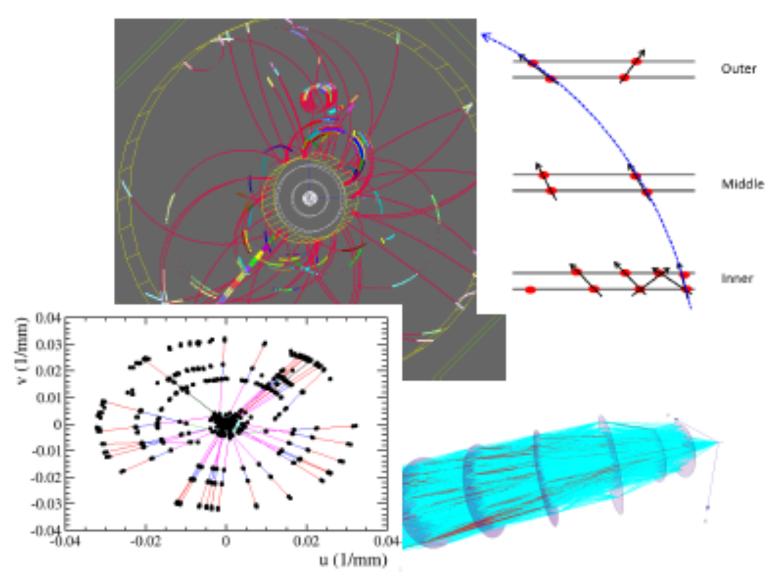
Track Reconstruction

Track reconstruction using DD4HEP surfaces

- Pattern recognition/track finding algorithms
  - From **detector specific**: *Clupatra* for TPC; mini-vector for vertex detector double layers
  - to **geometry agnostic**: pattern recognition in conformal space
- Track fitting, fairly generic: DDKALTEST, AIDATT
  - ACTS might be long term replacement (AIDA2020)
- Geometry: Interfaced via DDREC and Surfaces

DDKALTEST using DD4HEP surfaces for track fitting





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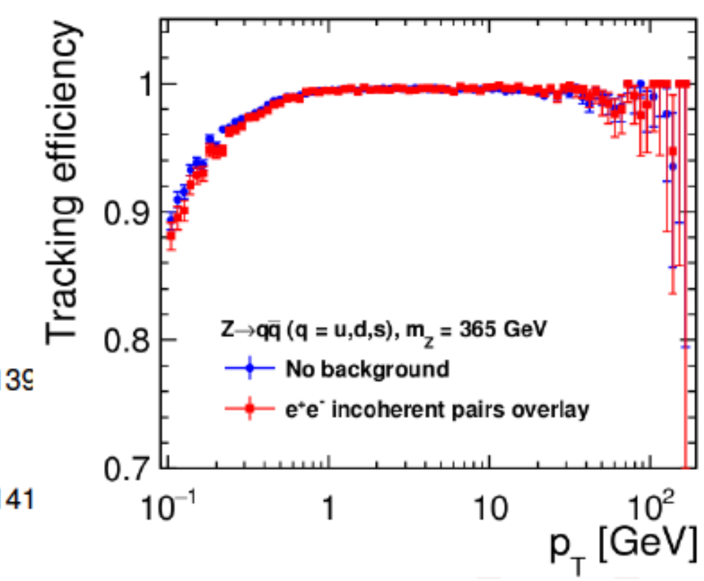


Tracking efficiency with and without pair background at 365 GeV

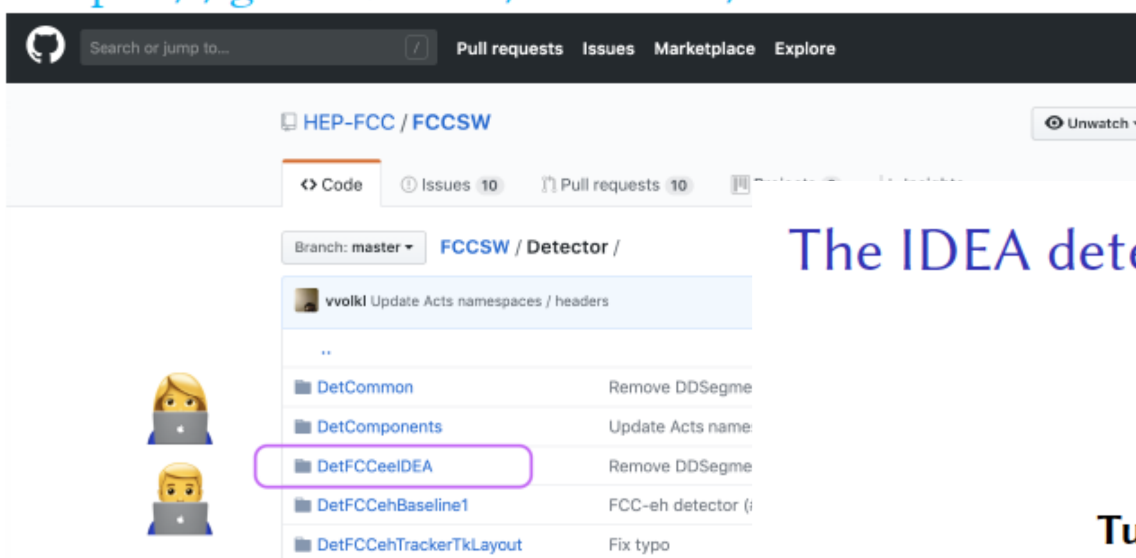
E. Leogrande

FULL SIMULATION OF MDI AND TRACKER FOR IDEA DETECTOR

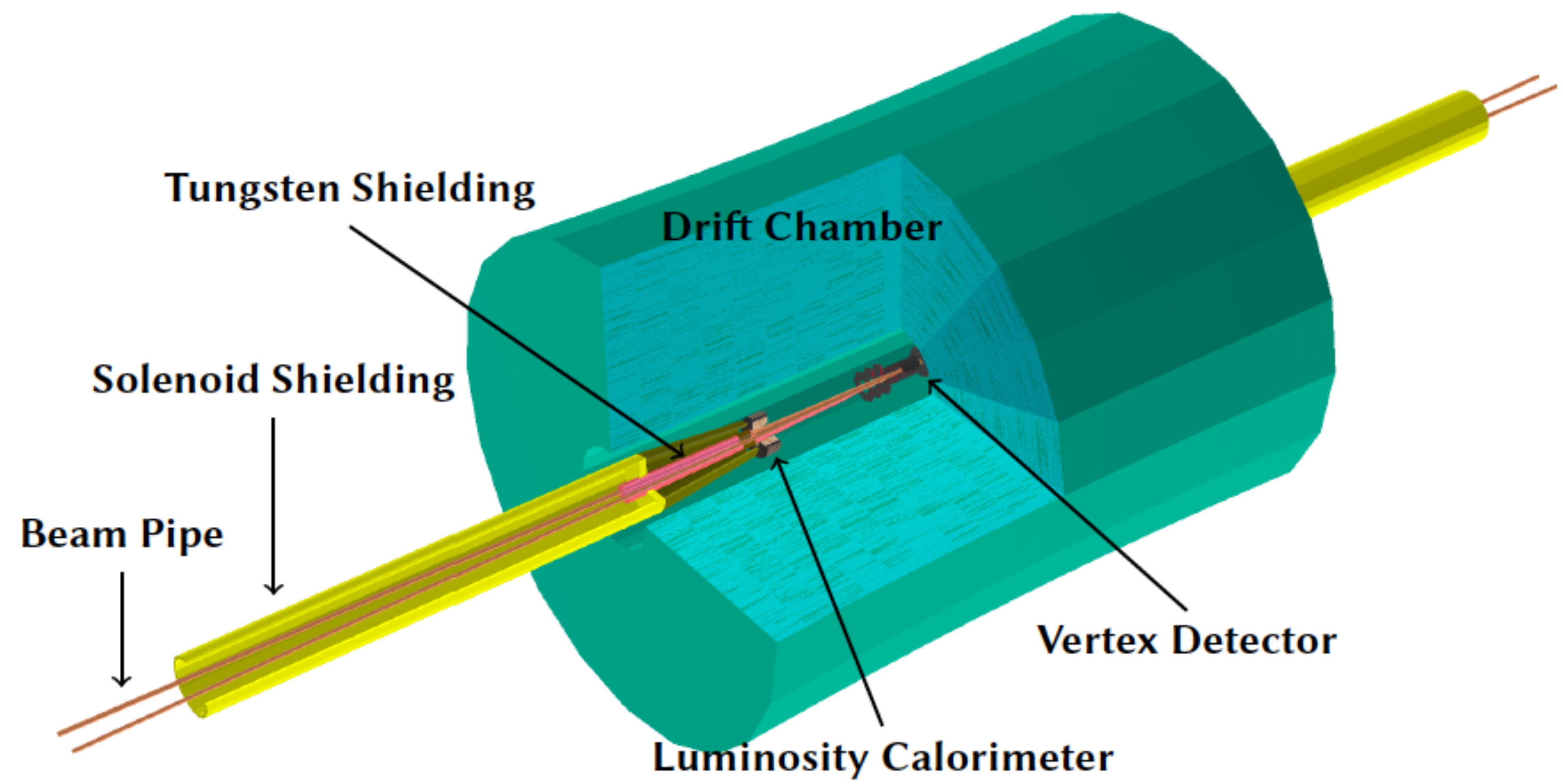
➤Working example in FCCSW framework of FullSimulation: includes the MDI region the silicon detector and the drift chamber

Niloufar Alipour Tehrani

https://github.com/HEP-FCC/FCCSW



The IDEA detector as visualized with FCCSW

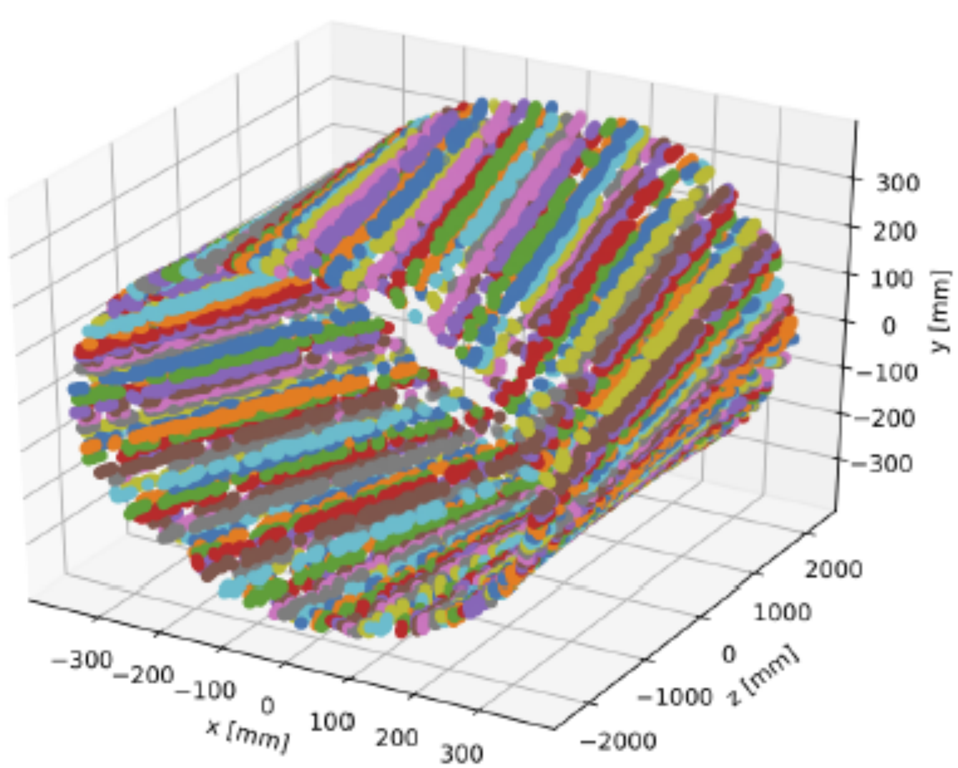


Niloufar Alipour Tehrani

FIRST STUDIES WITH SIMULATED HITS

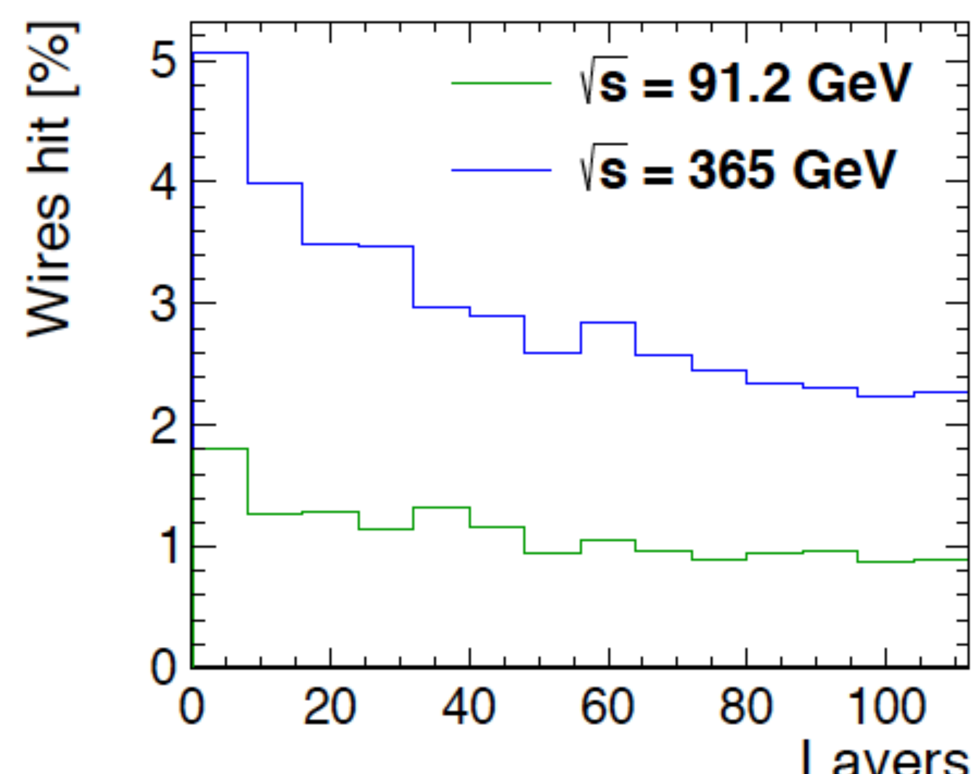
The simulation of the drift chamber

- The sensitive wires as simulated in the first layer of the drift chamber with FCCSW.
- The DD4hep segmentation (DDSEGMENTATION) is responsible to associate a hit to the wire it drifts to
  - Reduces the running time by avoiding to place each wire individually



Background from incoherent ee pairs

- e^+e^- pairs is the background with the highest Impact
- The occupancy is defined as the percentage of wires hits per layer
- The average bunch spacing
  - At the Z stage ($\sqrt{s}$ =91.2 GeV): 19.6 ns
  - At the top stage ($\sqrt{s}$ =365 GeV): 3396 ns
- At the Z stage, the background is integrated over 4 BX to take into account the readout time for the signal.



TRACKING IN THE IDEA DRIFT CHAMBER

Gianfranco Tassielli

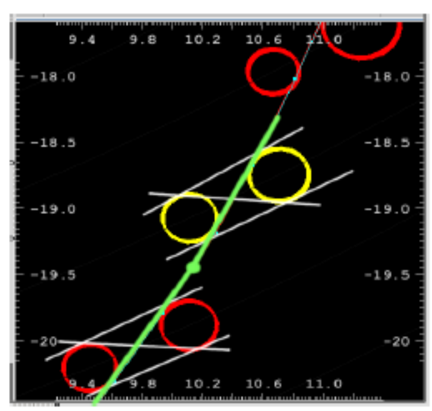
- Several new generic tracking tools available and mantained in the framework (ACTS for instance) but not easily adaptable to a drift chamber type of hit.
- Track reconstruction for IDEA DC exist in a standalone package.
- Currently though the seeding (with 2 or 3 hit pairs) is just relying only on the DCH information, while in the real detector the seeding will be provided also by an inner (and outer) silicon layers

Track finding - current IDEA PR (Local Method) (DCH only)

Seeding from 2 pairs of hits (each pair on same layer) pointing at the origin

- 2 consecutive hits in same layer
  → 4=2x2(Left-Right) pairs with direction
- 2 pairs from nearest layers compatible:
  $|\Delta\cos(\varphi(\text{direction})-\varphi(\text{position}))|<0.2$,
  crossing Z inside DCH
- 1 pair with origin → Pt estimate
  (averaged over 2 pairs)
- Cross Point of 2 opposite stereo pairs give Z-coordinate (with $\Delta\varphi$ correction from Pt)
- Pz = 0 at beginning

Z measurement give additional compatibility check between 2 hits and between 2 pairs



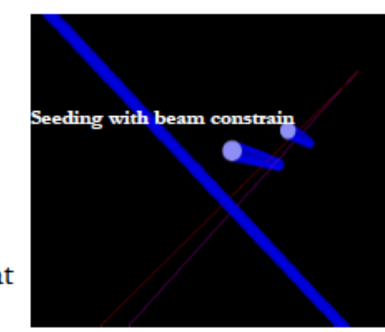
Red hits projection at z=0 plane
Yellow rotated according to φ

Combinatory low: 2 local compatibilities + 1 from opposite stereo view, but with direction angle check

Track finding - current IDEA PR (Local Method) (DCH only)

Seeding from 3 hits in different layers with origin constraint

- Take any 2 free hits from different stereo layers with a gap (4 or 6 layers)
- Cross Point of 2 wires give Z-coordinate (must be inside DCH volume)
- Select nearest free hits at middle (+-1) layer
- 2 hits from same stereo layer give initial angle in Rphi
- origin added with sigma Rphi~ 1mm Z ~ 1mm
- Seeds constructed for all 2x2x2=8 combination of Left-Right possibilities
- Checked that at -4 (+-1) layer are available free hits with $\chi^2 < 16$
- Extrapolate and assign any compatible hits (by χ^2) from last to first hits
- Refit segment to reduce beam constraint
- Check quality of track segment:
  - $\chi^2/NDF < 4$
  - number of hits found (>=7)
  - number of shared hits (<0.4Nfound)



Combinatory high: local compatibility over different layers, + 1 from different stereo view

IDEA STANDALONE DRIFT CHAMBER TRACKING PERFORMANCE

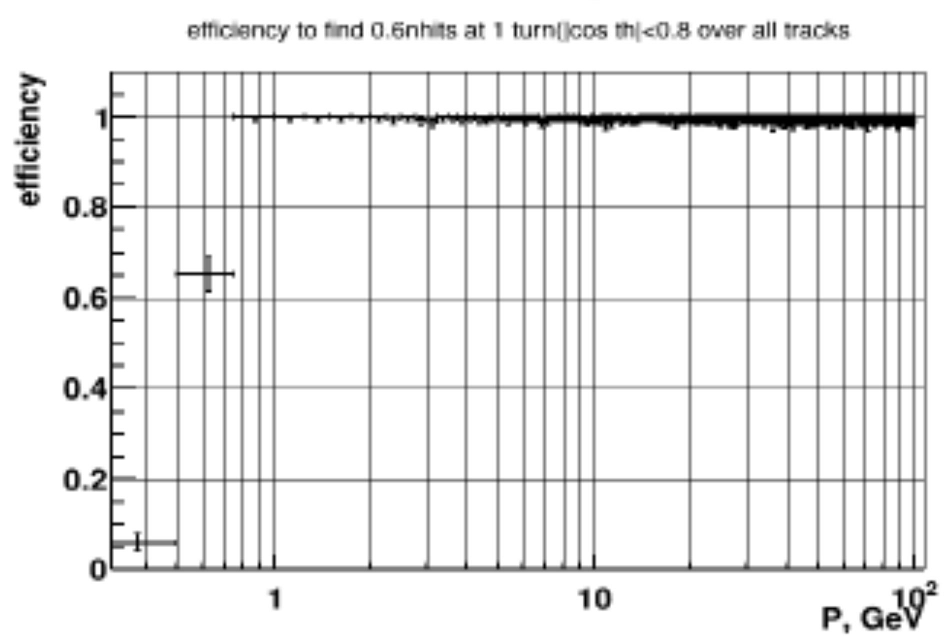
➤Next step is to include the silicon detectors for seeding and tracking

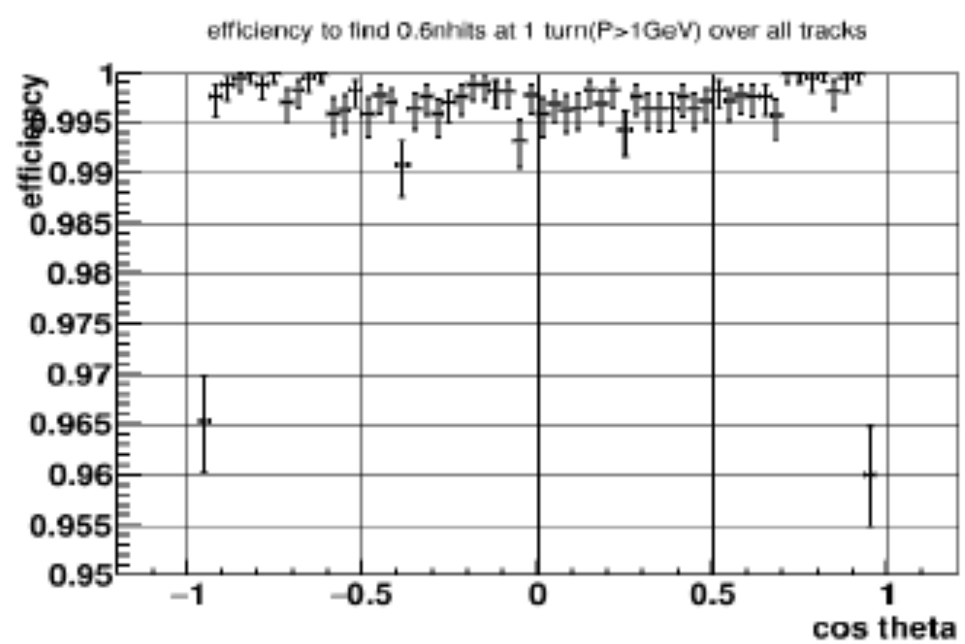
Track finding - current IDEA PR (Local Method) performance

10 μ's (0-100 GeV), DCH only (no longitudinal info used) with Z vtx preselection of seeds

eff ~ 99.5%
particle separation $\Delta\varphi_0$ ~ 0.005 rad

to be tested for secondary particles with vertex out of the SVX

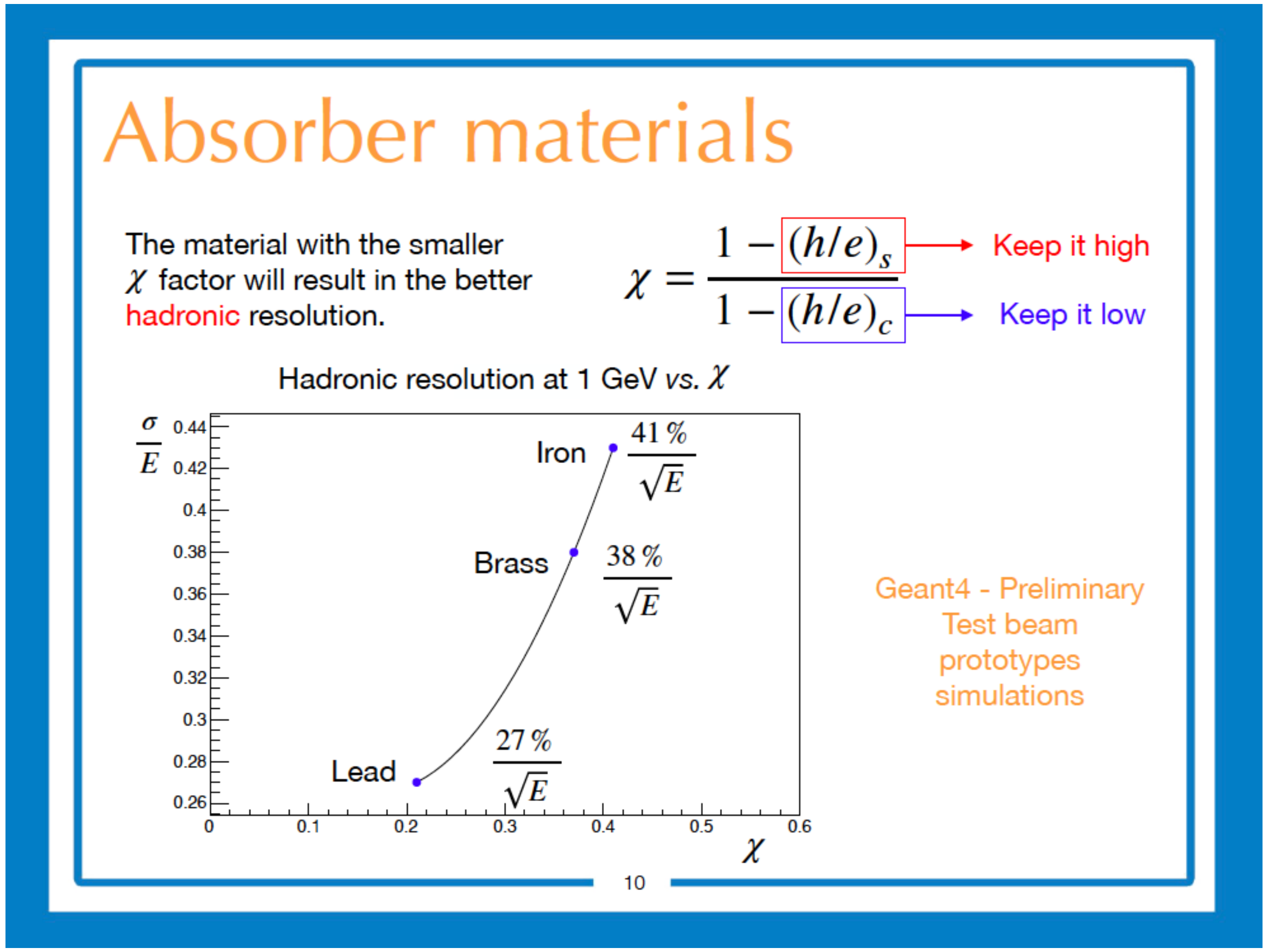


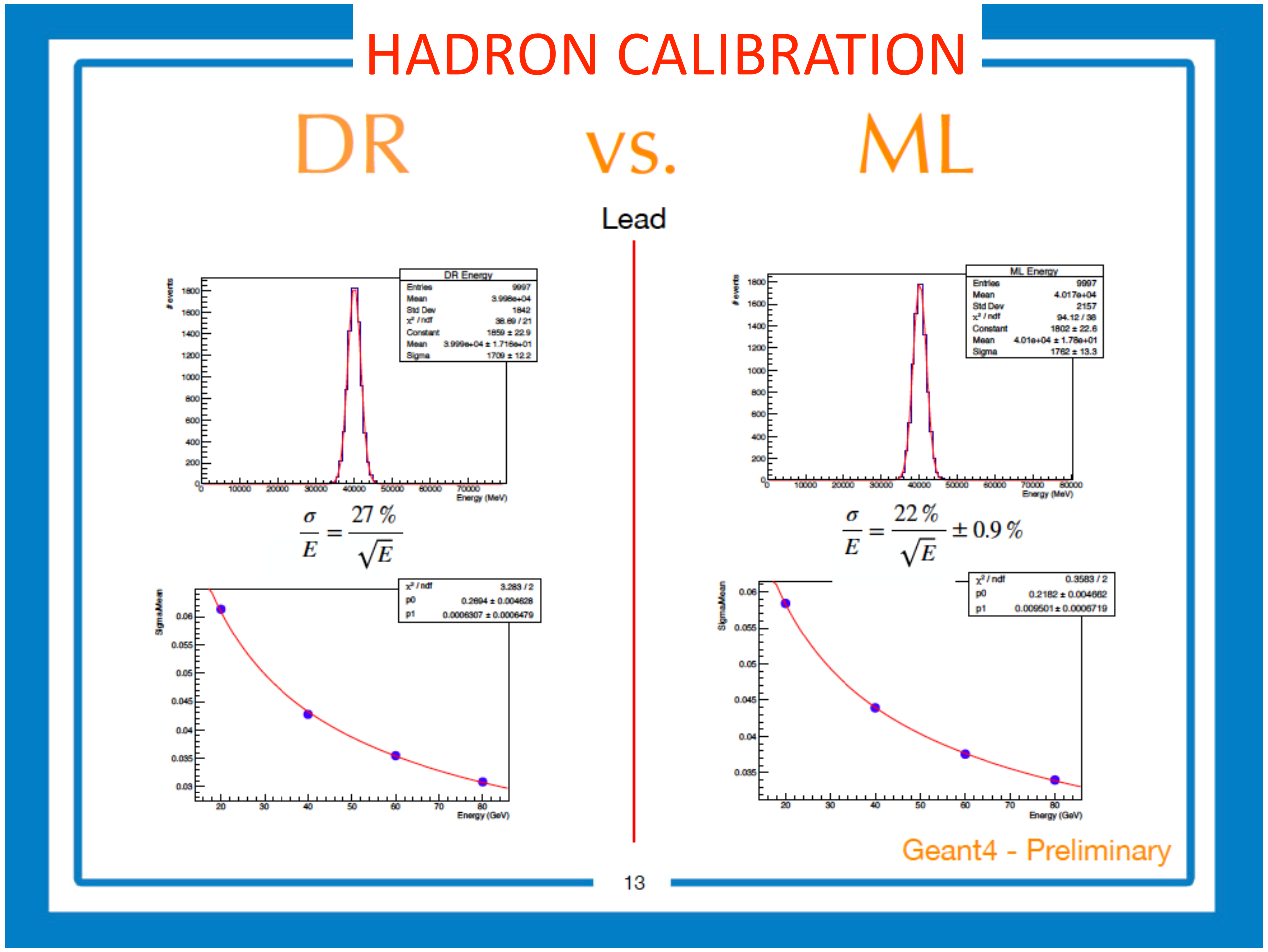


Lorenzo Pezzotti

DUAL READOUT CALORIMETER FULL SIMULATION

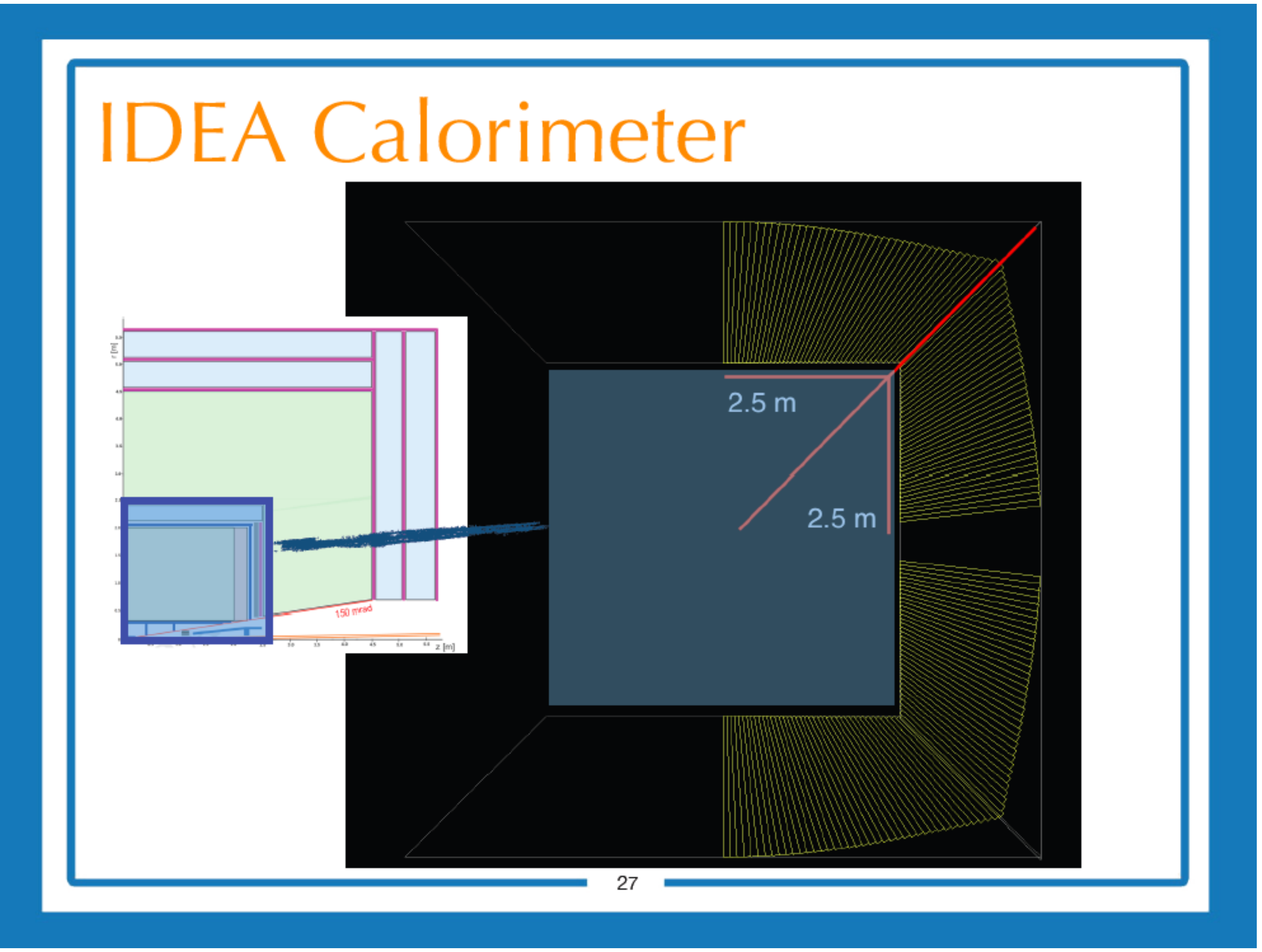
- The dual-readout approach for calorimetry allows to provide a better performance profiting of the measurement of both the hadronic and em-fraction event-by-event via a scintillation signal (scintillating fibers) and a Cherenkov signal (clear plastic fibers)
- Implementation of such a calorimeter in the full simulation is essential for performance studies, understanding, optimization, comparing real test beam data with Geant description
- First studies of response and calibration new ideas in Geant ongoing

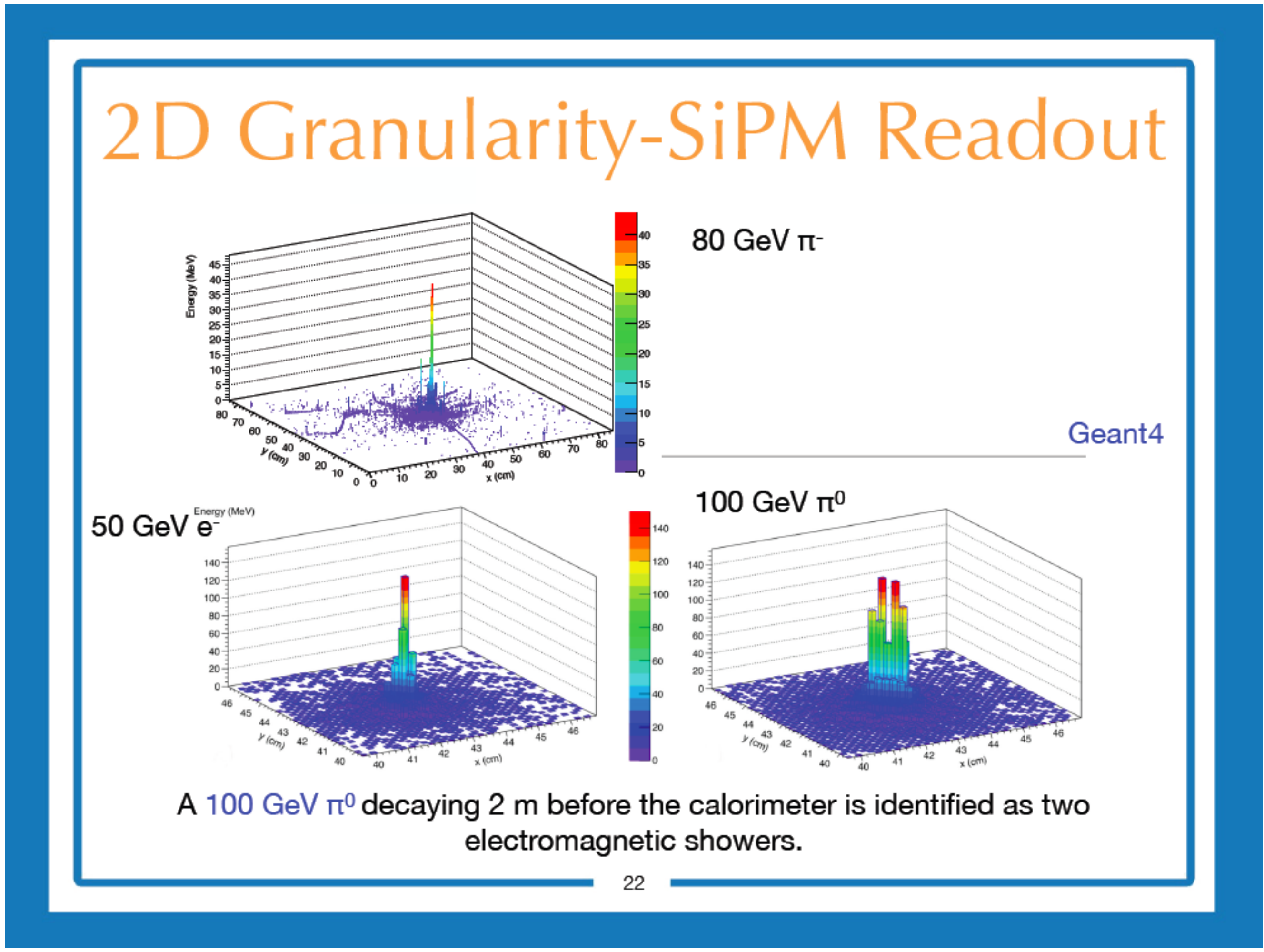




DUAL READOUT CALORIMETER IMPLEMENTATION

- ➤Chosen fully projective geometry implemented: possible now to optimize other details
- ➤With SiPM readout *every fiber* is readout adding granularity. Performance being validated between data and Geant simulation





Massimiliano Antonello, Lorenzo Pezzotti

PARTICLE ID STUDIES IN DR CALORIMETER

Multiple particles in DR - preliminary work

Separation using clustering algorithm in development

Molly Jensen, supervised by Mogens Dam, Niels Bohr Institute

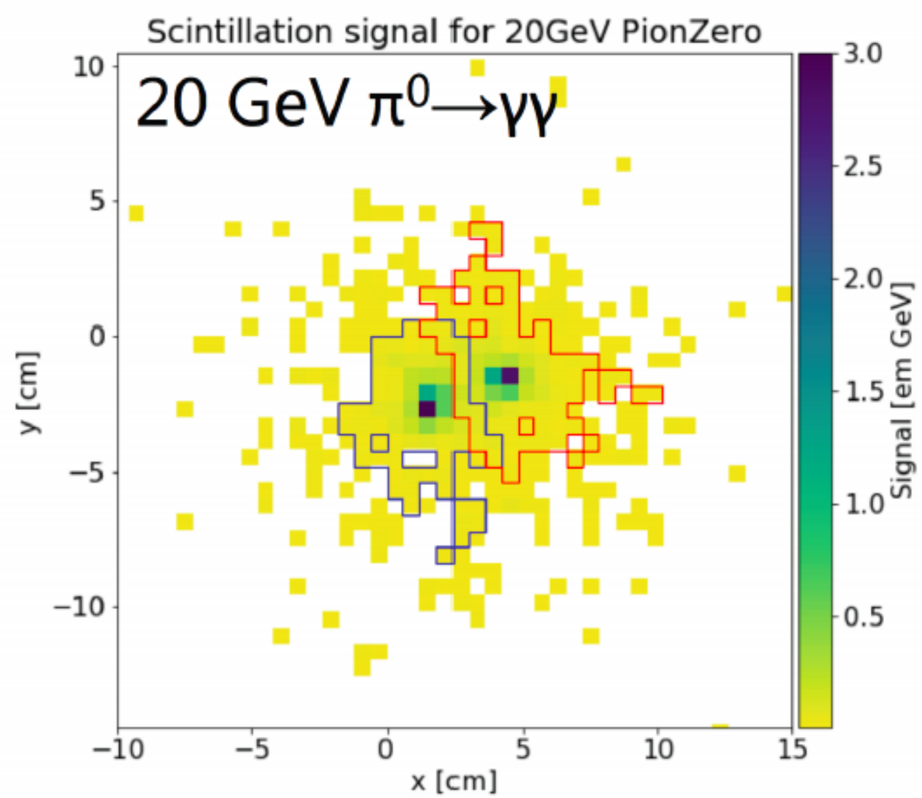
- Study tau physics:

$$\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau \quad (17.39\,\%)$$
$$\tau^- \to e^- \overline{\nu}_e \nu_\tau \quad (17.82\,\%)$$
$$\tau^- \to \pi^- \nu_\tau \quad (10.82\,\%)$$
$$\tau^- \to \pi^- \pi^0 \nu_\tau \quad (25.49\,\%)$$

The goal is to separate decay channels and measure the energy of each decay product, to reconstruct the energy of the mother particle

- Easy to cluster EM showers in both scintillation and Cherenkov signal, e.g.

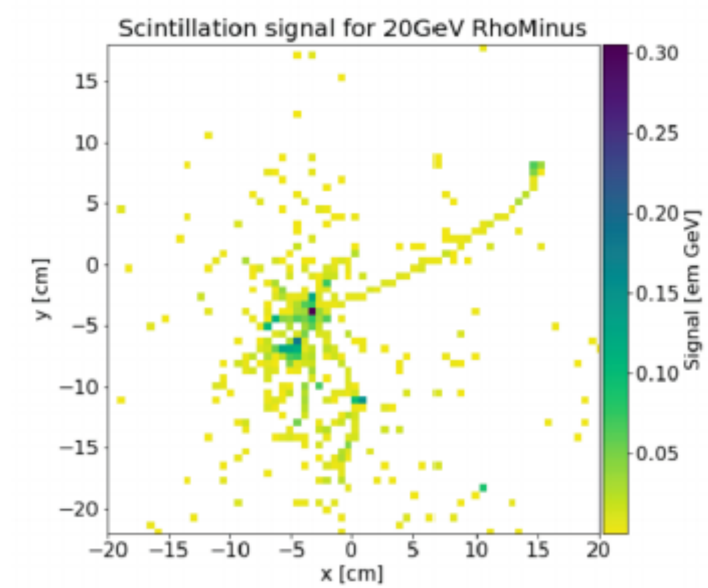
$$\pi^0 \to \gamma\gamma$$

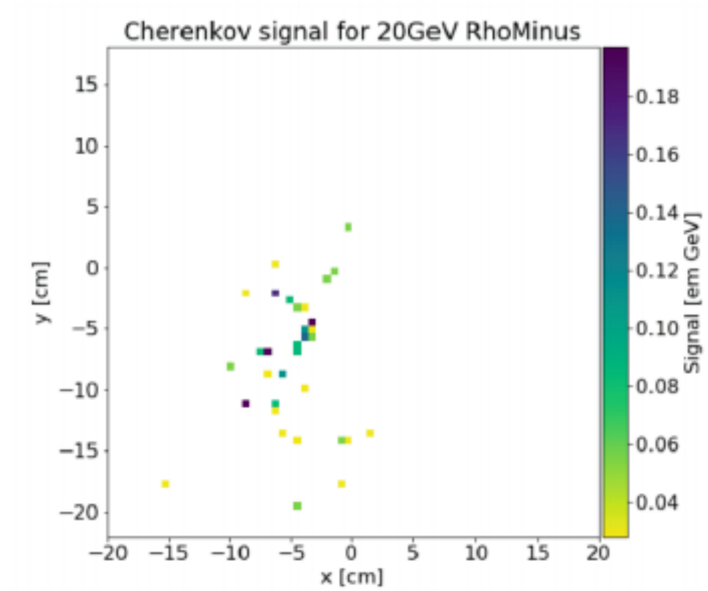


Geant4 simulation: https://github.com/lopezzot/DREAM.git
Plot shows two reconstructed clusters outlined by red and blue. Particle gun 2 m from calorimeter surface. Towers of 4x4 fibers: 8 Scintillating, 8 Cherenkov.

Adding hadrons complicates life

20 GeV $\rho^- \to \pi^- \pi^0$

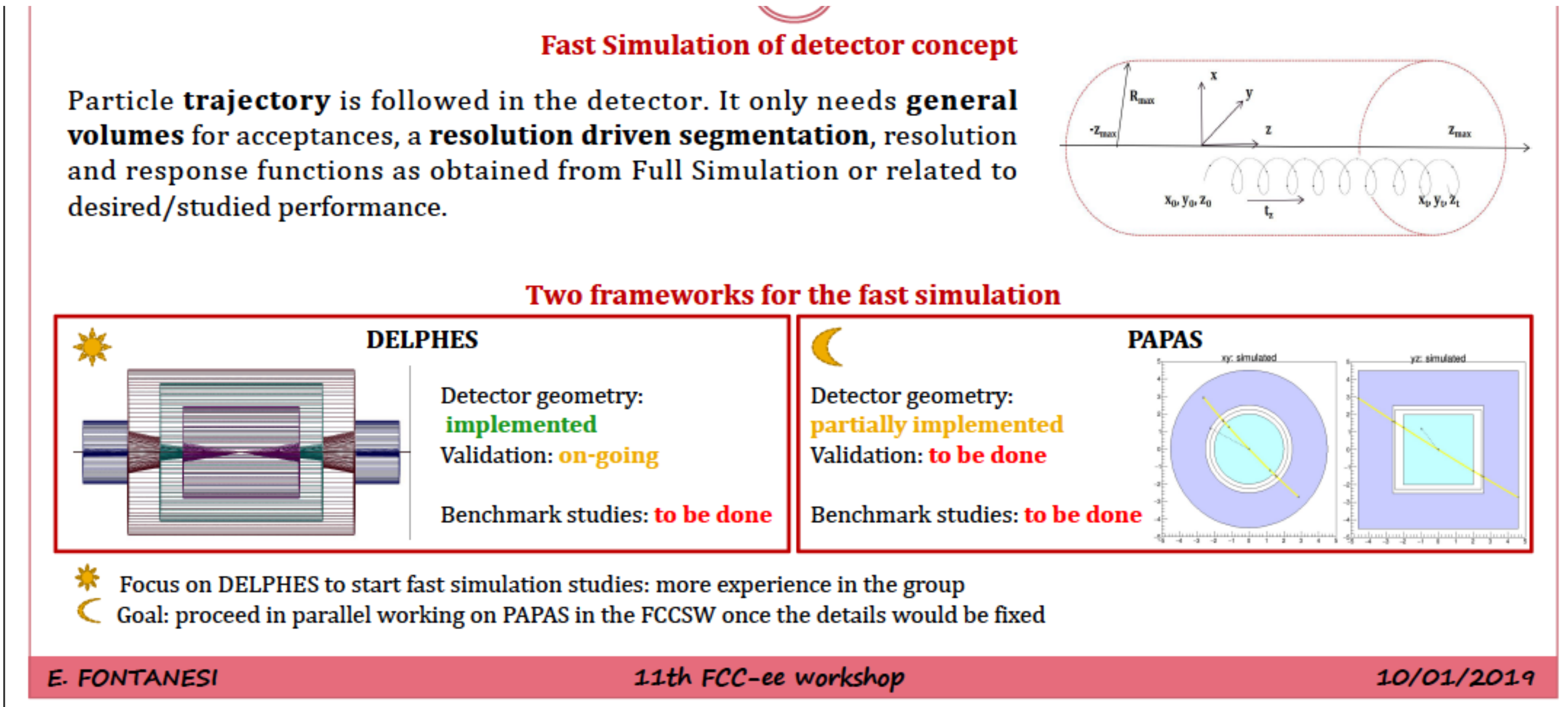




Molly Jensen, Mogens Dam

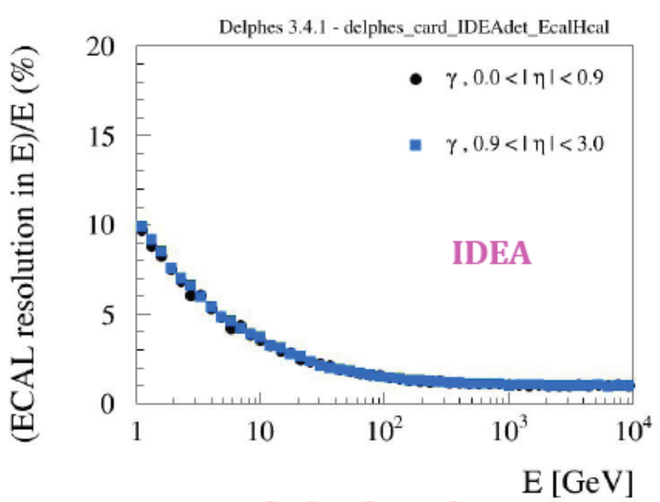
FAST SIMULATION STATUS

- ➤Fast Simulation for FCCee includes already several type of detector cards (CMS, ILD, CLD) in Delphes and in Papas (native FCC-ee particle flow based approach).
- ➤Validated and usable for physics studies



ADDING THE IDEA DETECTOR CARD IN FASTSIM

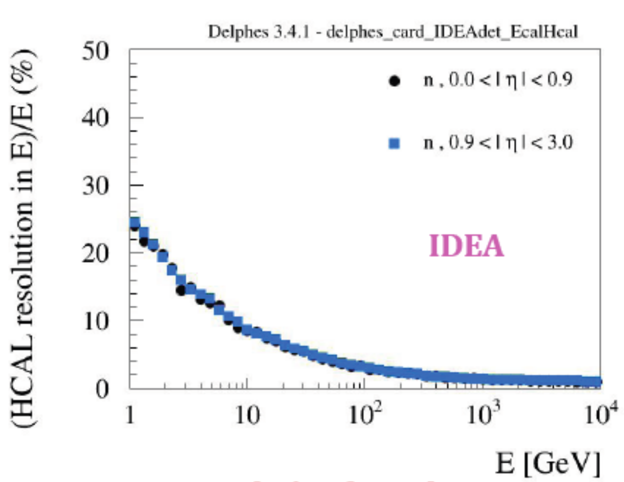
- ➤Dual readout calorimeter needs specific development to have it in a FastSimulation. Profit of input from FullSim studies to have a first attempt at its implementation.
  - ➤ splitting Em and Had response with different response and ID probability from FullSim
- ➤First validation of principle done.



Energy resolution formula

$\sigma = \sqrt{(0.01^2 E^2 + 0.11^2 E)}$

Same for barrel and endcap regions

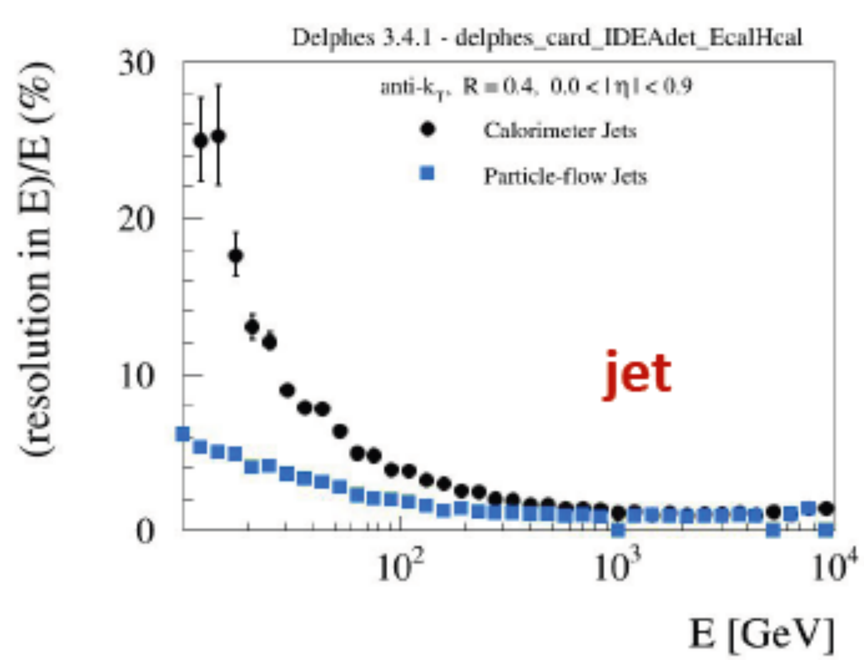


Energy resolution formula

$\sigma = \sqrt{(0.01^2 E^2 + 0.30^2 E)}$

Same for barrel and endcap regions

IDEA - Barrel



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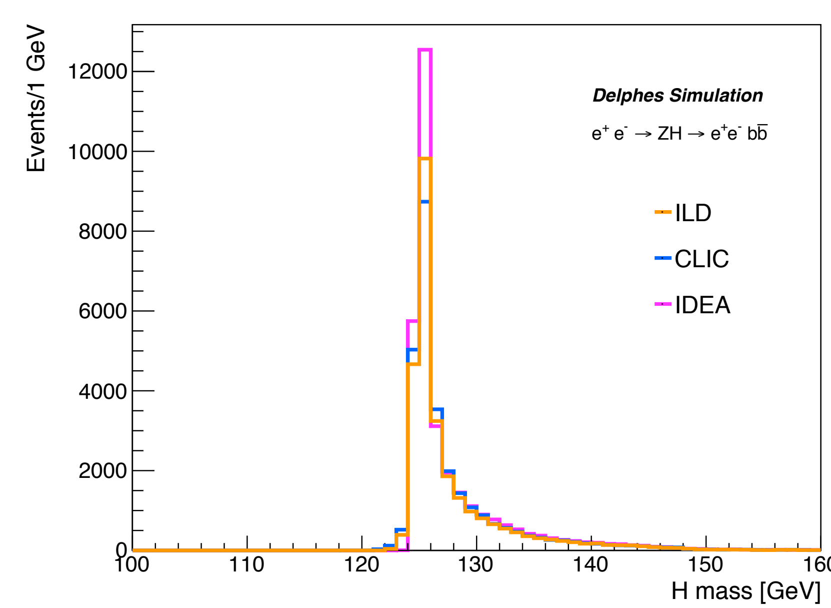

Elisa Fontanesi

NEXT STEPS - DISCUSSION

- How to use a complex software easily
  - Bridge for experts to add experiment/detector specific component to a common software framework (CSF)
  - Bridge to bring users and people interested to participate to use the a CSF
  - Encouraged to participate to CSF meetings and make it an effective forum with active discussion and to monitor progress

➤Very rich Agenda and amount of work presented

- ➤ Refreshing to see several young new collaborators enthusiats and engaged.
- ➤ Deep appreciation for senior experts also participating to the full session and actively engaging in the brainstorming and discussion

➤Desire for a Common Software Framework where the different specific needs for different projects can be plugged in easily.

➤Support from computing experts (SFT, HSF) essential to guarantee stable infrastructure

➤Establishement of « Discussion forums » to help the developers (both experts and newcomers) Also possibly establishing an advisory committee with senior physicists?

➤Strenghten the communication and organize regular working meetings

➤Most importantly the understanding that the software and reconstruction for these new long term projects is as essential and crucial as the detector R&D and requires significant resources in terms of people and funding to be achieved in a timely way.

- ➤ priority is to have a definition of resources from the experts to have a usable long term supported software within a year