Work package 1: Physics & Simulation
Status Report & Plans

11/03/2020 Meeting with RD-FA Referees
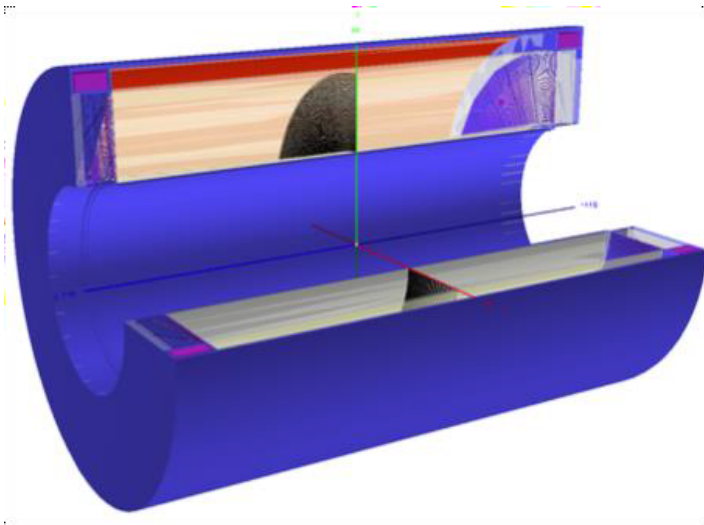
P. Azzi (PD), S. Braibant (BO)

Summary since last meeting September 2019

- International collaboration activities:
    - FCC-ee and CEPC participation (responsability roles and working meetings)
    - EC-China grant FEST assigned
    - EC Grants submitted: AIDAinnova, MSCA-ITN

- Continued development of IDEA FullSim description and performance studies

- Continued development of IDEA FastSim in Delphes

- Development of a global software framework effort for future experiments/machines (Key4HEP)

IDEA Tracker System Simulation Status

E. Fontanesi (BO), G. Tassielli (LE), P. Azzi(PD)

- **Standalone GEANT implementation of drift chamber: detailed simulation and tracking now available on lxplus and in github.**

    - Simplified description of drift chamber in FCCSW already available, can now be compared with the more detailed one, in collaboration with CERN fellow (V. Volkl, CERN)
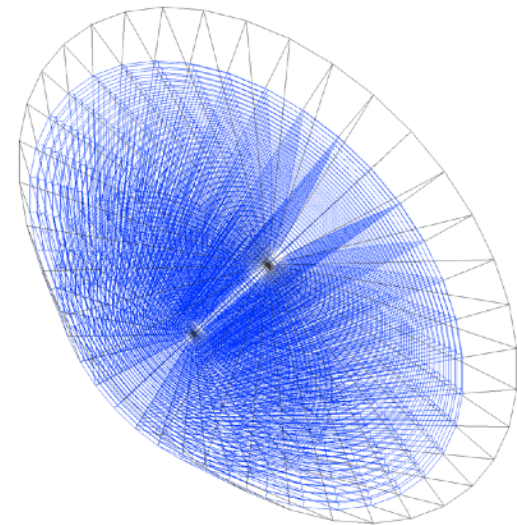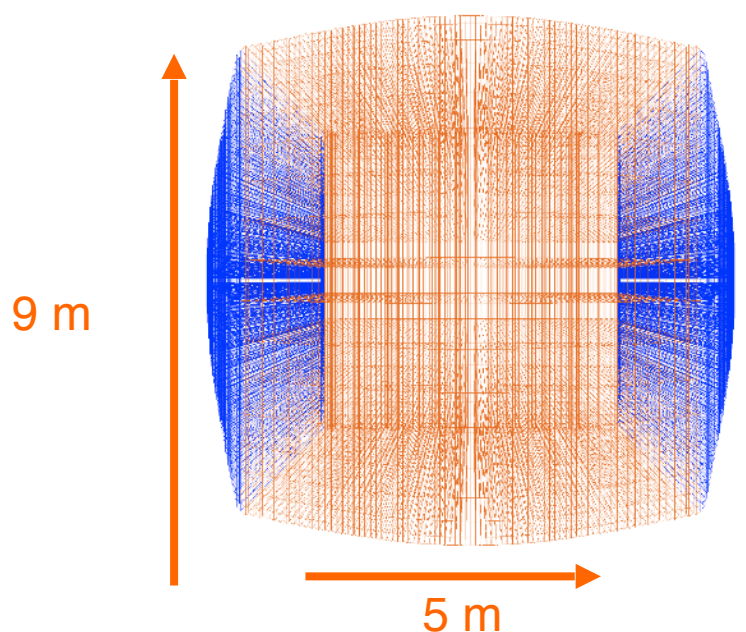

with instructions!

Dual Readout Calorimeter Status

L. Pezzotti(PV), M. Antonello (MI), J. Vivarelli (Sussex)

- **Geant4 fully projective fiber calorimeter description available in GitHub/lxplus**
- **Performance studies with single particles, jets and physics events**
- New 2Million grant obtained by South Korea to work on DR Calo (see other presetnation) will help also simu development work. Collaboration planning made already in January.

9 m

5 m

Dual Readout Calorimeter Performance

IDEA Preliminary

$e^+e^- \rightarrow Z \rightarrow jj$

Jet clustering on:
True jets
Cherenkov signal
Scintillation signal
DR correction
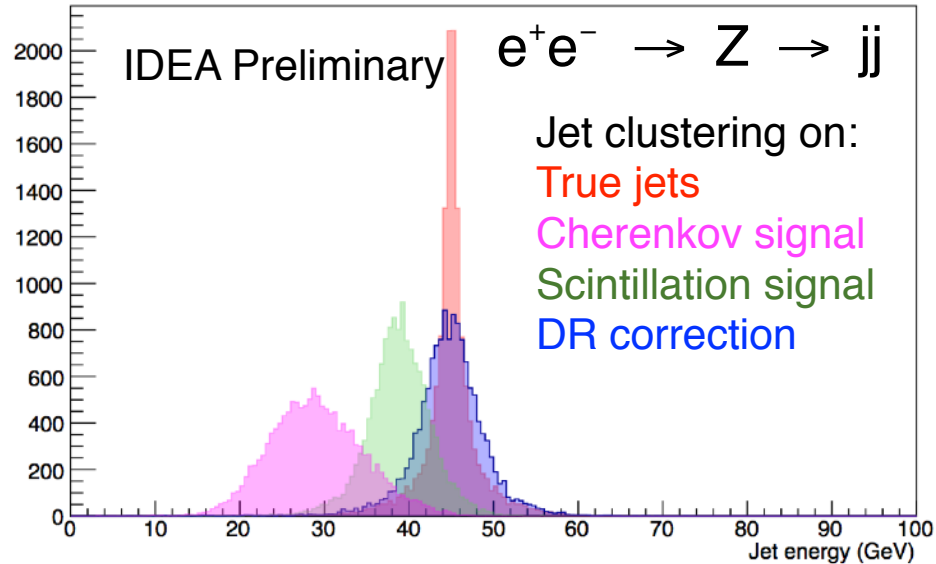
Jet energy (GeV)

- Single had energy resolution:

$$\frac{\sigma}{E} \simeq \frac{33\%}{\sqrt{E}}$$

- Jet energy resolution:

$$\frac{\sigma}{E} \simeq \frac{38\%}{\sqrt{E}}$$

- A matching of scintillating and Cherenkov jet candidates is performed using the minimum angular separation

- W, Z, H in 2 jet decays clearly identified

IDEA Preliminary

Mass (GeV)
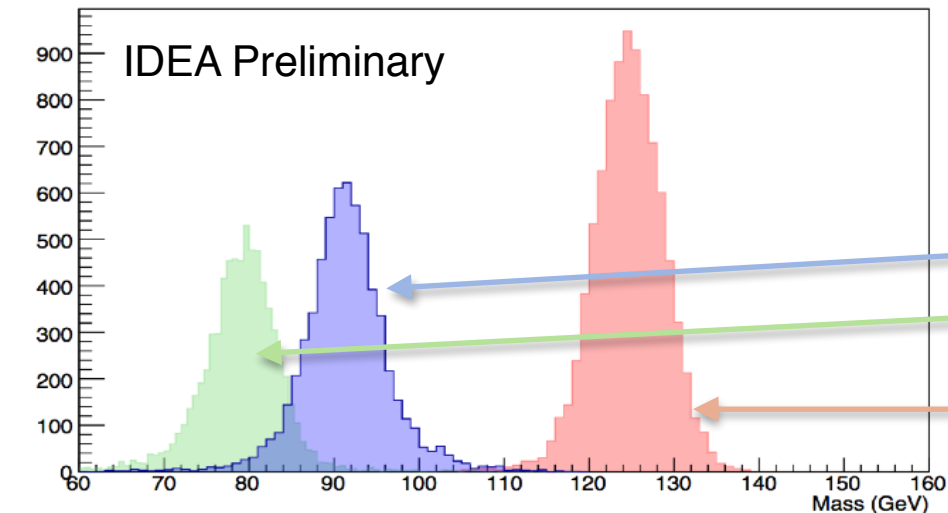
$e^+e^- \rightarrow HZ \rightarrow \tilde{\chi}^0 \tilde{\chi}^0 \, jj$

$e^+e^- \rightarrow WW \rightarrow \nu_\mu \mu \, jj$

$e^+e^- \rightarrow HZ \rightarrow bb \, \nu\nu$

IDEA Software Simulation Report 11/03/2020

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E. Fontanesi (BO), S. Lo Meo (BO)
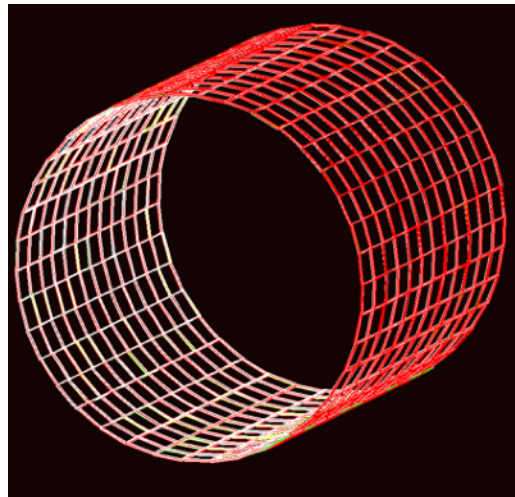
- **Implementation of a μ-RWELL detector in Geant4**

- All the materials and dimensions of a HR μ-RWELL HR-SG2++ have been considered
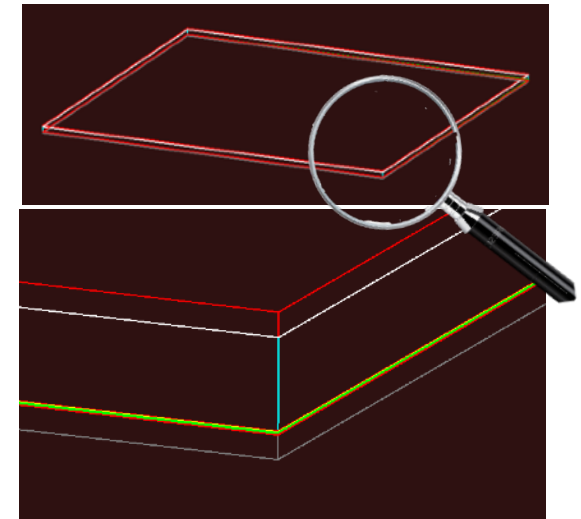
Barrel   Endcap option 1   Endcap option 2
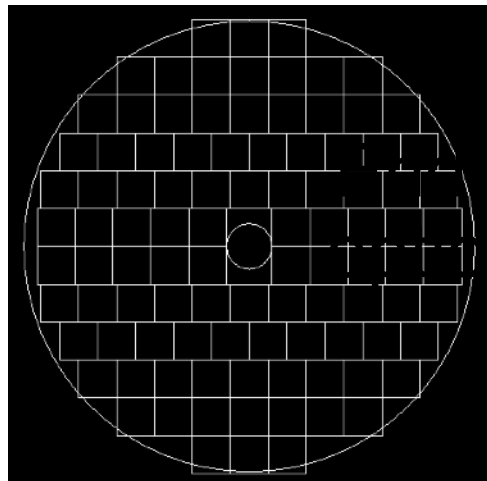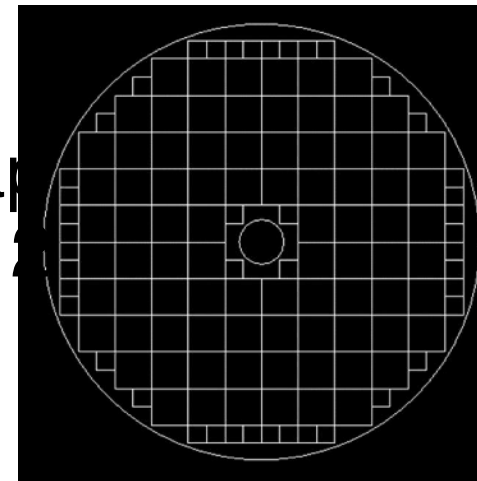
Delphes Fast Simulation of IDEA Detector Concept

E. Fontanesi, S. Braibant (BO), L. Pezzotti(PV)

■ Delphes provides the response of a multipurpose detector in a parameterised way

Schematic view of the baseline
DELPHES detector
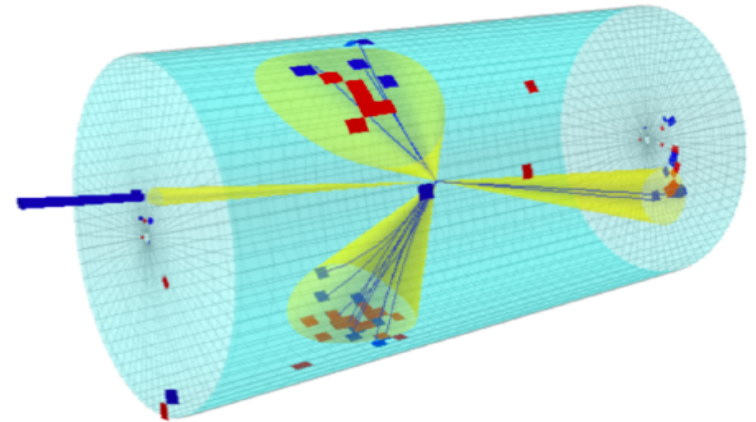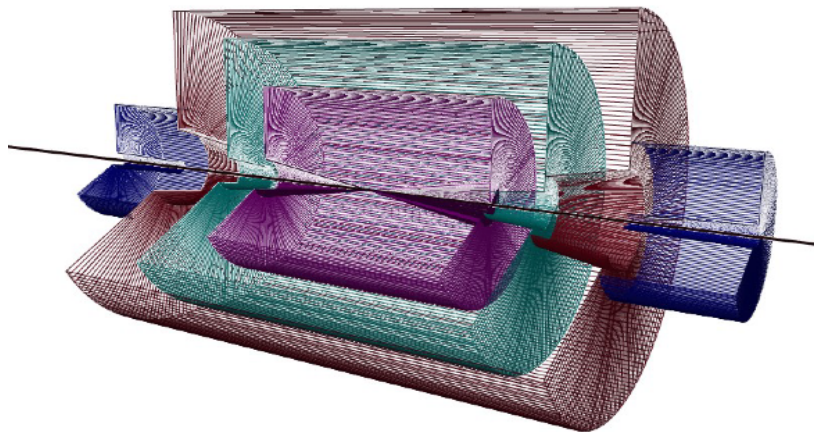
■ **Implementation of the IDEA concept performance in a new « detector card » included in the new official Delphes release (3.4.2pre18):**

   ■ https://github.com/delphes/delphes/blob/master/cards/delphes_card_IDEA.tcl

   ■ Based on the output of dedicated Geant4 simulation of the IDEA tracker and DR calorimeter

New contribution to Delphes tracking simulation

F. Bedeschi(PI)

- **Developed a (standalone) code to extract a realistic full covariance matrix to parametrise track resolution**

  - currently in Delphes a diagonal smearing in the 5 tracking parameters is applied (unique for electron, muons and charged hadrons)

σ_{p_T}/p_T versus p_T (GeV)
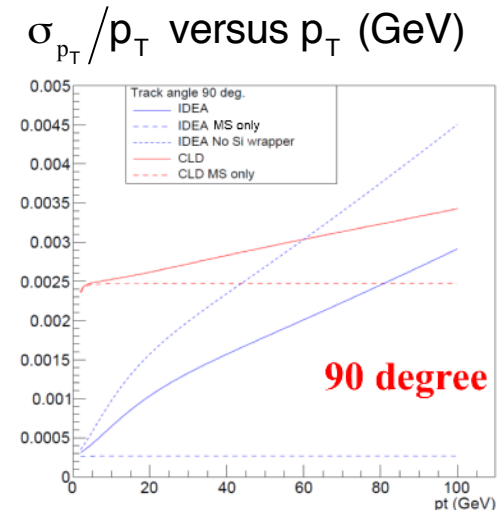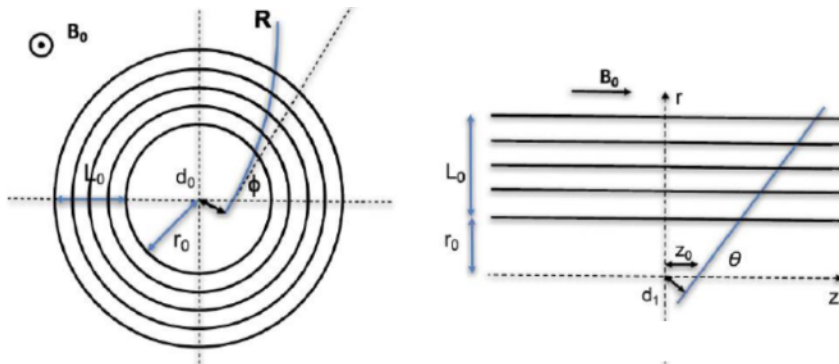
Performance with vertex detector + drift chamber + Si wrappers

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- This is crucial for:

  - Realistic study of the impact of the detector material

  - Realistic study of b-tagging algorithms and of heavy flavour physics cases

New Dual Readout Calorimeter description in Delphes

L. Pezzotti(PV), E. Fontanesi(BO), M. Selvaggi(CERN)

■ **Never studied and never implemented in a fast simulation before**

■ **Implementation of a monolithic calorimeter in a dedicated IDEA card:**

- single segmentation: cell size of 6 cm x 6 cm

- different energy resolution for electromagnetic and hadronic showers

$$\sim \frac{30\%}{\sqrt{E}}$$

$$\frac{11\%}{\sqrt{E}}$$

Cherenkov
Scintillation
Combined

Legend (second plot):
- Energy fluctuations
- Cherenkov fluctuations
- Scintillation fluctuations

If $E_{em} > 0$ and $E_{had} = 0 \rightarrow$
$\sigma(EM)$ e.g. γ

If $E_{had} > 0 \rightarrow$
$\sigma(had)$ e.g. π^+ or (γ, π^+)

Performance Study of τ jets with DELPHES IDEA card

E. Fontanesi(BO)

- **Demonstrate usefulness of Delphes FastSim also for detector requirement studies (not only physics analysis)**

- ZH(ττ+jets): ρ invariant mass

Combination of both $\pi^{\pm}$+ 2γ and $\pi^{\pm}$+ 1γ categories

$e^+e^- \to ZH \to$ Jets (u,d,s)

$\quad\quad\quad \to \tau^+ \tau^-$

τ decay forced to

$\rho \to \pi^{\pm} \pi^0 \nu_{\tau}$

IDEA - Delphes
$e^+ e^- \to ZH \to \tau\tau$ jets (u, d, s)

— Cell size: 2 mm x 2 mm
— Cell size: 10 mm x 10 mm
— Cell size: 3 cm x 3 cm
— Cell size: 6 cm x 6 cm
— Cell size: 16 cm x 16 cm
— Cell size: 22 cm x 22 cm
— Cell size: 30 cm x 30 cm

- For the current version of the IDEA card: cell size 6 cm x 6 cm is chosen

- Investigation will continue in parallel with the development of the full simulation

Plans for a Common Software Stack (key4HEP)

P. Giacomelli(BO), P. Azzi (PD)

- **INFN took initiative to propose towards a common software framework for different experiments at future colliders.**

- "Future Collider Software Workshop" held in Bologna on the 12th and 13th of June 2019:
  - Many leading software experts (from ILC, CLIC, CEPC, FCC, SCTF) and several institutions present (CERN, IHEP, DESY, INFN, Princeton, Bunker INP and JINR).
  - Started international collaboration for the development of common software tools

- « Mini-WS on Detector and Software for ee collider » Jan 16-17,2020@HK (Chair: Giacomelli-BO, J. Da Costa-IHEP)
  - Definition of WG + plans for regular longer future Workshops

- **Consensus reached among software and computing experts on:**
  - Common Event Data Model (EDM4HEP) managed by the PODIO-like tool
  - Common Turnkey Software Stack (Key4HEP) connecting and extending the individual packages to enable a complete data processing framework

Detector Requirements Studies: benchmarks

- **For FCC-ee and CEPC: focus on benchmark physics studies to extract detector performance requirement.**
  - At HK meeting, discussion on common software and common detector requirements needs between CEPC and FCC-ee
- **Study physics cases at each energy scale (Z, H, top) to better define the real detector requirements.** Some of the benchmarks proposed (incomplete list!):
- Physics at the Z:
  - τ polarisation → high granularity and good energy resolution
  - b- and c-tagging → light tracker: σpT/pT2
- Heavy flavor physics
  - PID (e.g. Ds π vs Ds K)
  - Good vertexing → excellent spatial resolution required
- Physics at the H
  - H → 4 jets: hadronic resolution
  - H → $\mu\mu$: momentum resolution
  - H from Z recoil → Transparency more important than asymptotic momentum resolution, …
- Physics at the top
  - Missing energy resolution: calo hermeticity
  - VBF study as a function of the calorimeter resolution

Activities for 2020

- Possibility of sending students to IHEP and HK with the FEST program for software development and detector requirement studies (COVID-19 situation to be cleared up) —> Several sections involved (BA,BO,FE,LE,LNF, MI,PI,PV,TO)

- Continue Delphes development with features necessary to its use for performance studies *(E. Fontanesi-BO, S. Braibant-BO, M. Selvaggi-CERN)*

- Continue GEANT4 standalone full simulation of IDEA complete detector and validation *(L. Pezzotti-PV, S. Lo Meo-BO, P. Azzi-PD, N. De Filippis-BA, G. Tassielli-LE)*

  - *CERN hiring more fellows for new software development Key4HEP*

  - *Stronger collaboration with SouthKorea and Sussex on Dual Readout Calorimeter software needs*

- Continue/increase work on object/event reconstruction

  - i.e. in DRCalo tau shower reconstruction using DNN *(S. Giagu-Roma1, L. Pezzotti-PV)*

European Funding Applications

- **AIDAinnova** proposal <u>submitted</u> (likely to be funded and start in January 2021): it includes key4hep and several IDEA detector and software developments. *(P. Giacomelli BO+CERN+DESY+etc)*

- Experimental MSCA ITN « **SPIRAL-NET** » <u>submitted</u> for performance studies and detector requirements at lepton colliders(SPIRAL-NET). Results in June. *(P. Azzi PD+8 European Institutes+CERN, DESY, KEK)*

Conclusions

- Software and physics activities for RD-FA are very complex and delicate topic. <u>Steady progress and significant impact with a small group of excellent people.</u>

- For the future:

  - Decision to create a global software framework (strong role of INFN) will allow to use IDEA description both for FCC and CEPC

  - Growing international collaboration to become even stronger with European grants