Work package 1: Physics & Simulation

Status Report & Plans

P. Azzi (PD), P. Azzurri(PI)

Meeting with RD-FCC Referees 3/6/2021

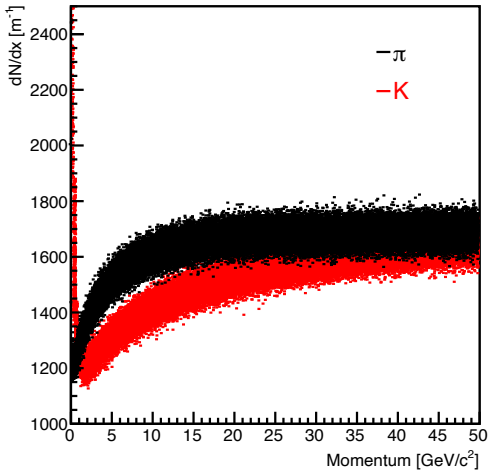
Summary since last meeting September 2020

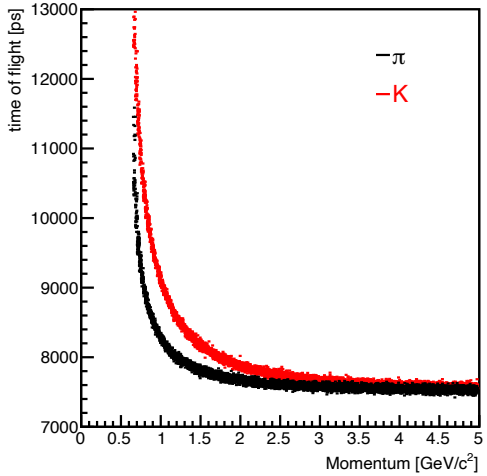
- International collaboration activities:
  - due to COVID trips planned to exchange students with IHEP (via FEST) have been blocked.
  - Collaboration with FCC-ee and CEPC communities via virtual meetings, conference and workshops
  - Participation to effort for Snowmass process (paused in the US) for R&D and analysis(LOIs) continuing
- Continued participation to the global software framework effort (key4HEP) for future experiments/machines (FCC-ee, CEPC, etc)
- Continued development of IDEA FullSim and FastSim (DELPHES) description.
- Development of new analysis tools and start of the AIDA-Innova tasks
- Beginning of new physics analyses & case studies

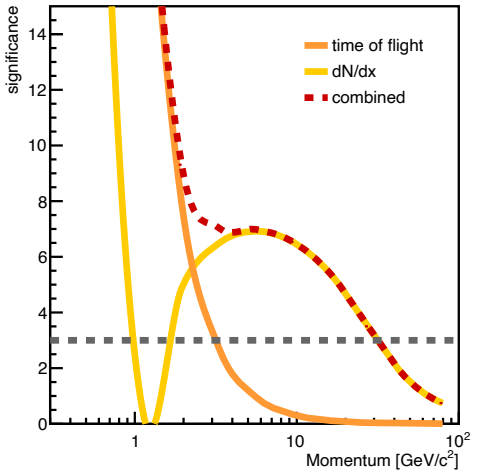
Delphes Fast Simulation of IDEA Detector Concept

F. Bedeschi(PI), S. Braibant(BO), M. Selvaggi(CERN)

- Delphes provides the response of a multipurpose detector in a parameterised way
- **Addition of several ORIGINAL features and tools to the official Delphes code:**
  - **Full covariance matrix description for tracks:** possibility to study in detail detector configurations (position of Silicon layers) even in FastSim
  - **Vertexing:** for primary and secondary vertexing with external constraint and track addition/ removal feature
  - **ClusterCounting:** returns the cluster info given a volume crossed (stand-alone), returns a track complete with cluster information in Delphes output
  - In progress: long lived particles



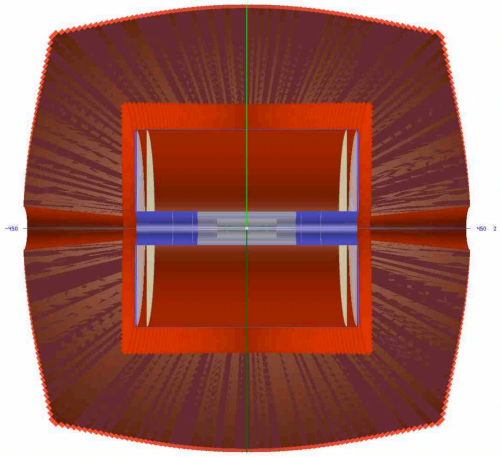


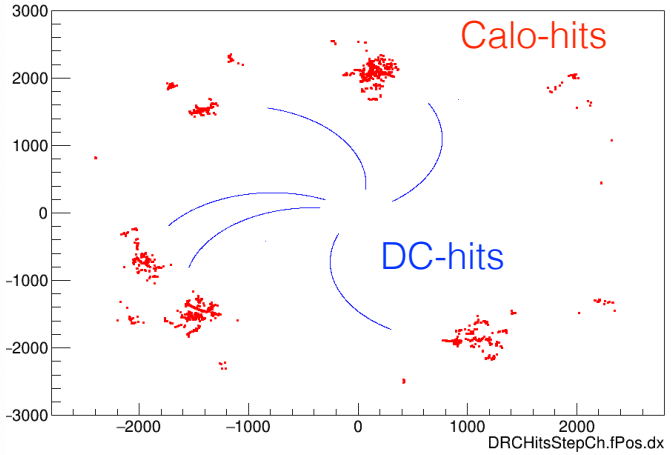


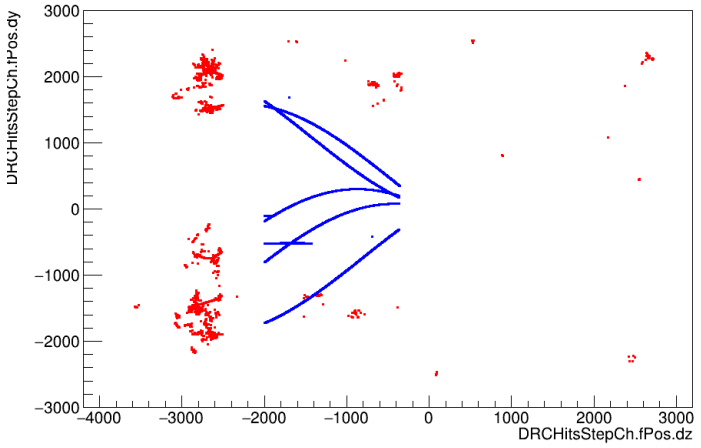
Full Simulation of IDEA Detector Concept Status

G. Tassielli (LE), W. Elmetenawee(BA), N. DeFilippis(BA)

- **Standalone GEANT4 implementation of IDEA** Tracker+Calo







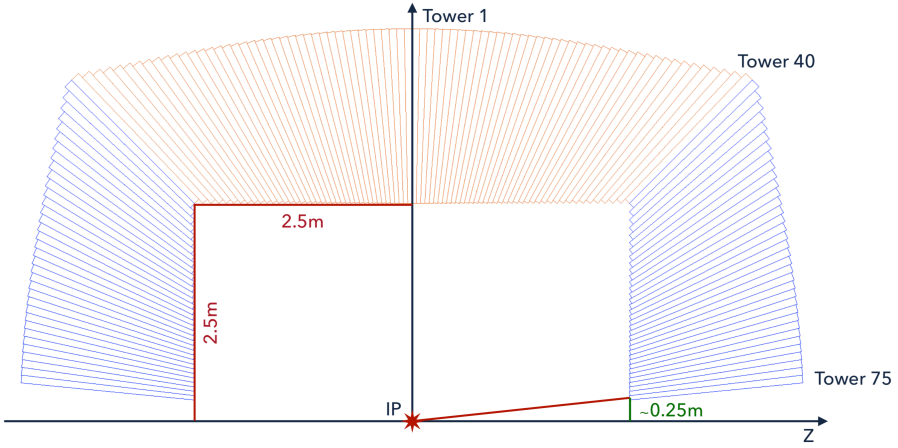
L. Lavezzi (TO), L. Pezzotti (CERN), G. Tassielli(LE), I.Vivarelli (Sussex)

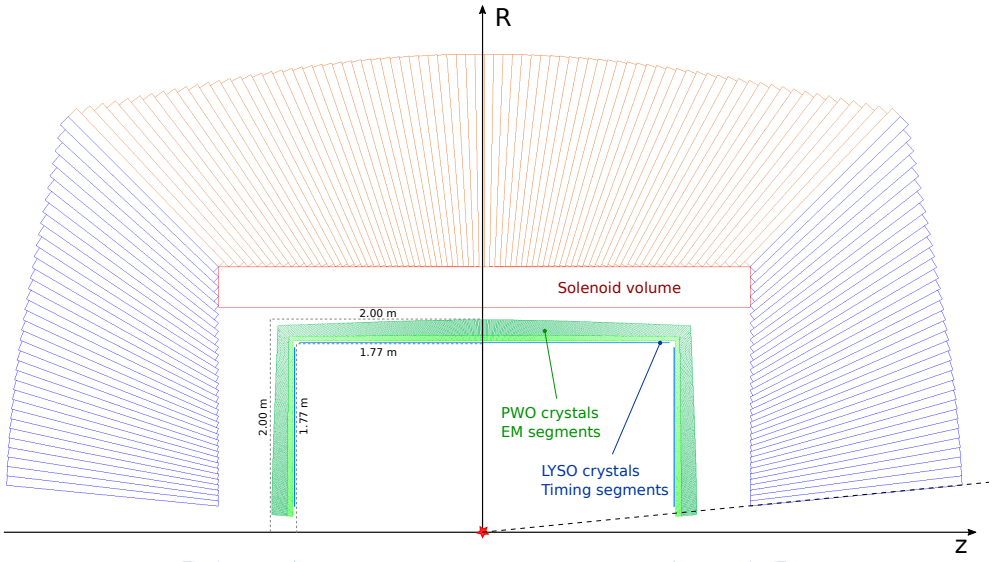
- **Code to translate the output (hits & Tracks) of the standalone G4 simulation of the IDEA detector in the new EDM4HEP format.** This allows the communities of FCC-ee and CEPC to profit of the IDEA FullSimulation response for performance studies
  - Having reconstructed tracks from FullSim available in the events in the EDM4HEP format is crucial for further development of many other tools (Particle Flow, particle ID, LLP etc…)

Dual Readout Calorimeter Status + Crystal Option

M. Lucchini(MIB), L. Pezzotti(CERN), J. Vivarelli (Sussex)

- **Fully projective fiber calorimeter description ported from GEANT4 to DD4HEP geometry** (with Sussex and South Korea)
- **Recently proposed, a dual-readout crystal em calorimeter integrated** in the existing Geant4 Calorimeter application for performance studies
  - Goal: maintain the key capability to correct for fluctuations of the electromagnetic fraction in hadronic showers while boosting the energy resolution for photons and electrons to about $3\,\%/\sqrt{E}$.



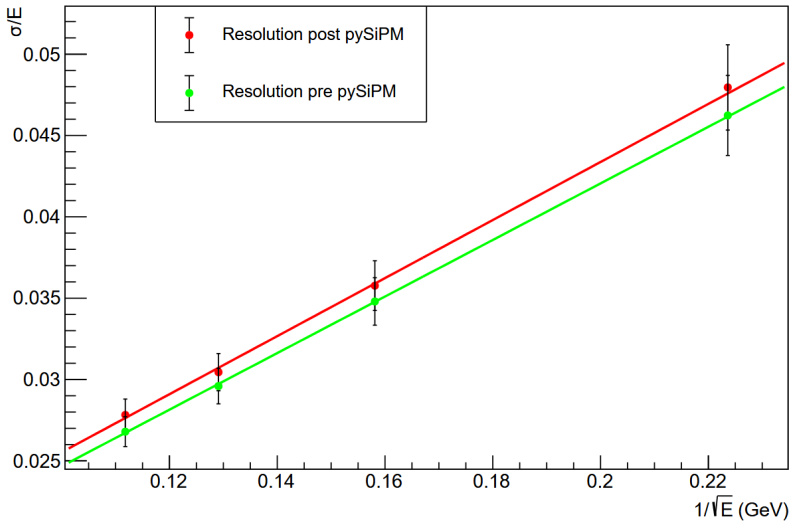


Dual Readout Calorimeter Status: SiPM digitisation

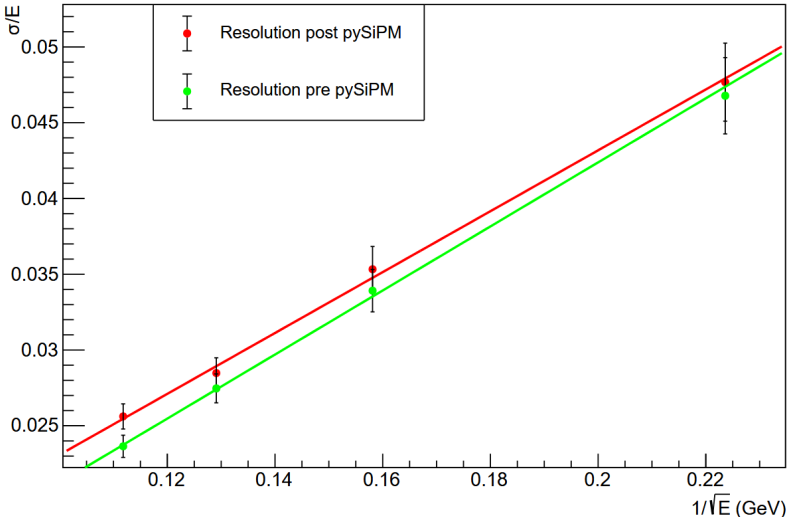
L. Pezzotti, E. Proserpio, R. Santoro, A. Villa(PV)

- **A simulation of the SiPM transfer function has been developed** at the U. of Insubria and extensively tested at the U. Of Pavia
  - The digitisation SW was tested by taking the output of the G4 simulation as timestamps of each p.e. and returning the SiPM digitized signals.
- The impact of the digitisation on the energy resolution (after calibration) has also been estimated. No significant degradation of the energy resolution observed.

20 - 80 GeV electron - Scintillation



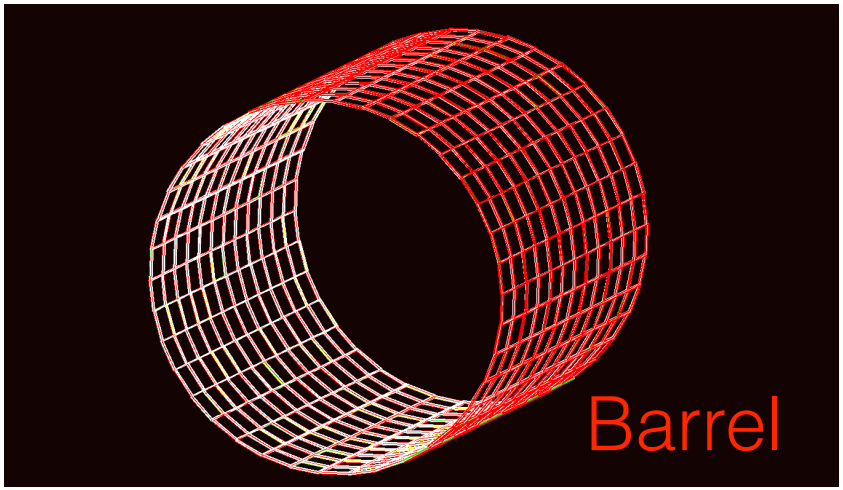
20 - 80 GeV electron - Cherenkov

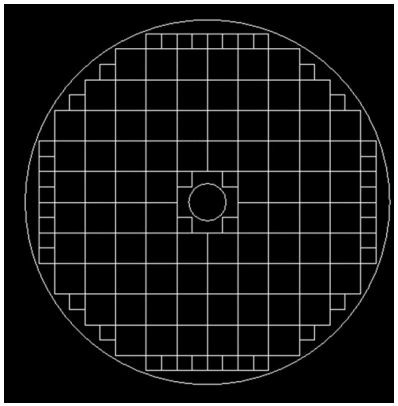


Preshower + Muon Detector (μ-RWELL)

G. Cibinetto(FE), V. Diolaiti(BO), I. Garzia(FE), P. Giacomelli(BO)

- General description of a μ-RWELL detector element already implemented in Geant4 by Elisa Fontanesi(BO)
- Pre-shower full barrel description in G4 standalone, **next develop Endcap geometry**
  - Also add sensitive volumes
- **Muon Detector: to be developed by end of July in a simplified way in G4 first.** Will include the magnet return yoke.
- AidaInnova Task 12.4 (simulation + ML for MPGDs): work plan prepared, **resources identified, first AdR selection in progress**



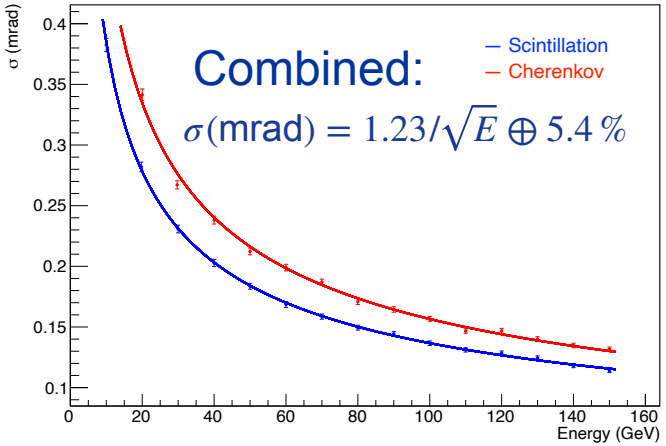


Endcap design to be optimised

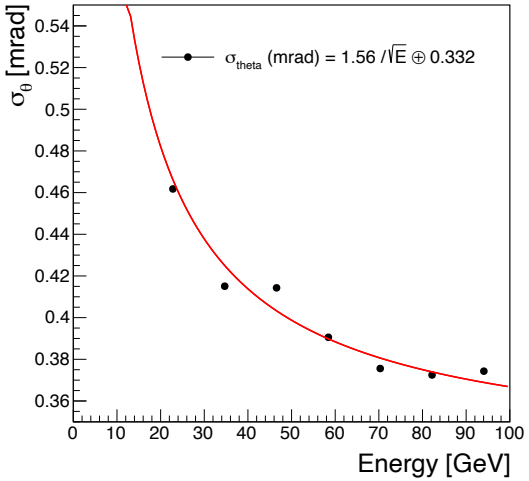
Performance studies: Calorimeter DR(+Crystal)

L. Pezzotti(PV), M. Lucchini(MIB), J. Vivarelli (Sussex)

Fiber calorimeter only

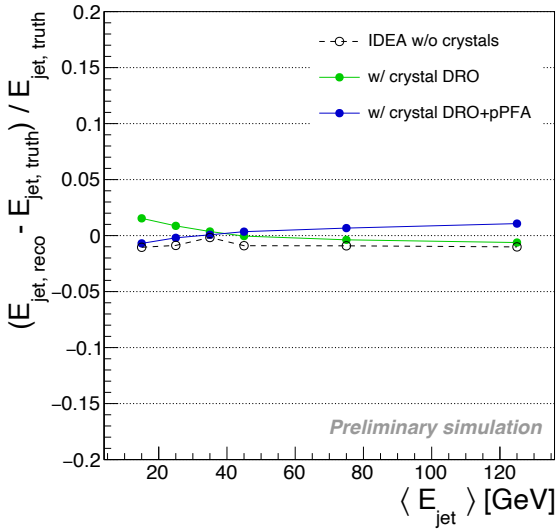


Crystals option

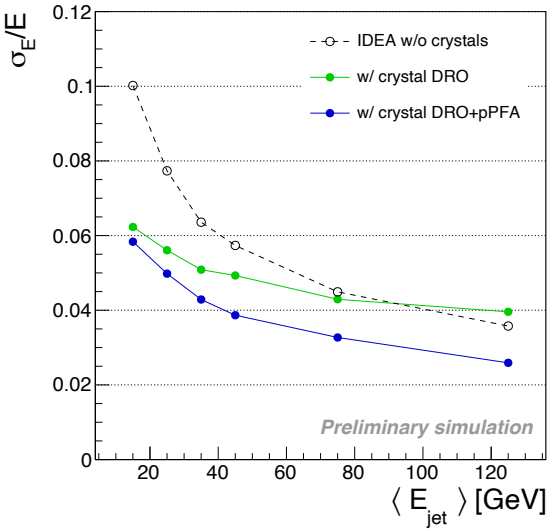


Excellent EM shower angular resolution in both cases

Jet linearity



Jet resolution

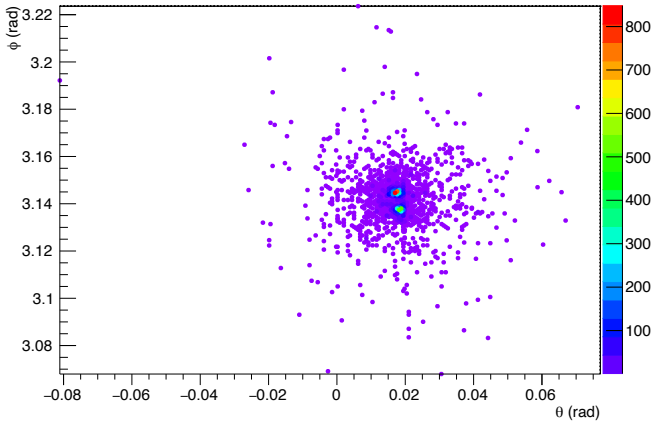


good jet energy resolution provided by the DR calorimeter + promising results combining a PFA approach

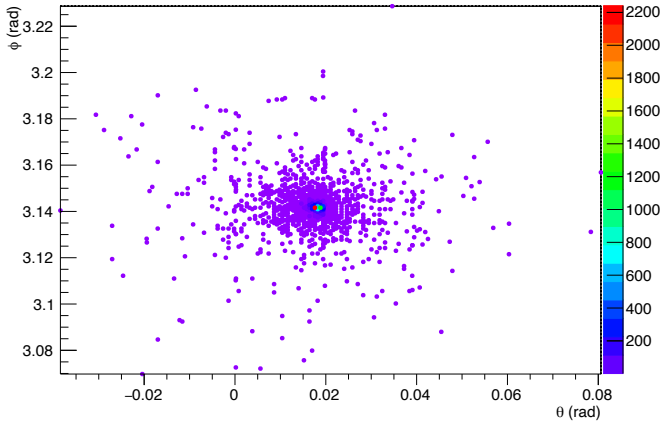
Particle Identification in DRCalo: γ/π^0

S. Giagu(RM1), L. Pezzotti(PV), A.Villa(PV)

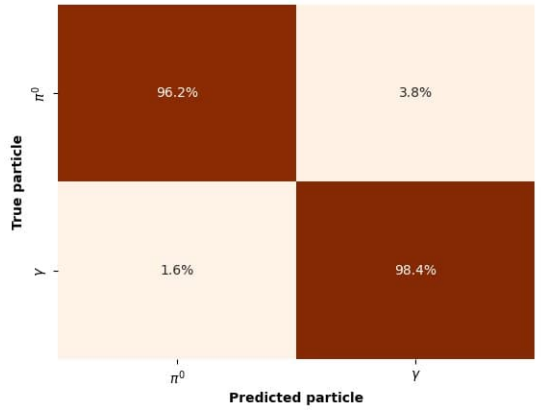
- The extremely high 2D-granularity of the IDEA Calorimeter brings to some spectacular results. An example is the π^0 identification from two γ-initiated showers
- **A quantitative analysis on the possibility to distinguish between π^0 and γ was performed using a convolutional neural network.** Results on events with no selection and fully digitised.



40 GeV π^0 - scintillation



40 GeV γ - Cherenkov



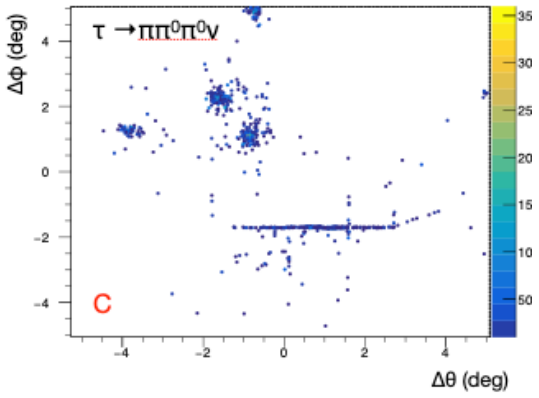
Confusion Matrix

AI-BASED TAU Identification in DR-Calo

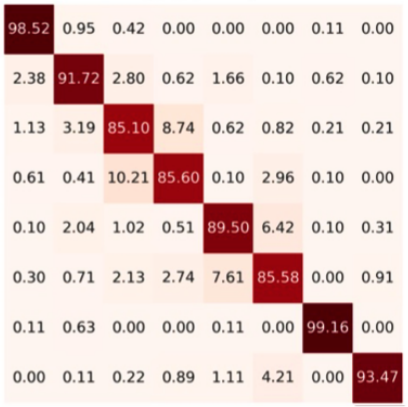
S. Giagu, L. Torresi, M. Di Filippo (RM1+INFN)

- **Develop powerful identification techniques to optimise physics potential for tau physics** with the IDEA detector. Starting from DR Calorimeter information, to be extended
- Very promising realistic performances using full sim of DR Calorimeter + simulation of SiPM
  - robust against noise
  - already 88% accuracy just from the geometrical information (high segmentation + C vs S patterns)
- implementation of of individual object identification inside jet/tau images (e, mu, photons, pions, ...), as a first prototypal particle flow algorithm

Example display



default cut



ACCURACY = 91.0%

- extend the model by adding features from other detectors
- deploy as a software tool
- apply to tau polarisation analysis

Particle Flow Development Plans

B. Di Micco (RM3) resp Task + others

Target: build a Particle Flow Algorithm for jet reconstruction in dual-readout calorimeters using machine learning techniques

Tools: use Pandora Toolkit for development and KEY4HEP as software environment integration

- **Project getting started:** collecting information, defining strategies, planning hiring of a postdoc.

INFN: Roma-3, Pavia, Padova, Roma-1 (B. Di Micco contact person)
(P. Azzi, M. Biglietti, B. Di Micco, R. Di Nardo, A. Farilla, R. Ferrari, G. Gaudio, S. Giagu)

plans: development of the algorithms in Pandora, machine learning training, training on FPGA and GPU, physics performance studies with mono-jet events

Sussex: Iacopo Vivarelli, Andreas Löchcke

plans: development of the GEANT-4 simulation and digitization for fiber/copper and (on a longer term) crystal EM calorimeters

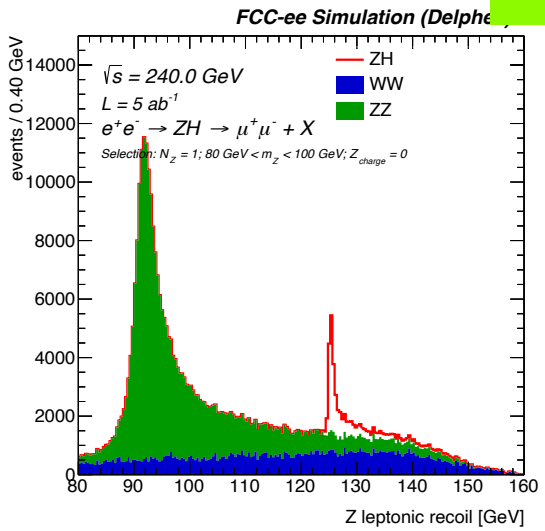
CERN: S. Vallecorsa, F. Carminati, L. Pezzotti

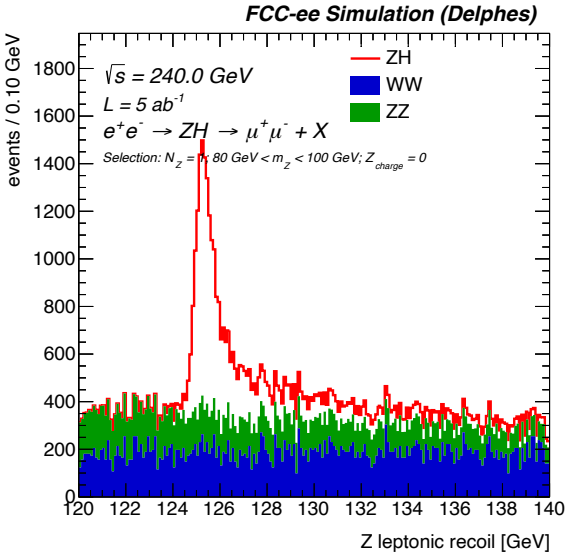
performance test of NN algorithms and configurations in collaboration with Sussex and INFN, calorimeter simulation and ML testing

Institutions Involved

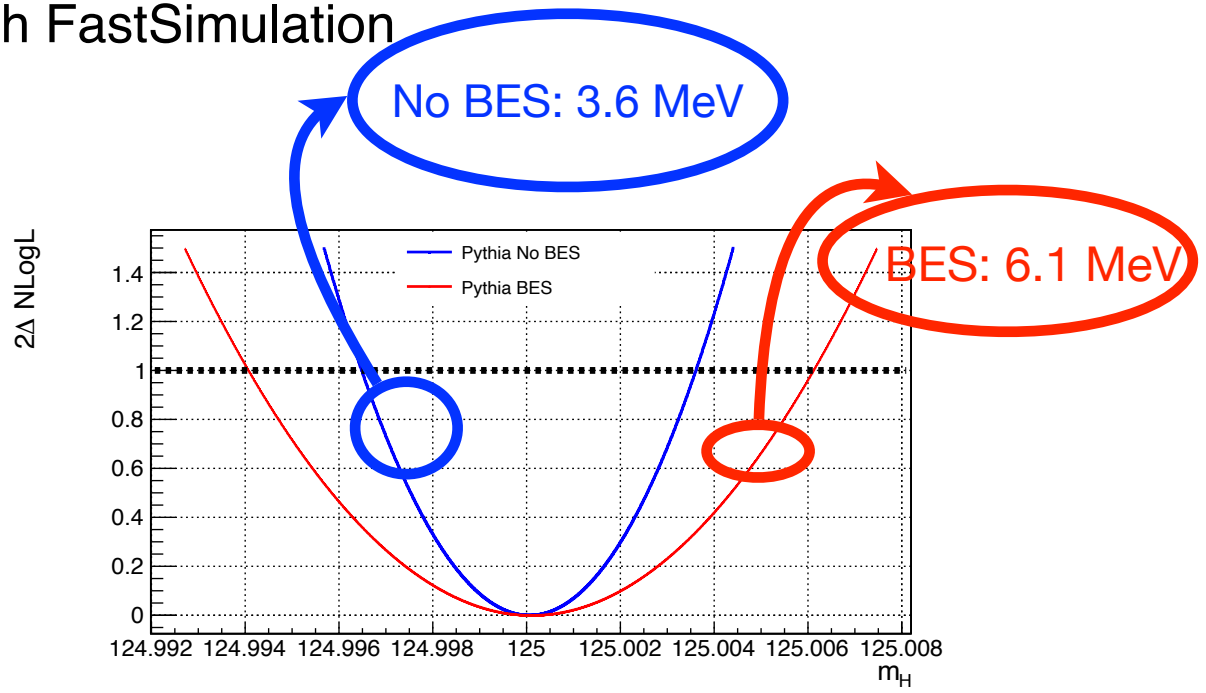
ZH recoil analysis

S. Braibant, V. Diolaiti, P. Giacomelli (BO), G. Ortona (TO)



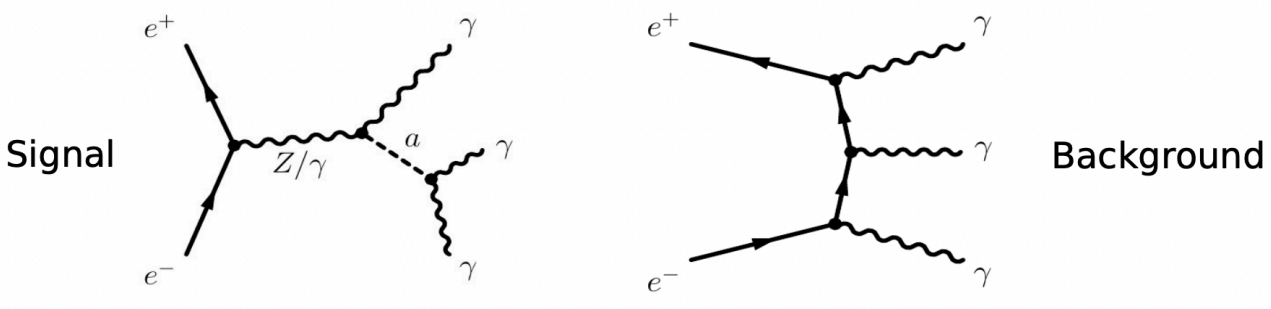


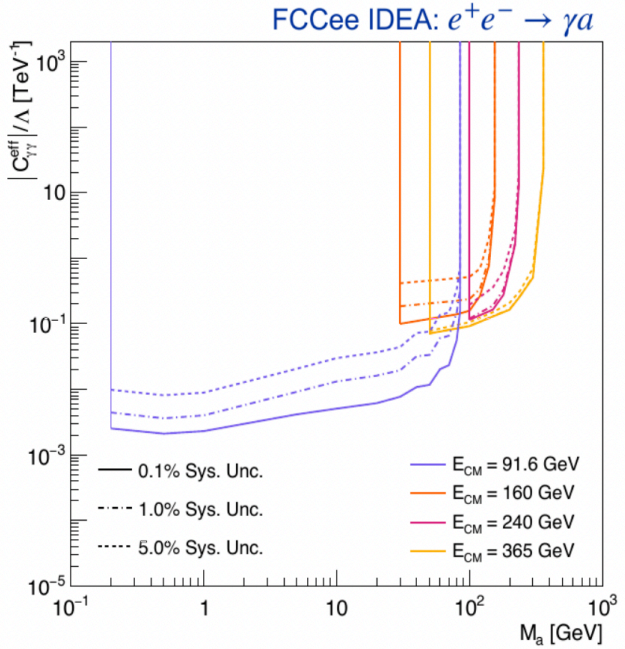
- **Analysis for determination of the uncertainties on the Higgs mass and cross section**
- Analysis on EDM4HEP central samples using new framework tools
- Several effects that can be studied and evaluated already with FastSimulation



Search for ALPS

L. Pezzotti, G. Polessello (PV)



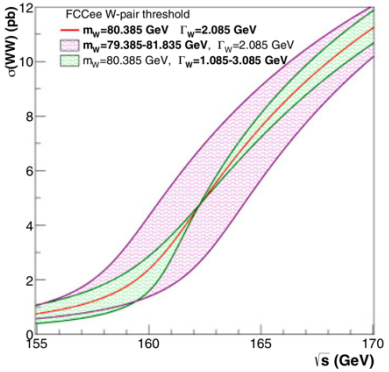


- **Direct search for ALPS BSM signal in 3γ final state**
- Delphes IDEA detector configuration
- Studying all the c.o.m. energies of the FCC-ee run plan
- Important benchmark for optimisation of photon response in particular in the low mass region of the ALP
- Fairly mature analysis, high profile

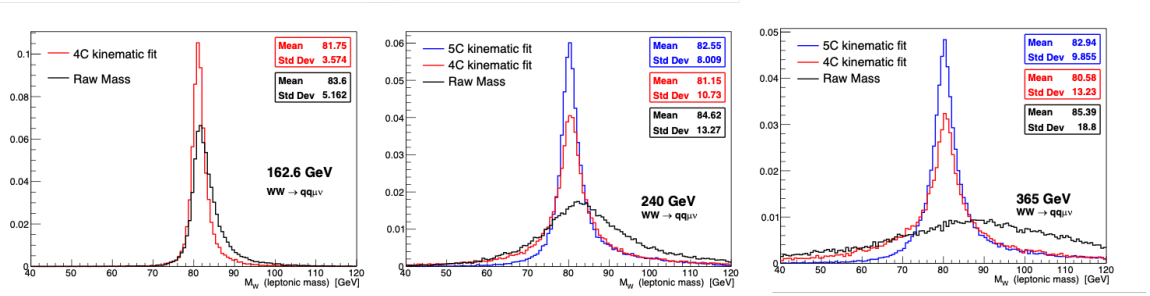
New physics analysis efforts (1/2) - key measurements

P. Azzurri(PI) + student

- **W mass/width** at threshold and above (Δm_W=0.3 MeV $\Delta\Gamma_W$=1 MeV)



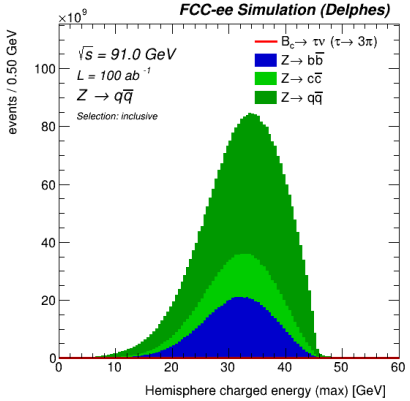
EPJC 80 (2020) 1 most recent work on threshold strategy optimization with systematics



Kinematic reconstruction PoS EPS-HEP2019 (2020) 653

P. Azzi, R. Rossin (PD)

- **Top properties** at threshold (mass, width, yukawa) with differential distribution in all hadronic channel and FCNC: analysis setup with new tools, case study for jet performance and b-tag



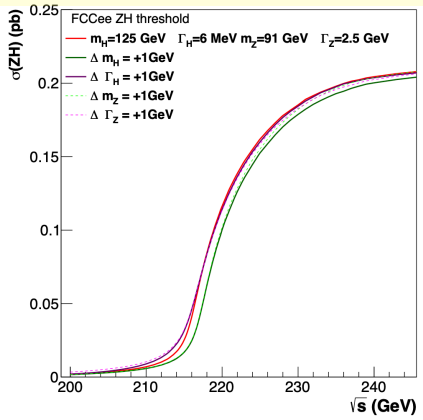
M. Cobal(UD), G. Panizzo(UD), P. Azzi(PD)

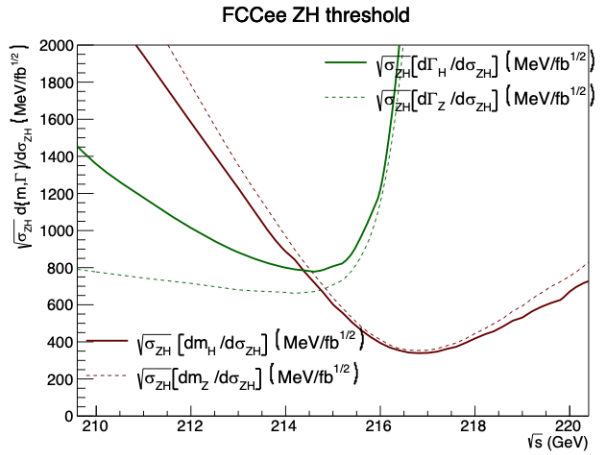
- $A_{0,b/c}^{FB}$ **estimate:** analysis setup using new tools. Key benchmark for b-tag, charge tagging & dilution

New physics analysis efforts (2/2) - new ideas

F.Bedeschi, P.Azzurri, P.Spagnolo, P.Francavilla, C.Roda, G.Chiarelli, S.Leone, F.Ligabue (PI)

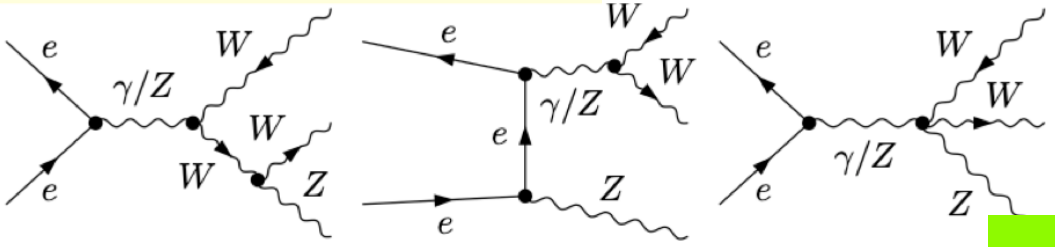
ZH threshold





run at **217** GeV
... on the way to
the **electron-Yukawa**
(to appear in EPJ+)

Multiboson couplings

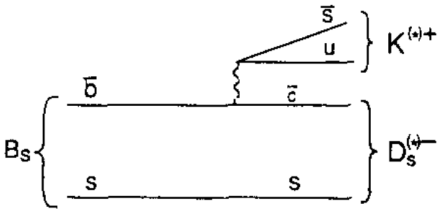


Similar x-sections and luminosity wrt HL-LHC, but much better acceptance & purity @365GeV

M. Scodeggio(FE), G. Cibinetto(FE)

Flavor $B_s^0 \to D_s^{\pm} K^{\mp}$ and $B_s \to J/\psi\phi$

to estimate $\varphi = \gamma_{CKM} + \gamma_{ds} - 2\beta_s$ and $2\beta_s$



Italian/European Funding Applications & Publications Plans

- **PRIN "RAZOR"** for the study of the Z boson couplings to heavy fermions at the FCC-ee, submitted last year (UD, MI, PI, PD, BA)
- **EPJ+ Special Issue on FCC-ee challenges (Part II)**: contains several contribution related to RD-FCC work
- **Experimental MSCA ITN « SPIRAL-NET »** for performance studies and detector requirements at lepton colliders(SPIRAL-NET) will be resubmitted in 2021. Includes collaboration across all future e+e- projects.
- **Frontier Collection on "Novel Ideas for Accelerators, Particle Detection and Data Challenges at Future Colliders"** (editors: Azzi, Merkel, Shiltsev, Tricoli) will contain several contribution of current work on detectors and also software tools.

Conclusions

- Software and physics activities for RD-FCC have been progressing well, even during pandemic. **Significant developments both on the tools and on the analyses.**
  - Contributions crucial to the overall FCC-ee activities
  - Addition of new collaborators on software and physics
- For the future:
  - Growing internal and international collaboration to increase with European/International grants (barring COVID19)
  - Expanding simulation and reconstruction work to be applied to concrete benchmark cases for detector requirement. Nicely connected to R&D studies as well