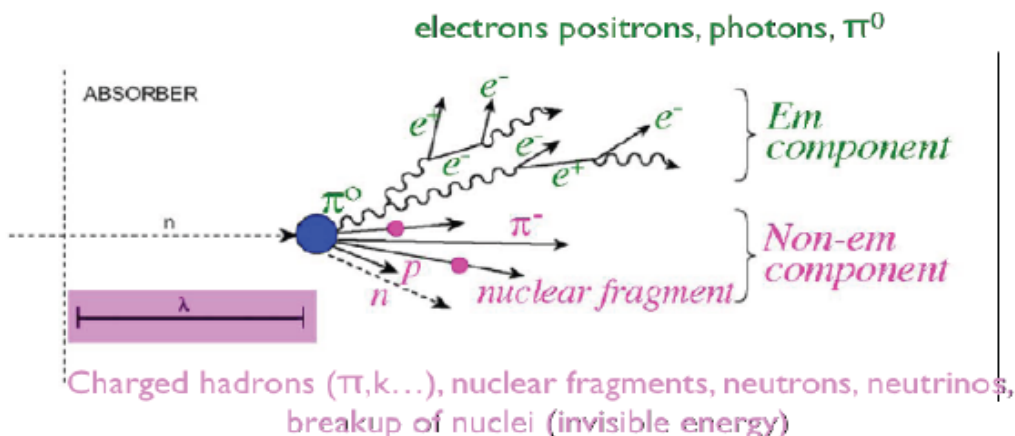


A Dual Readout Calorimeter for FCC-ee ?

Gabriella Gaudio
on behalf of the IDEA Dual-Readout Calorimeter Collaboration
January, 21st 2021

Dual-readout in a nutshell



Cherenkov light (C)	only produced by relativistic particles, dominated by electromagnetic shower component
Scintillation light (S)	measure dE/dx

Measure the electromagnetic fraction event by event to equalize the response off-line

$$S = [f_{em} + (h/e)_s \times (1 - f_{em})] \times E$$

$$C = [f_{em} + (h/e)_c \times (1 - f_{em})] \times E$$

e/h ratios ($c = (h/e)_c$ and $s = (h/e)_s$ for either Cherenkov or scintillation structure) can be measured

- **Compensation** achieved without construction constraints
- **Calibration** of a hadron calorimeter just with electrons
- **High resolution** EM and HAD calorimetry

$$\cot \theta = \frac{1 - (h/e)_s}{1 - (h/e)_c} = \chi$$

Θ and χ are independent of both energy and particle type

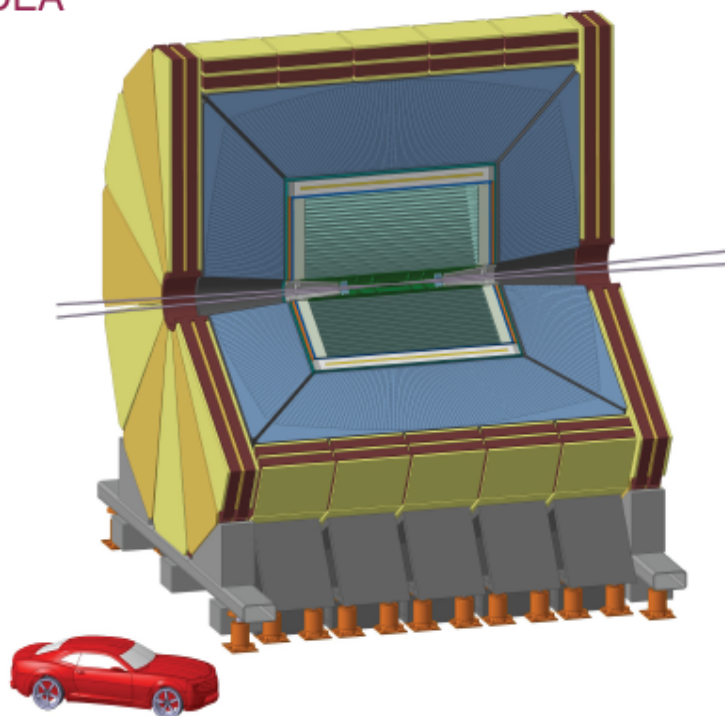
It is possible to evaluate

$$f = \frac{c - s(C/S)}{(C/S)(1 - s) - (1 - c)} \quad \text{and} \quad E = \frac{S - \chi C}{1 - \chi}$$

Dual-readout calorimeter: international collaboration

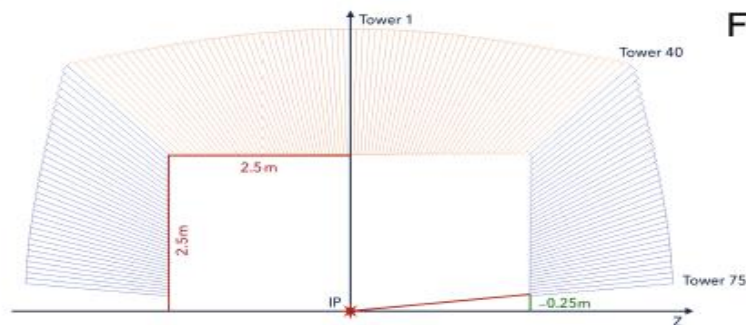
IDEA

- ◆ Included in FCC and CepC CDRs
- ◆ Growing international collaboration in
 - ◆ **Europe:** Croatia (RBI), UK (Univ. of Sussex), Italy (INFN-BO, INFN-CT, INFN-PI, INFN-PV, Univ. of Insubria)
 - ◆ **Asia:** Korea (Kyungpook Univ., Seoul Univ., Univ. of Seoul, Yonsei Univ.)
 - ◆ **USA:** Iowa State Univ., Texas Tech Univ., Univ. of Maryland, Univ. of Princeton



Innovative Detector for Electron-positron Accelerators

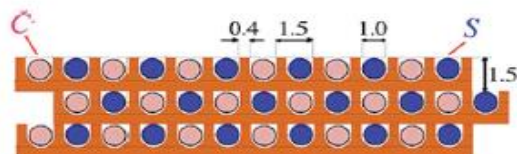
idea-dualreadout@cern.ch
<https://indico.cern.ch/category/10684/>



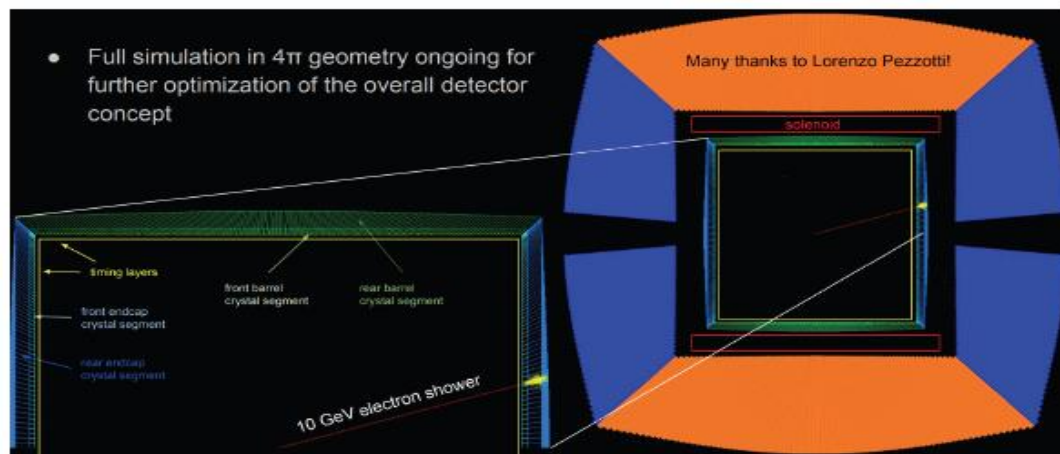
Fiber DR calorimeter

G4 standalone simulation

Fiber+crystal options



75 projective elements x 36 slices
Copper + scintillating and Cherenkov fibers



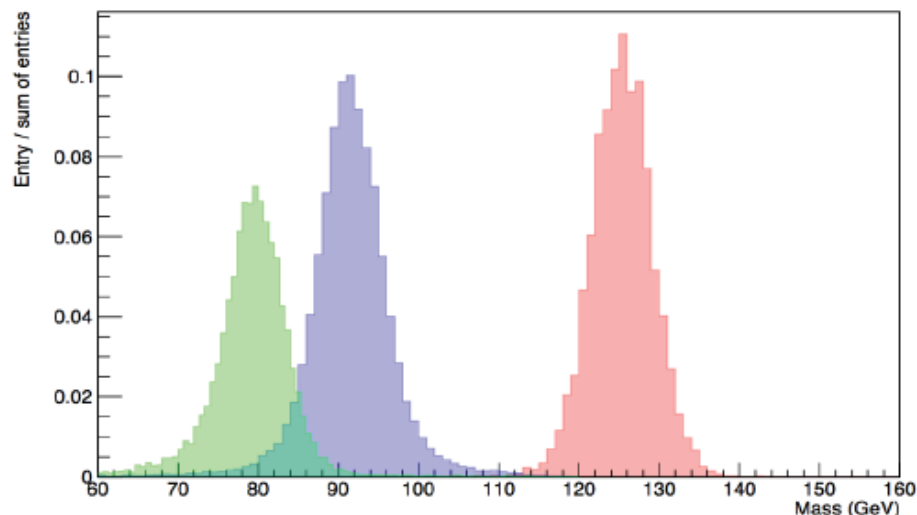
Jet generated with PYTHIA8, tuned to LEP measurement
Propagated in GEANT4 calorimeter
Obtain C and S response + (θ, ϕ) of the tower
Get jet 4-momenta
Clustering with FASTJET (Duhram kt algorithm)

$$e^+e^- \rightarrow HZ \rightarrow \tilde{\chi}^0 \tilde{\chi}^0 jj$$

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

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

PYTHIA8 + GEANT4 + FASTJET



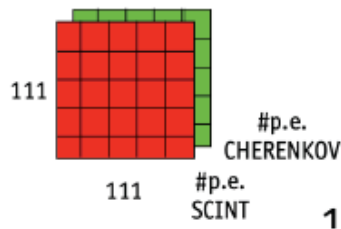
Machine-Learning approach

Reconstruct and identify particle is under development with promising results.

3-class label	8-class label	
0	0	$\tau \rightarrow \mu\nu\nu$
0	1	$\tau \rightarrow e\nu\nu$
1	2	$\tau \rightarrow \pi\nu$
1	3	$\tau \rightarrow \pi\pi^0\nu$
1	4	$\tau \rightarrow \pi\pi^0\pi^0\nu$
1	5	$\tau \rightarrow \pi\pi\pi\nu$
1	6	$\tau \rightarrow \pi\pi\pi\pi^0\nu$
2	7	$Z \rightarrow qq$ jets

DNN models:

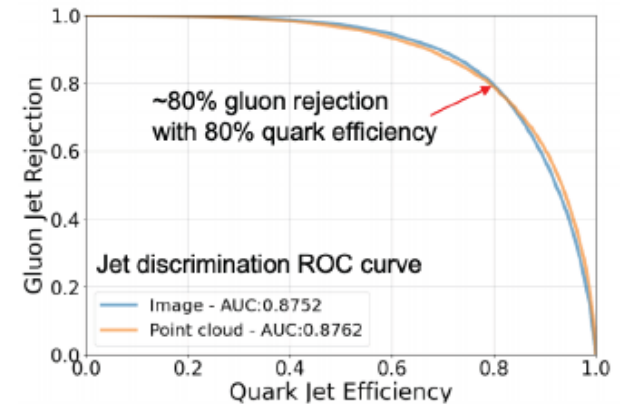
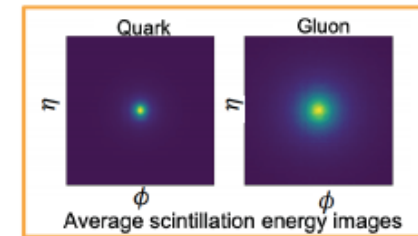
- VGG-like CNN with 3D and 2D convolutions: jet/tau representation 2-channel 111x111 mesh
- DGCNN: jet/tau representation: 2D point-cloud of fibres coordinates + #p.e. as features



Truth BR	$\tau \rightarrow \mu\nu\nu$	$\tau \rightarrow e\nu\nu$	$\tau \rightarrow \pi\nu$	$\tau \rightarrow \pi\pi^0\nu$	$\tau \rightarrow \pi\pi^0\pi^0\nu$	$\tau \rightarrow \pi\pi\pi\nu$	$\tau \rightarrow \pi\pi\pi\pi^0\nu$	$Z \rightarrow qq$ jets
$\tau \rightarrow \mu\nu\nu$	97%	2%	1%					
$\tau \rightarrow e\nu\nu$	1%	97%	1%	1%				
$\tau \rightarrow \pi\nu$	1%	3%	87%	4%	1%	2%		1%
$\tau \rightarrow \pi\pi^0\nu$		1%	5%	78%	13%	1%	3%	1%
$\tau \rightarrow \pi\pi^0\pi^0\nu$				7%	88%		4%	1%
$\tau \rightarrow \pi\pi\pi\nu$			5%	2%		75%	15%	2%
$\tau \rightarrow \pi\pi\pi\pi^0\nu$			1%	1%	4%	8%	81%	5%
$Z \rightarrow qq$ jets					1%	1%	2%	96%

Predicted BR
(B field and material)
average accuracy: 87%

CNN model



- Many funding requests ongoing
 - S. Korea: large founding over ~5 years (APPROVED)
 - AIDA innova: mainly Post-doc positions (APPROVED)
 - Submitting PRIN at Italian MUR
 - Submitting INFN call CSN5: ~ 900k€ over three years (next summer)
 - SNOWMASS Process
 - https://snowmass21.org/instrumentation/calorimetry#submitted_loi
 - Large number of Lol submitted
-
- ◆ Very wide range of activities ongoing
 - ◆ Simulation, ML approach for reco, performance studies, physics studies ...
 - ◆ Development in both the calorimeter construction technique and readout...
 - ◆ These activities mostly affected by covid-19 spread.
 - ◆ Foreseen TB @Desy postponed from Nov. 2020 to Feb. 2021, to be understood
 - ◆ Collaboration is open to new groups interested in this detector technology

