Which calorimeter for FCC detector

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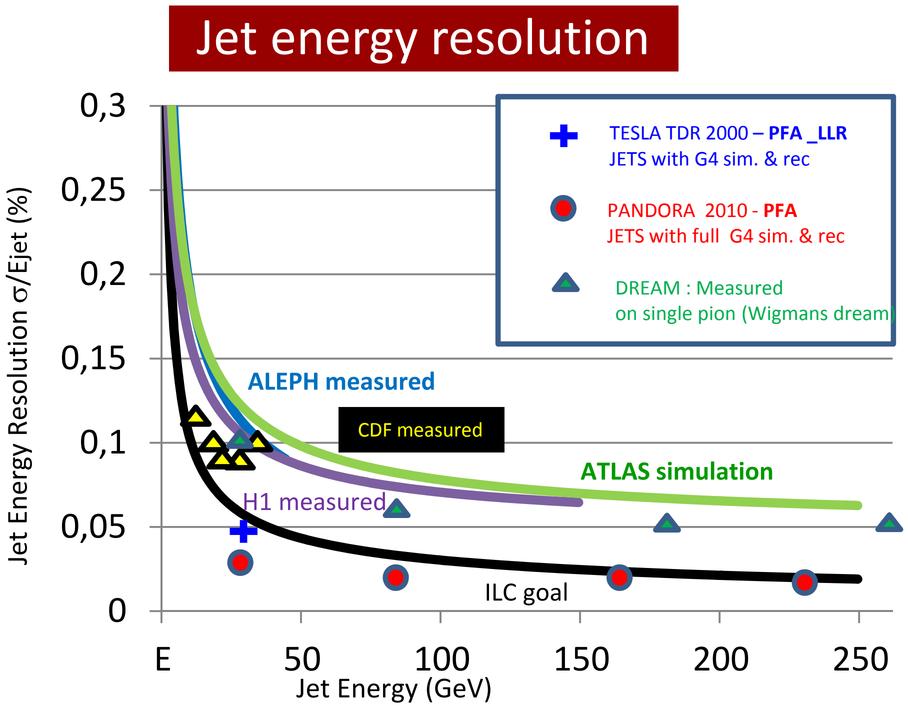
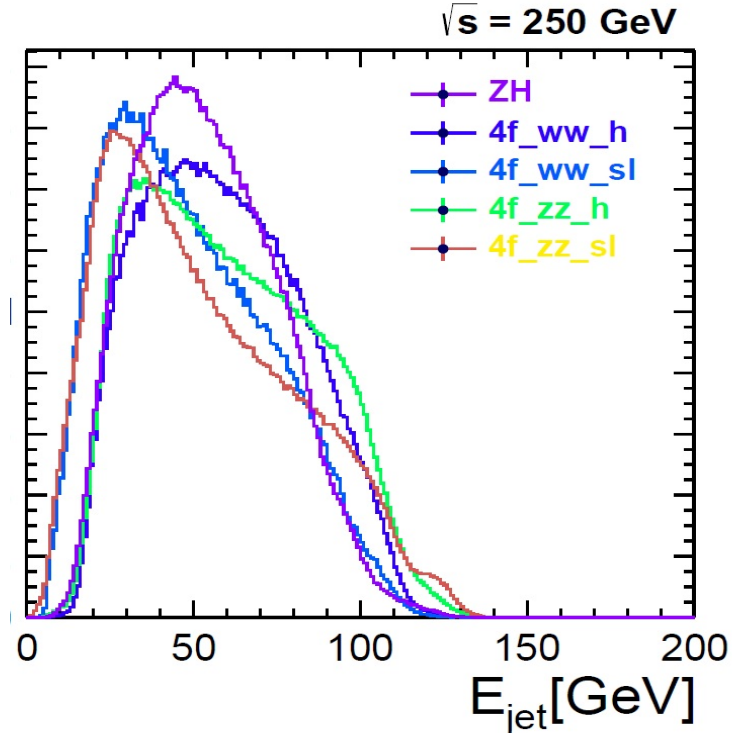
FCC to do what ?

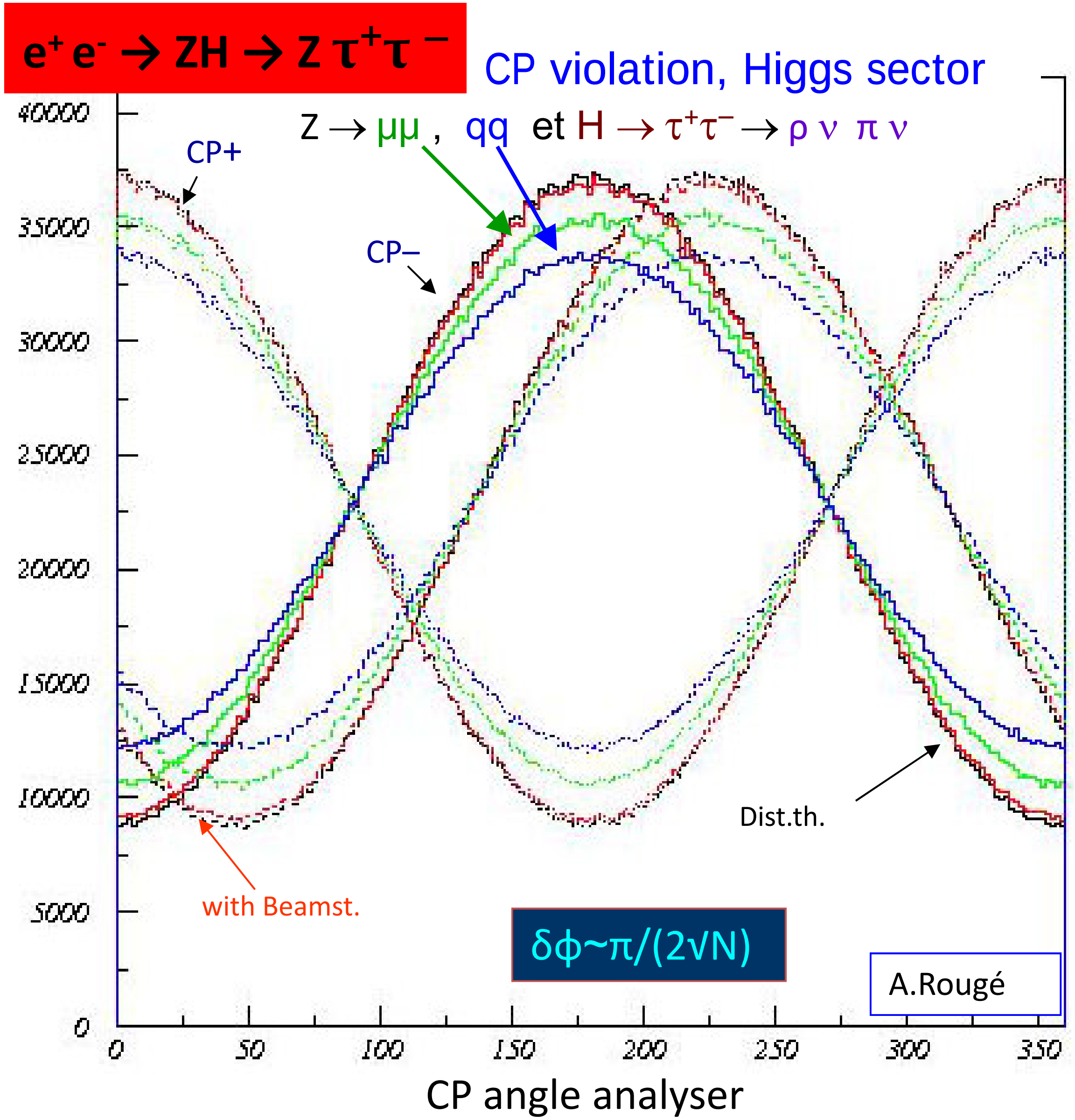
- Study of e^+e^- physics from Z to 350 GeV
- ZH, ZZ, WW , ttbar , etc…
- BEST use of luminosity : Tag the boson through 2 jets decays
- tau polarization (H CP violation, AFB(pol) …)



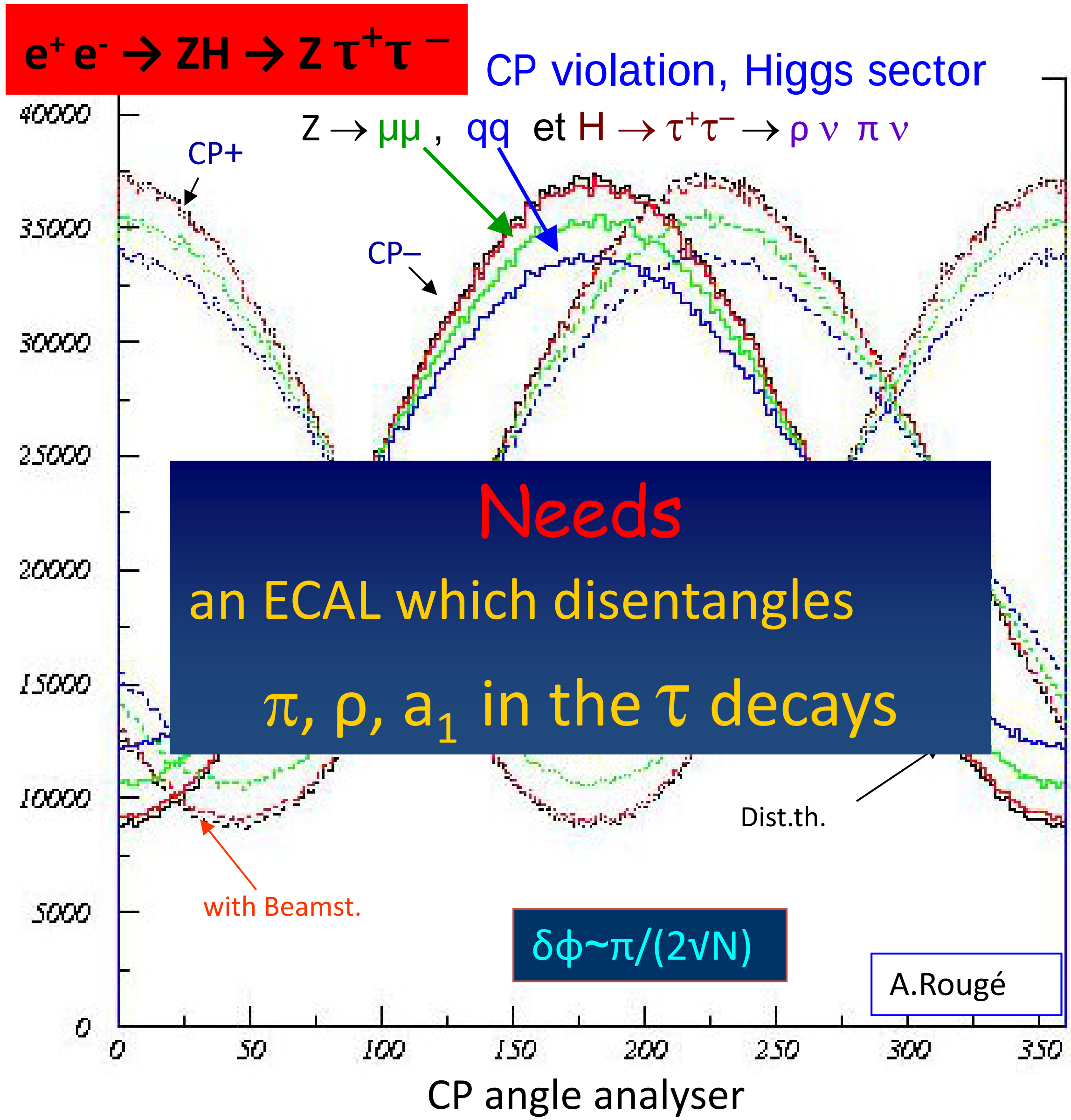


Same conclusion than ILC …. Use of PFA >>>> Ultragranular calorimeter with all detector inside coil ("a la CMS")

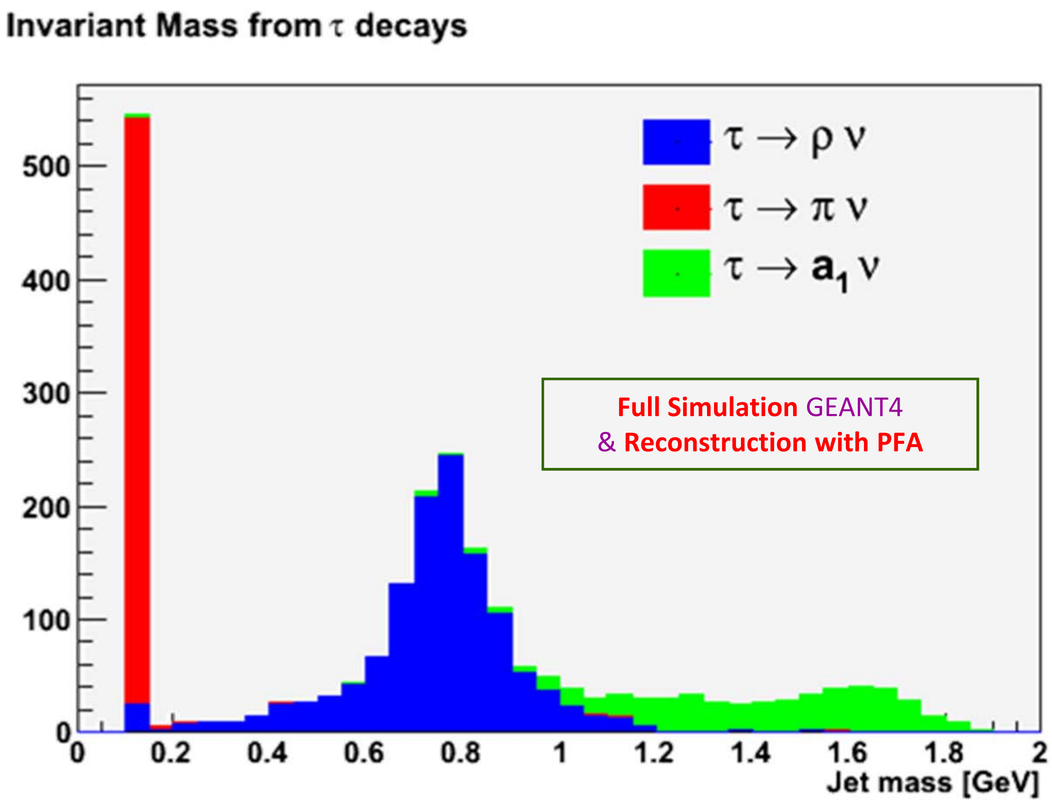
e+e- interaction : τ± as a polarisation analyser

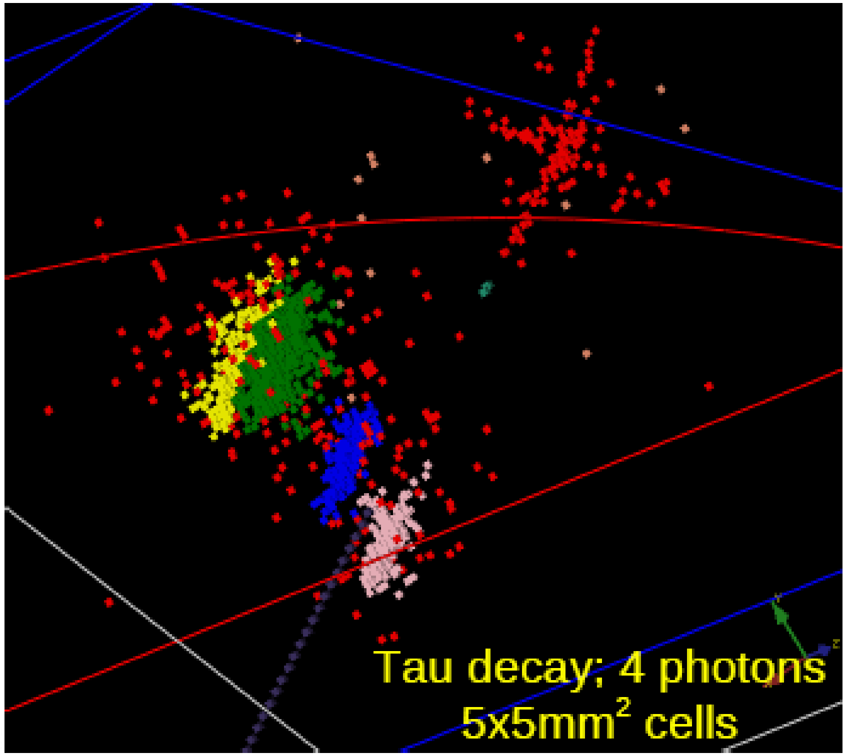


on e+e- interaction : τ± as a polarisation analyser



on e+e- interaction : $\tau^{\pm}$ as a polarisation analyser





	Jet mass < 0.2	Jet mass in 0.2-1.1	Jet mass >1.1
$\tau \rightarrow \pi\nu$	90.2 %	1.7 %	8.1 %
$\tau \rightarrow \rho\nu$	1.7 %	87.3 %	7.4%
$\tau \rightarrow a_1\nu$	0.6 %	7.4 %	92.0 %

ULTRAGRANULAR CALORIMETER

It is opening the following questions

a) Calibration of O(100) millions channels and signal stability (we want same response for same collision)

b) Capability to make zero suppress "on site" (we don't want to read empty pixel)

c) Keep S/N ≥ 10 at MIP level and coherent noise under control (noise , radio/TV , telephone, ground loop, etc…)

d) Multiplexing for the quantity of signal line out (we don't want to have 100M cables)

e) Power management due to large number of channels (we don't want to burn our electronics readout)

f) KEEP the COST UNDER CONTROL (we want an affordable cost)

A set of answers

a) Choose stable device (silicon) or control & monitor the signal stability (Scint. or Micromegas)

b) ADC& digital memory in readout chip, close to active layer. Read memories at each end of bunch train

c) i.e. Silicon PIN diodes …. AC/DC coupling , ground loop …

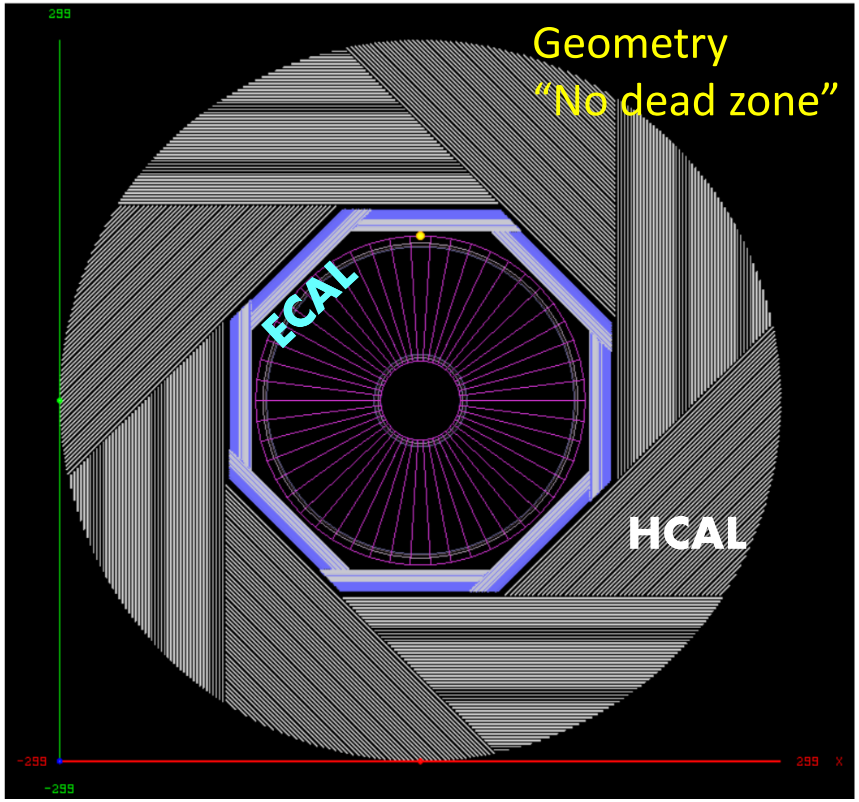
d) Large number of Channels/VFE ASIC… (KPIX, SKIROC), but only few readout line

e) Power pulsing (thanks to machine structure) → reduced the power to dissipate… no cooling inside

f) Reduce the overall surface or use lower cost active device (Micromegas, scintillator)

BUT warning versus point a) and c) . 10 years contacts with producers, defining wafers design which reduce the cost

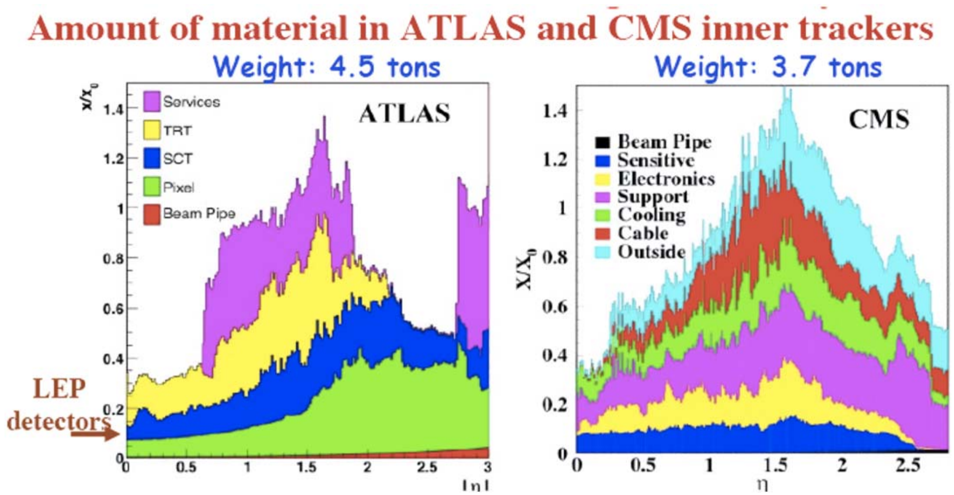
A possible detector

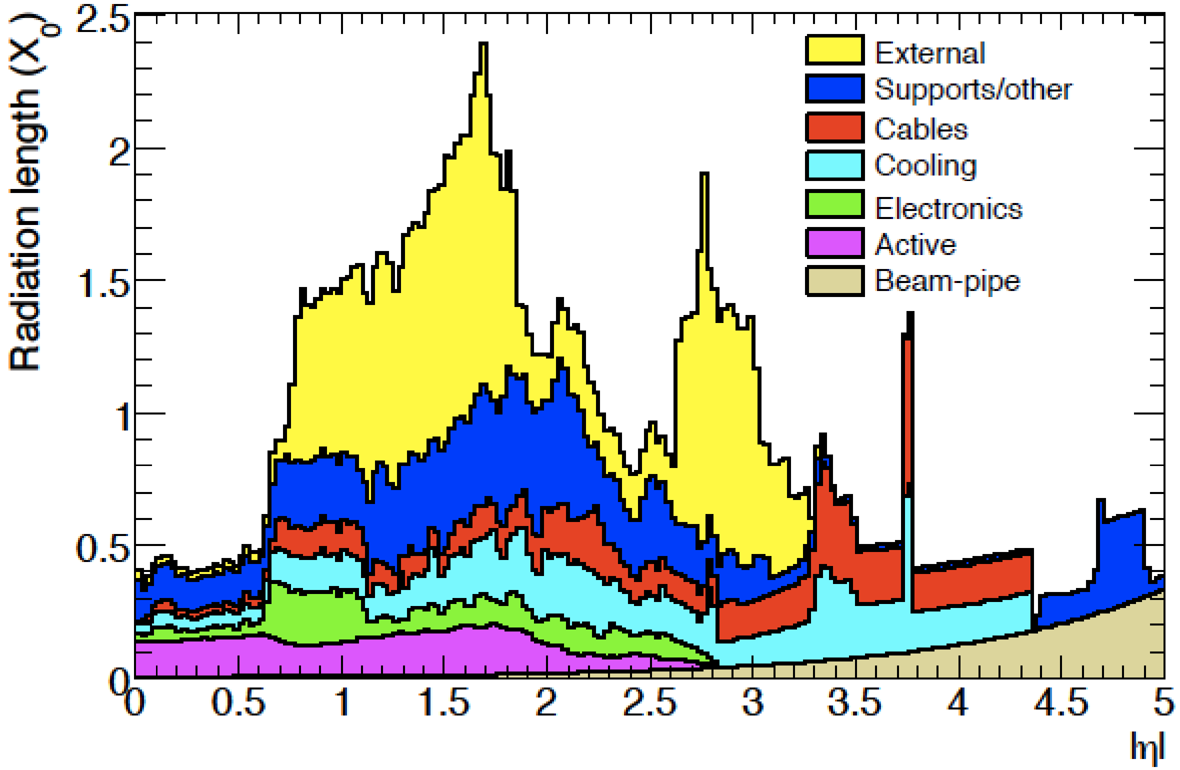


- A geometry without dead zone
- A small TPC (or Si Tracker) with Rout=140 cm
- A dense ECAL (25-35 cm for 24X0)
- A digital gas detector for HCAL (all in-one muon ID and HCAL, gas is better .. fast , cheap, small pixel, etc…)

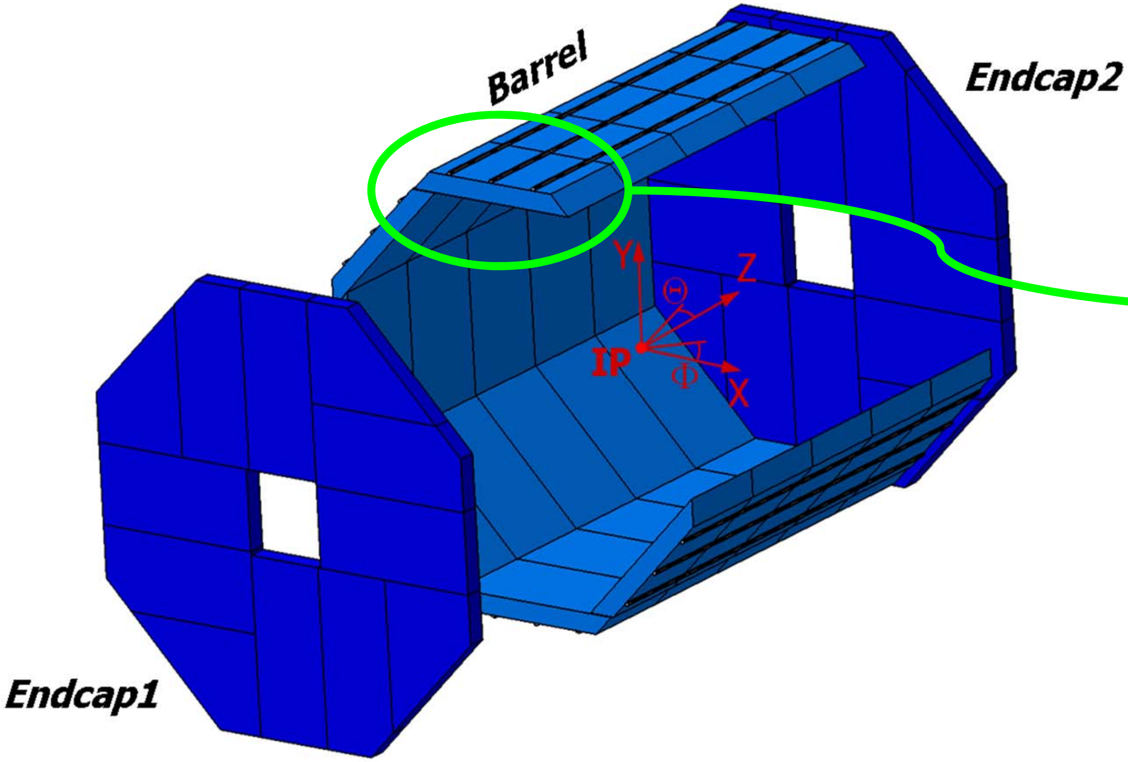
Le danger qui guette le chasseur

The danger which wait for the hunter

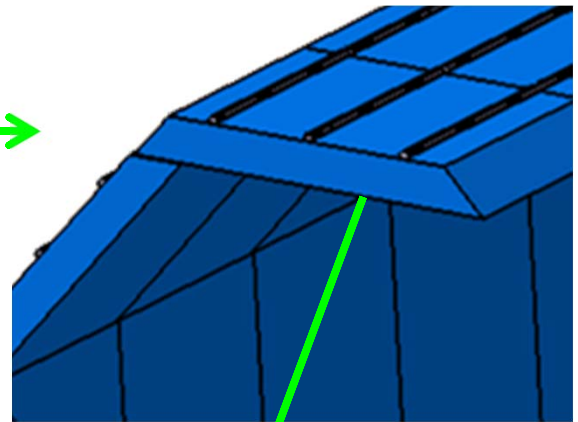


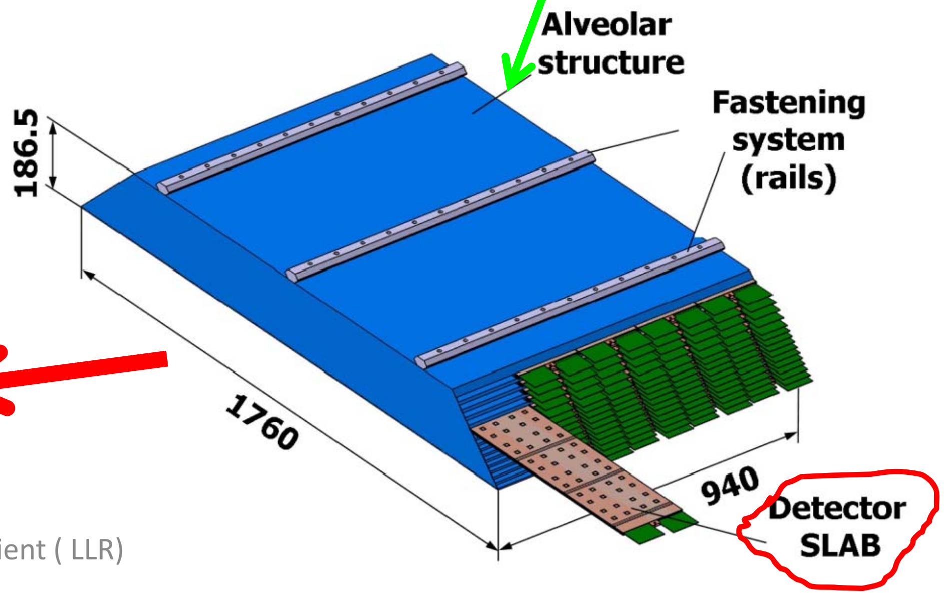


ECAL GEOMETRY



No DEAD ZONE !!!





Carbon fiber –Tungsten structure with Alveola
to slide in the active layers.

ECAL

But which level of granularity can be afforded without powerpulsing ?

- For physics, the smaller is the best (it continue to improve largely even for S_{Pixel}<<Rm)
  BUT for the electronics cost and cooling , … there is some limits

- Readout every 25 ns; no power pulsing
  readout frequency versus ILC x **14** (350 ns to 25 ns)
  conso/cell = 2.8 mW (Analogic part SKIROC2 without PP) +
  2,1 mW (=0,15 x**14** for digital part with readout every 25ns)

  = 5mW …. Propose to use 10 mW/channel (including a safety factor of 2)

- From CMS upgrade project-**HGCAL** , active cooling system can be stabilized in temperature
  for about 100W/layer, with fluid running in tube inside cooper plate (Rm not so good than ILC… but)

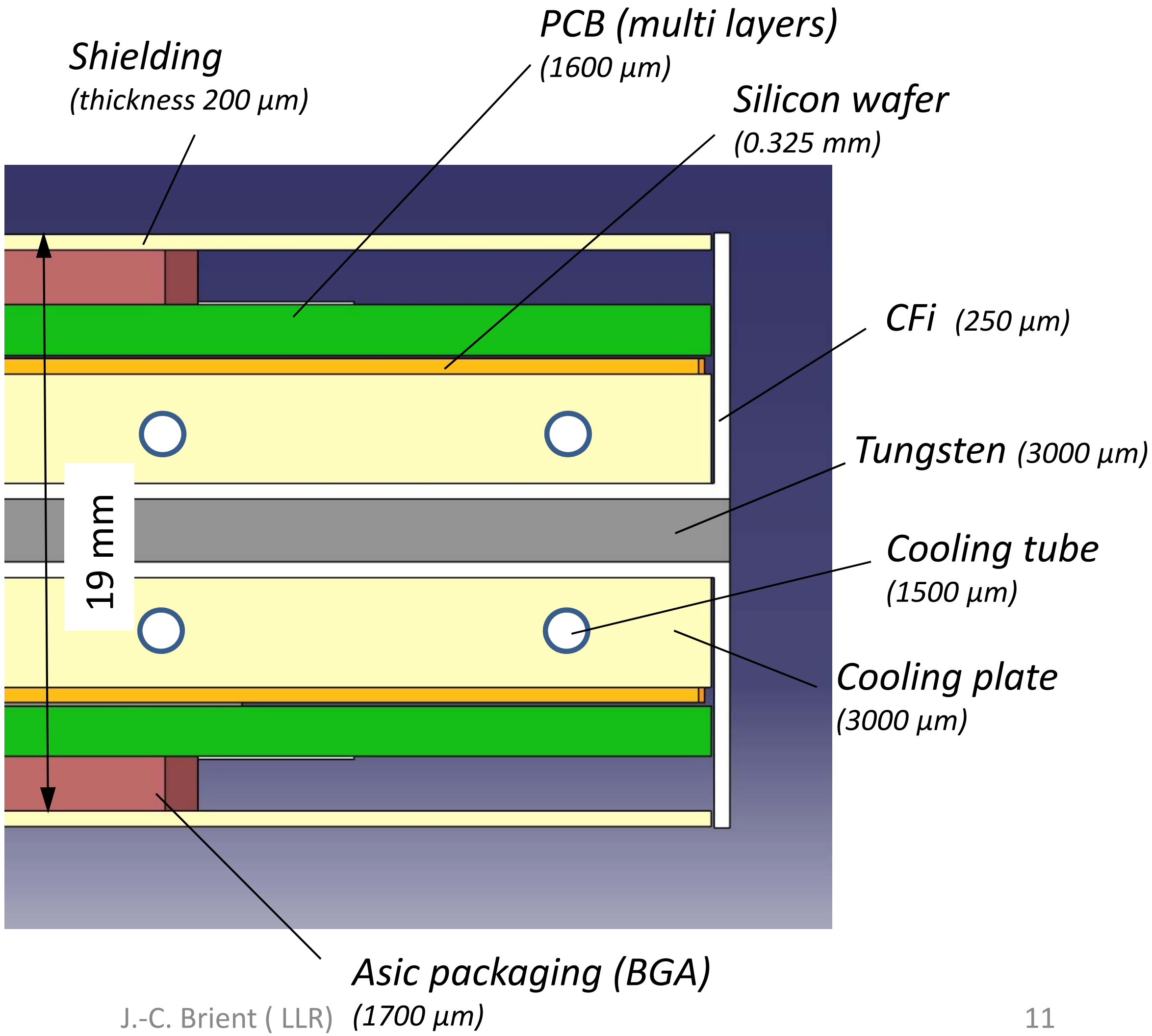
⇩

Taking into account the choosen layer size (= 150x20 cm²) and the 100W,
The cooling can afford pixel size of about 0.6x0.6 cm² !!! We have it

Possible cross section of the ECAL with active cooling (based on CMS study for HGCAL)

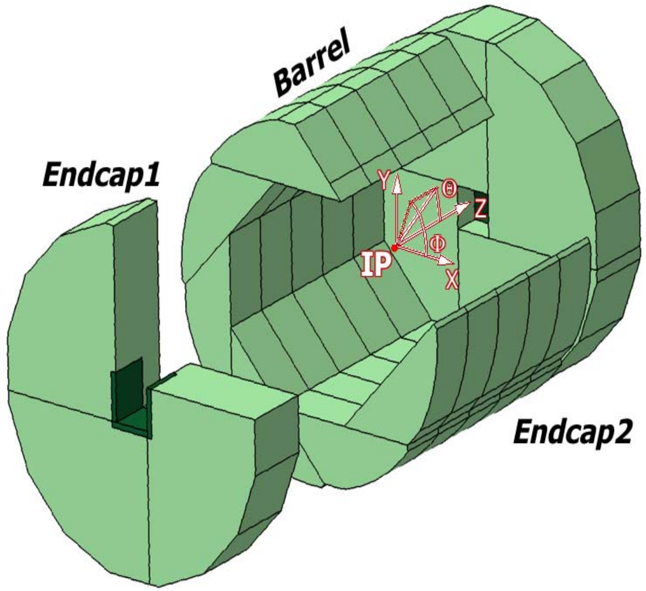
About 8.7 mm/layer

R_M^{eff}= 2.4 cm(2cm in CALICE-ILD)
Total thickness for 23 X0, 30 layers is 26 cm.



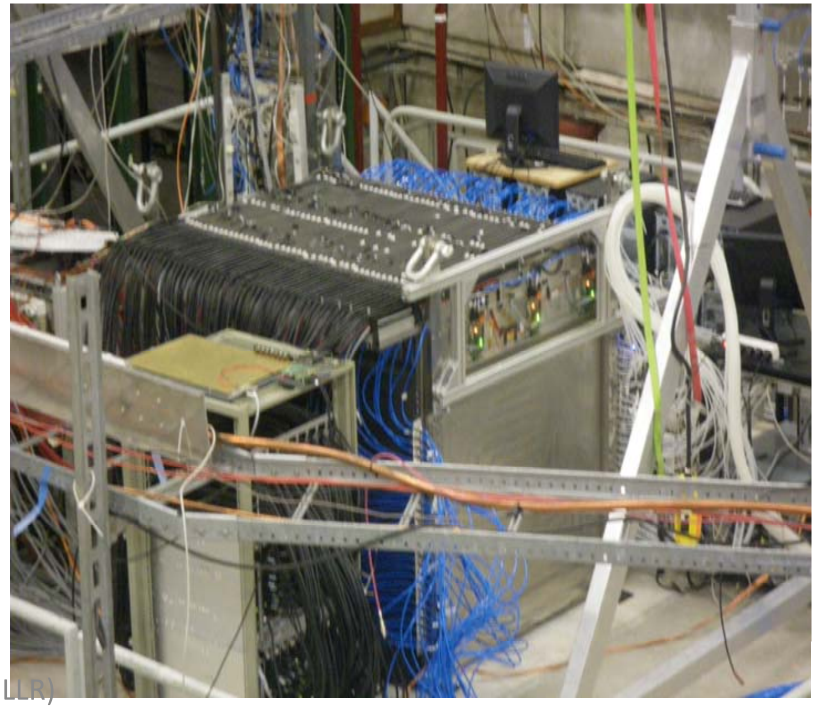
SDHCAL

The SDHCAL-GRPC modules are made of
48 GRPC chambers separated by 2cm steel ($6\lambda_I$)



The structure proposed for the SDHCAL-ILD :

- Is self-supporting
- Has negligible dead zones
- Eliminates projective cracks
- Minimizes barrel / endcap separation
  (services leaving from the outer radius)



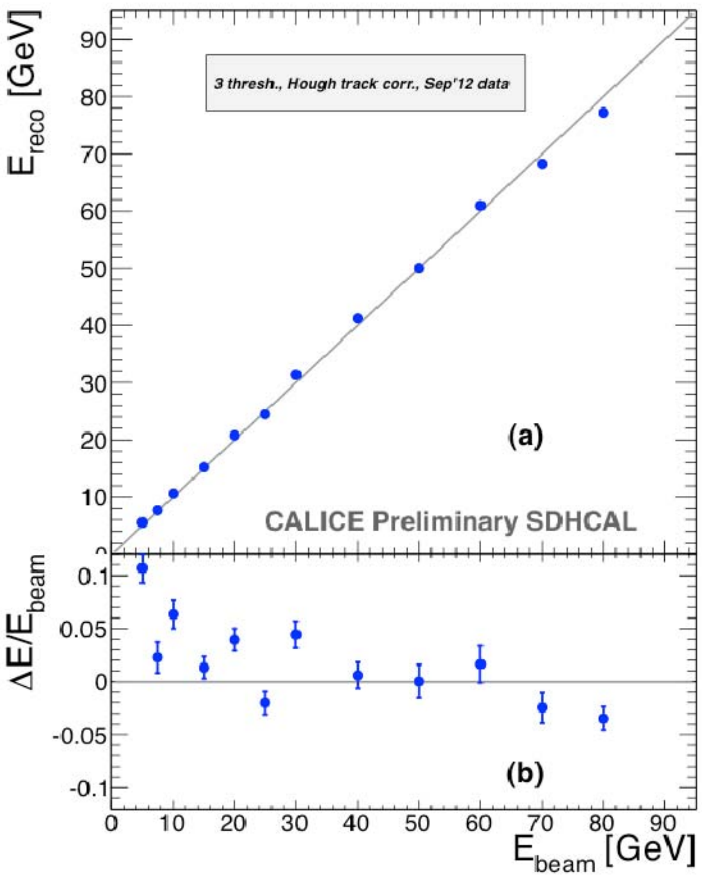
SDHCAL Prototype

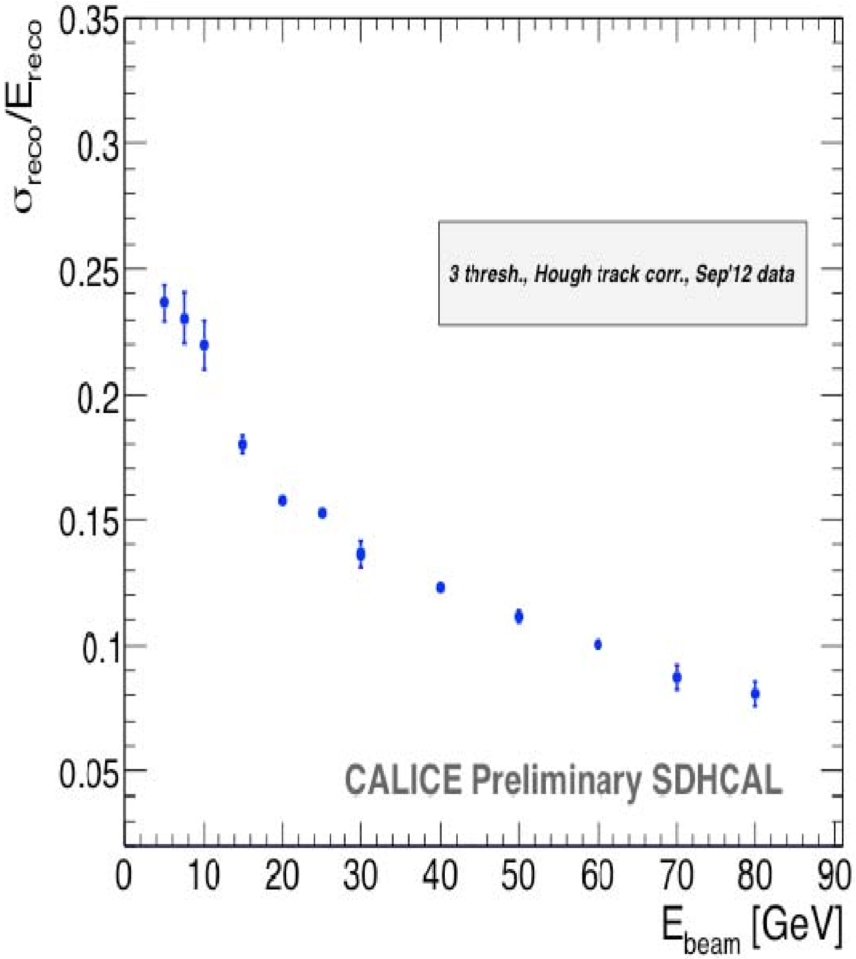
- Come as close as possible to expectations

-48 units (active layer + absorber)

Challenges

-Homogeneity for large surfaces
-Thickness of only few mms
-Services from one side
-Self-supporting mechanical structure



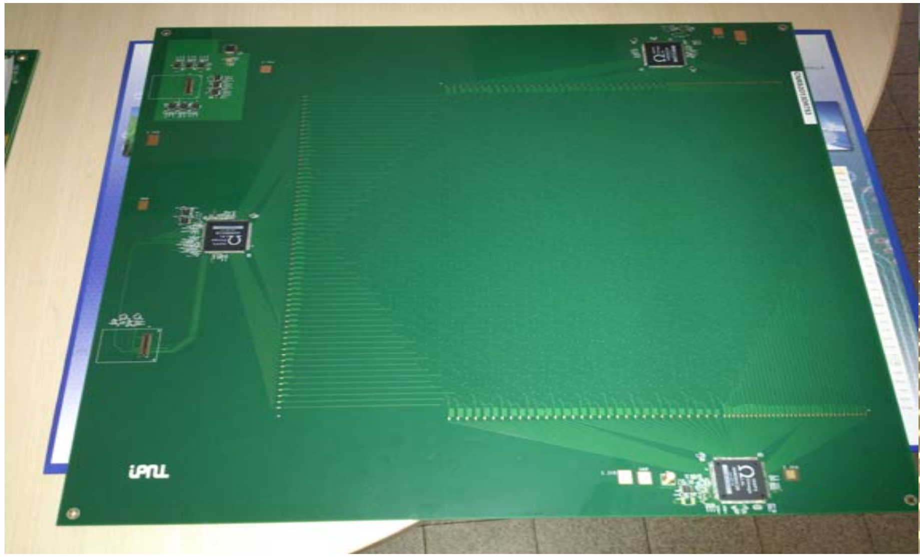


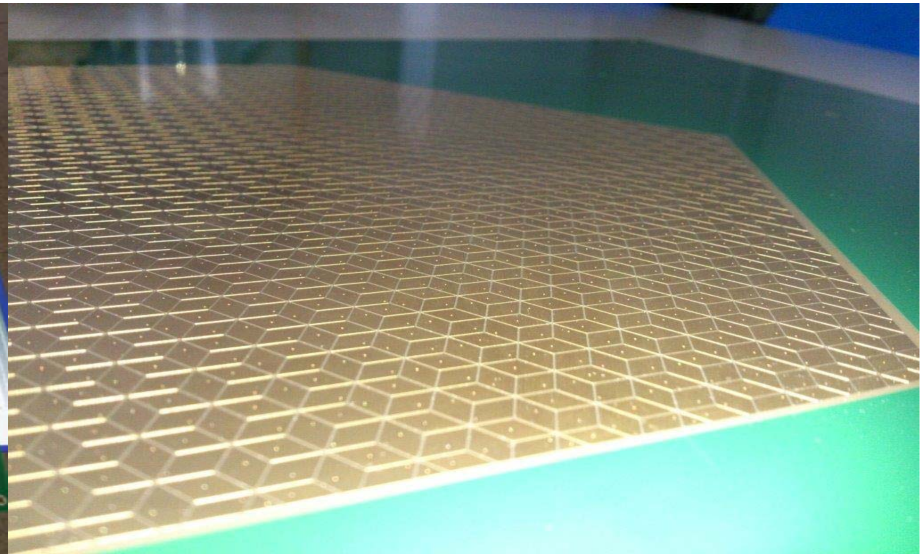
Linearity and energy resolution obtained
with the SDHCAL at H6-SPS@CERN

SDHCAL could be an excellent and a cost-effective solution to FCC-ee

Power dissipation under study

1- Reducing the power consumption (currently 1 mW/ch)
2- Using 2-phase CO_2 cooling using with pipes cast in grooves in the steel absorbers
3- Test new genuine schemes to reduce the number of electronic channels without impacting the effective granularity as the one developed in Lyon (woven three direction strips)





CONCLUSION

- Ultra granular calorimeter , optimized for PFA, would do the job

- For the ECAL, an active cooling , “a la CMS” , could do the job

- For the HCAL, Gas device , High granularity is consistent with the requirement and PFA

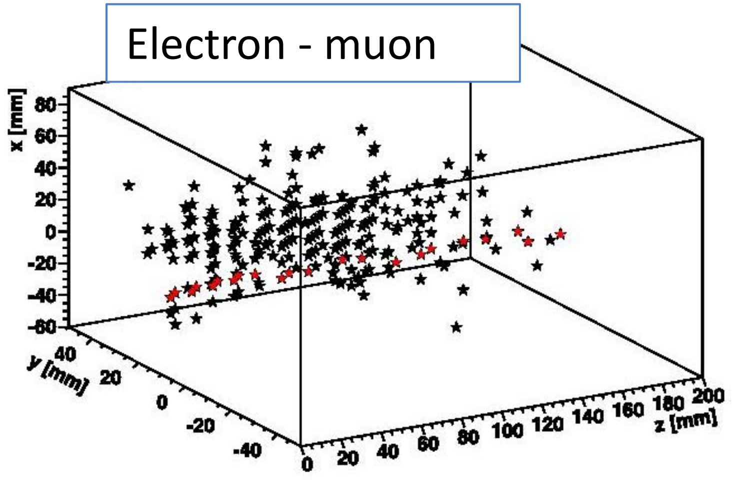
A personal remark….

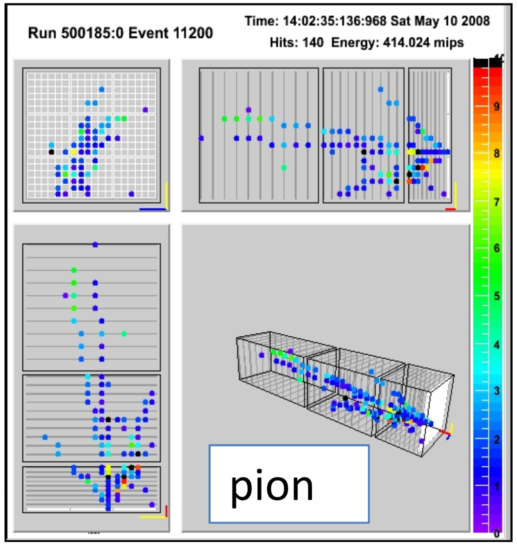
FCC means high lumi. e+e- …..
→ stat. errors will be small, small syst. Errors from detector is mandatory

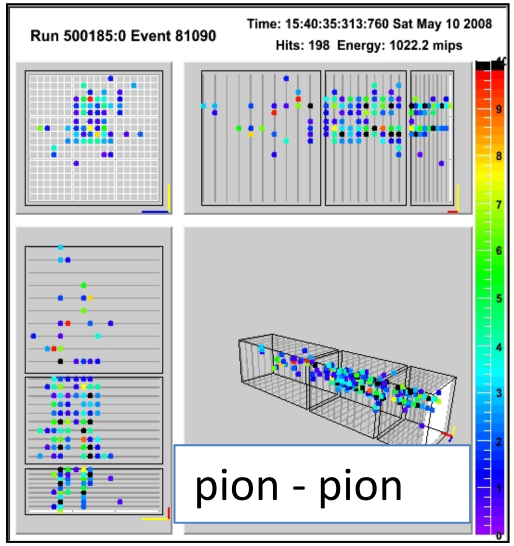
→ STABLE in time is better …. Could be better to avoid scintillator and SiPM

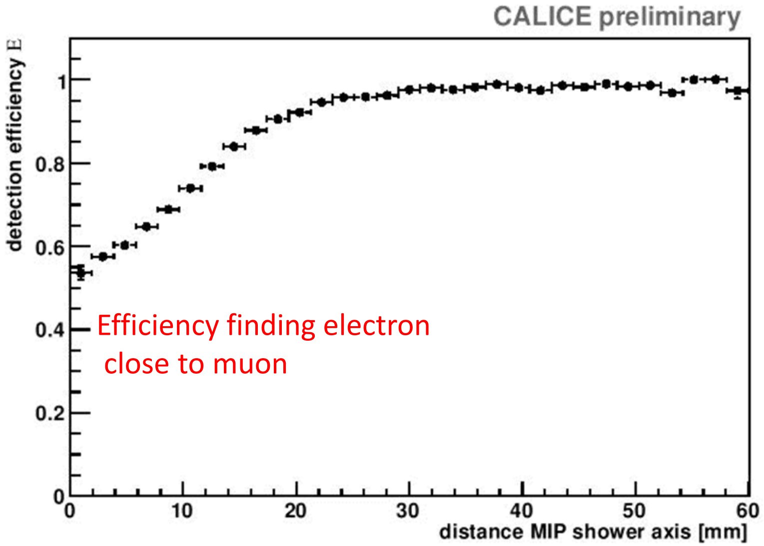
BACKUP

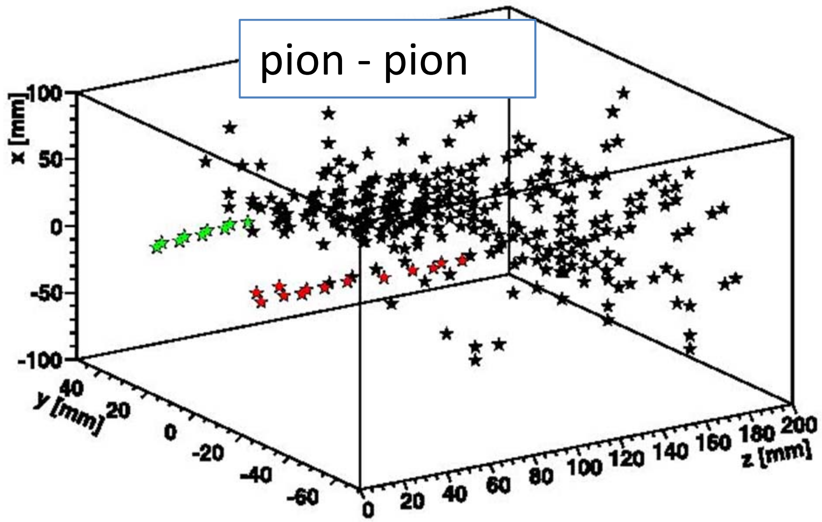
The tests of the camera











Quantitative test has been published by CALICE (test of PANDORA PFA with TB data)

Scintillator or silicon ?

- Stability
- Capability to go down to 0.5x0.5 cm^2
- Good S/N at MIP level
- VERY good uniformity (guarding vs uniformity in strip or tile)
- Cost …

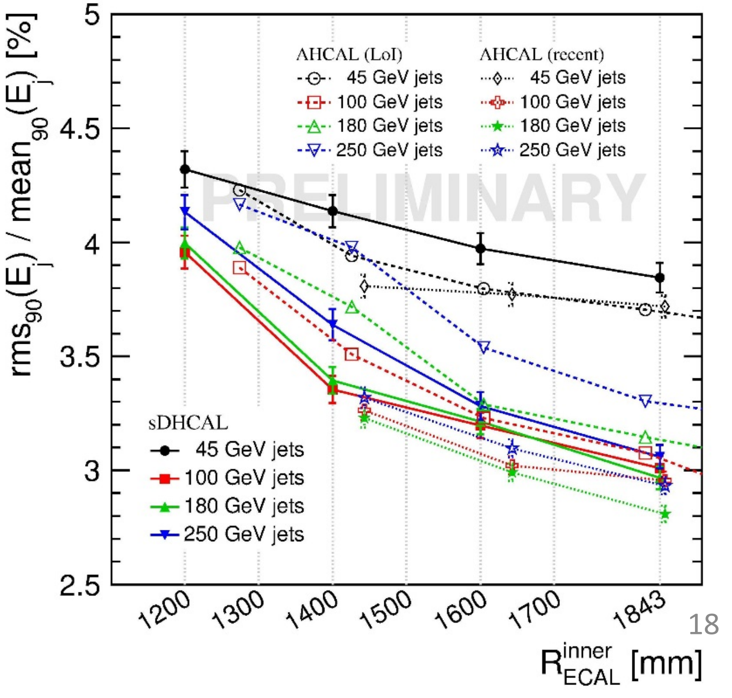
Today price is about **2.0-3.0 €/cm^2** for silicon PIN diodes
If you include the scintillator, fibers, monitoring system and SiPM the price is marginally different from silicon PIN

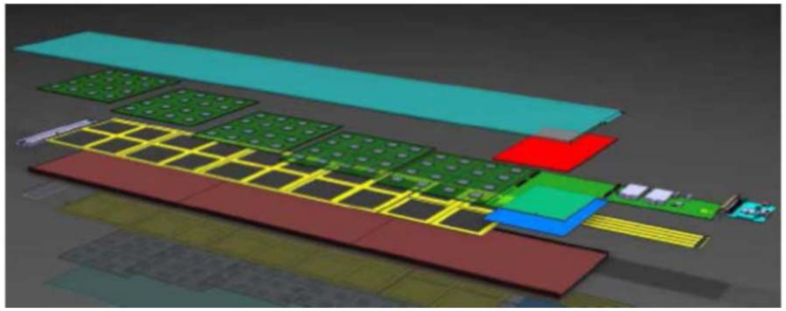
HOWEVER, about the overall detector cost
It depends of the ECAL barrel radius and length.
For the same physics(jet, tau, etc..) performances, a smaller detector with smaller pixel could do the job

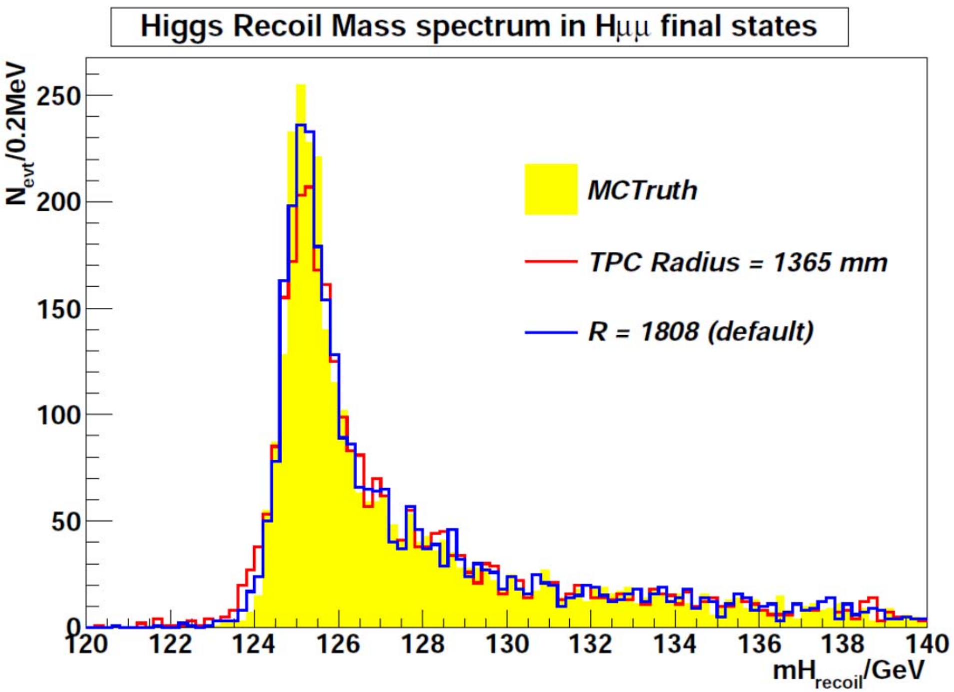
Smaller detector ⇒
smaller cavern, smaller Yoke, smaller return yoke, etc… **COST !!**

CONCLUSION

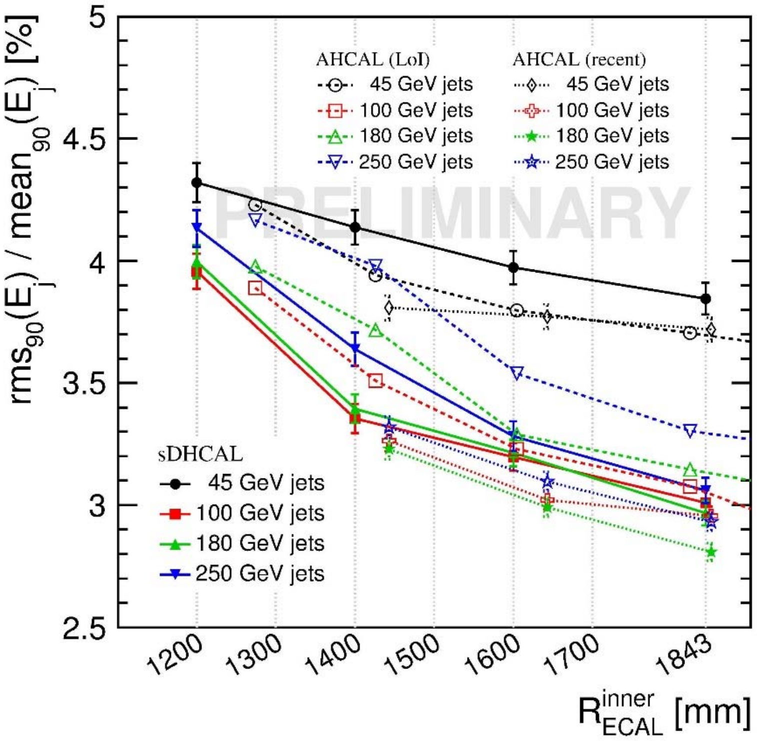
Small pixels, small radius
OR
Larger pixels (scintillator), larger radius
…
SID , ILD ===== same detector cost





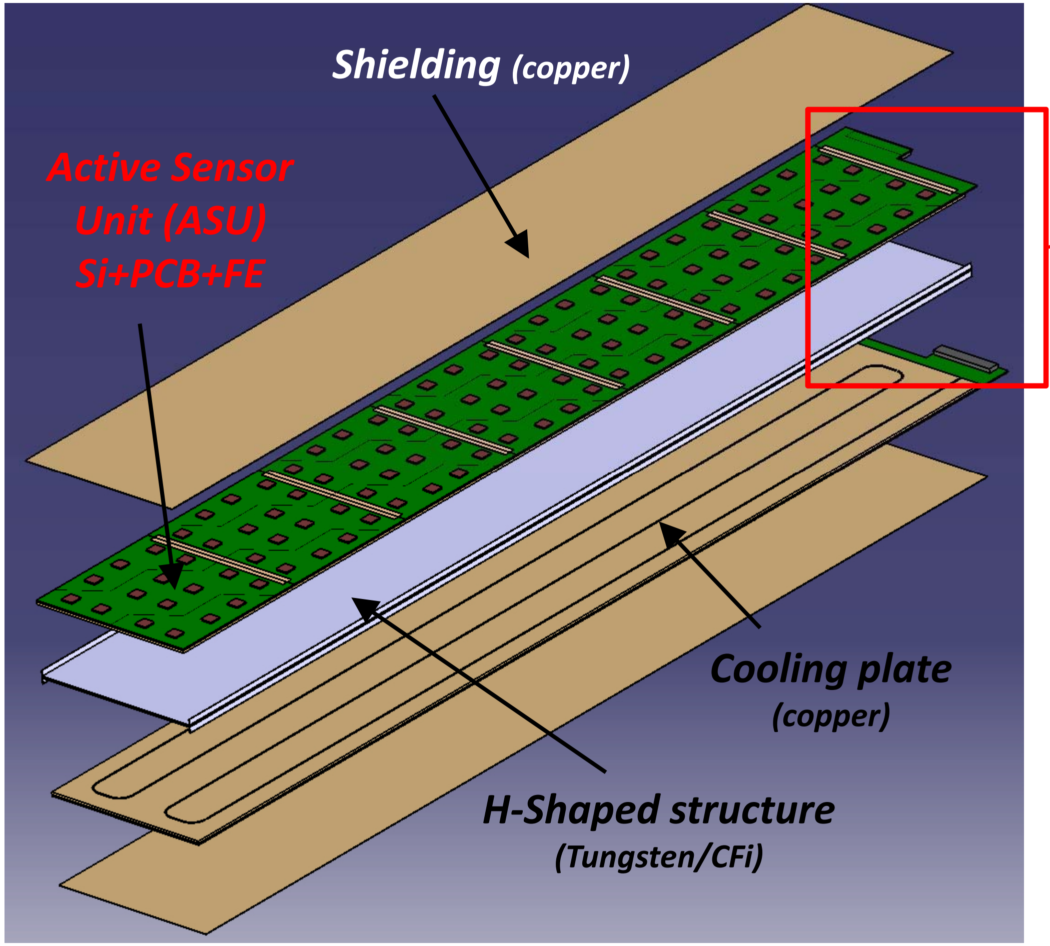


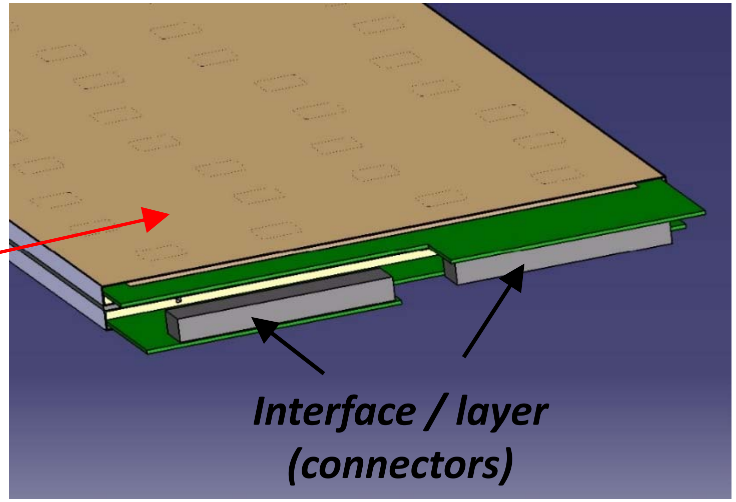
Higgs Recoil Mass spectrum in Hμμ final states
N_evt/0.2MeV
MCTruth
TPC Radius = 1365 mm
R = 1808 (default)
mH_recoil/GeV



rms90(Ej) / mean90(Ej) [%]
AHCAL (LoI)
45 GeV jets
100 GeV jets
180 GeV jets
250 GeV jets
AHCAL (recent)
45 GeV jets
100 GeV jets
180 GeV jets
250 GeV jets
PRELIMINARY
sDHCAL
45 GeV jets
100 GeV jets
180 GeV jets
250 GeV jets
R_ECAL^inner [mm]

Detector SLAB (exploded view)





Front of ECAL – Shower start