PFA AND TEST BEAM

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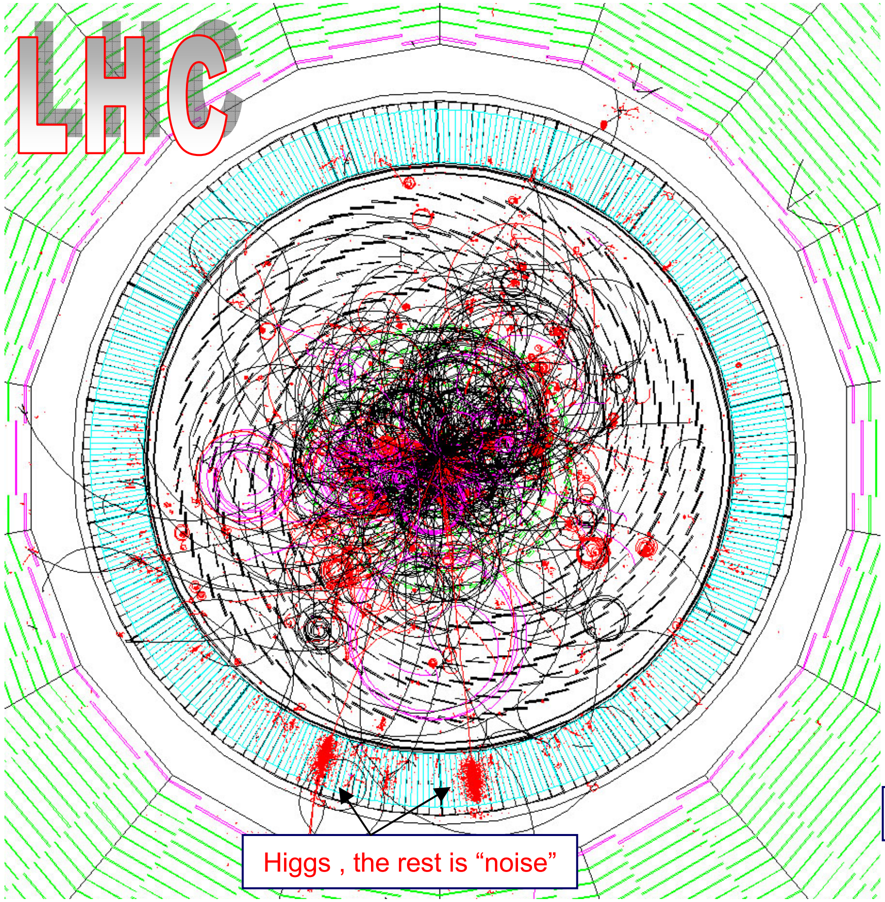
CNRS/IN2P3

WHY ILC ?

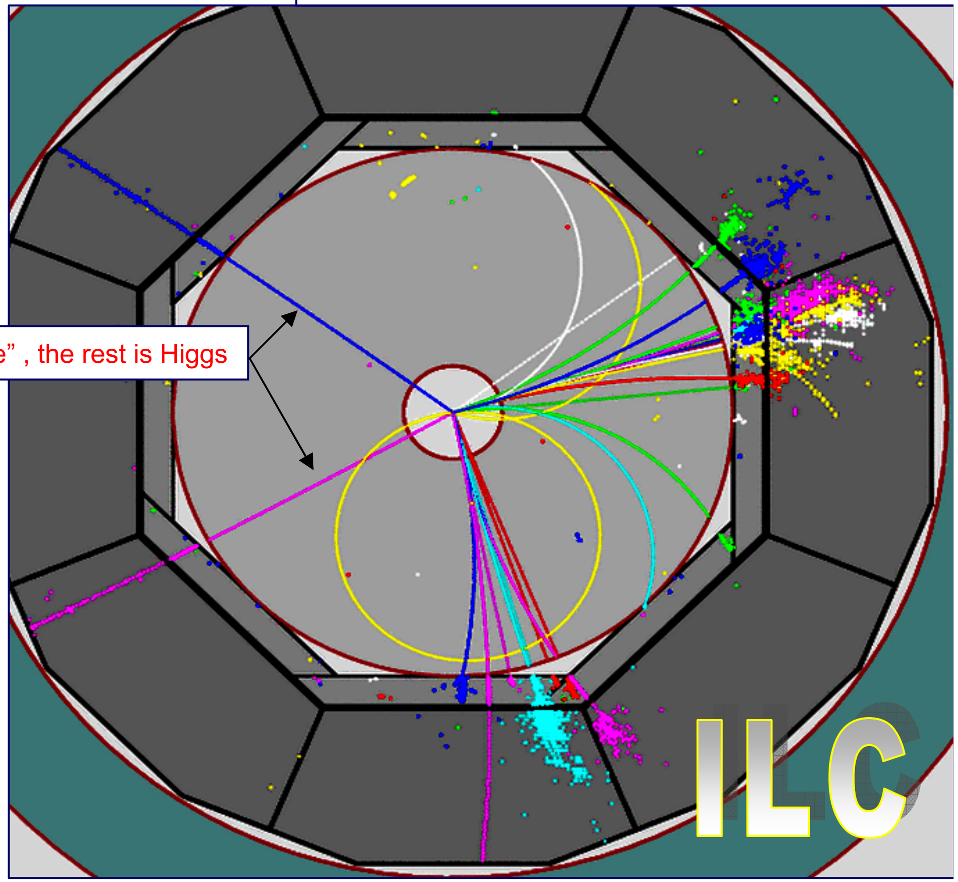
WHY PFA ?

Which test in TB ?

One Higgs event



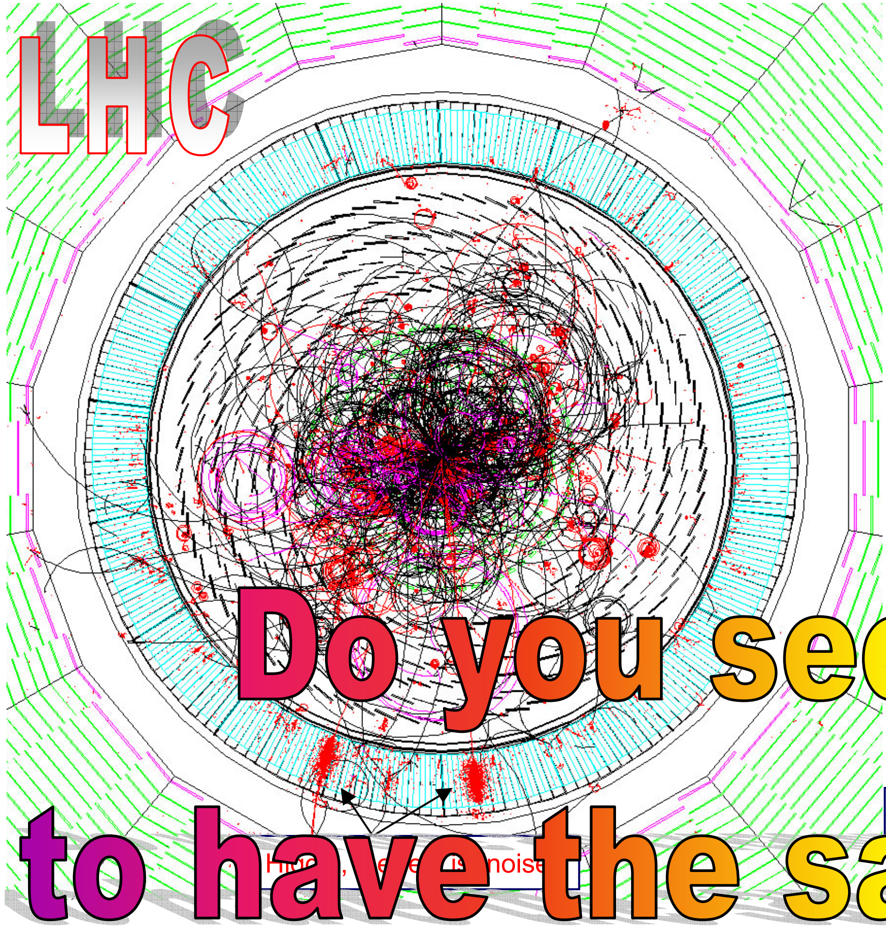
After removing the 2 muons,
All the rest of the event is
Coming from the Higgs decay



LHC will discover
(open the doors)

ILC will probe the underlying theory (turn on the light)

One Higgs event



After removing the 2 muons,
All the rest of the event is
Coming from the Higgs decay

Do you see any reason to have the same detector ??

<u>LHC will discover</u>
(open the doors)

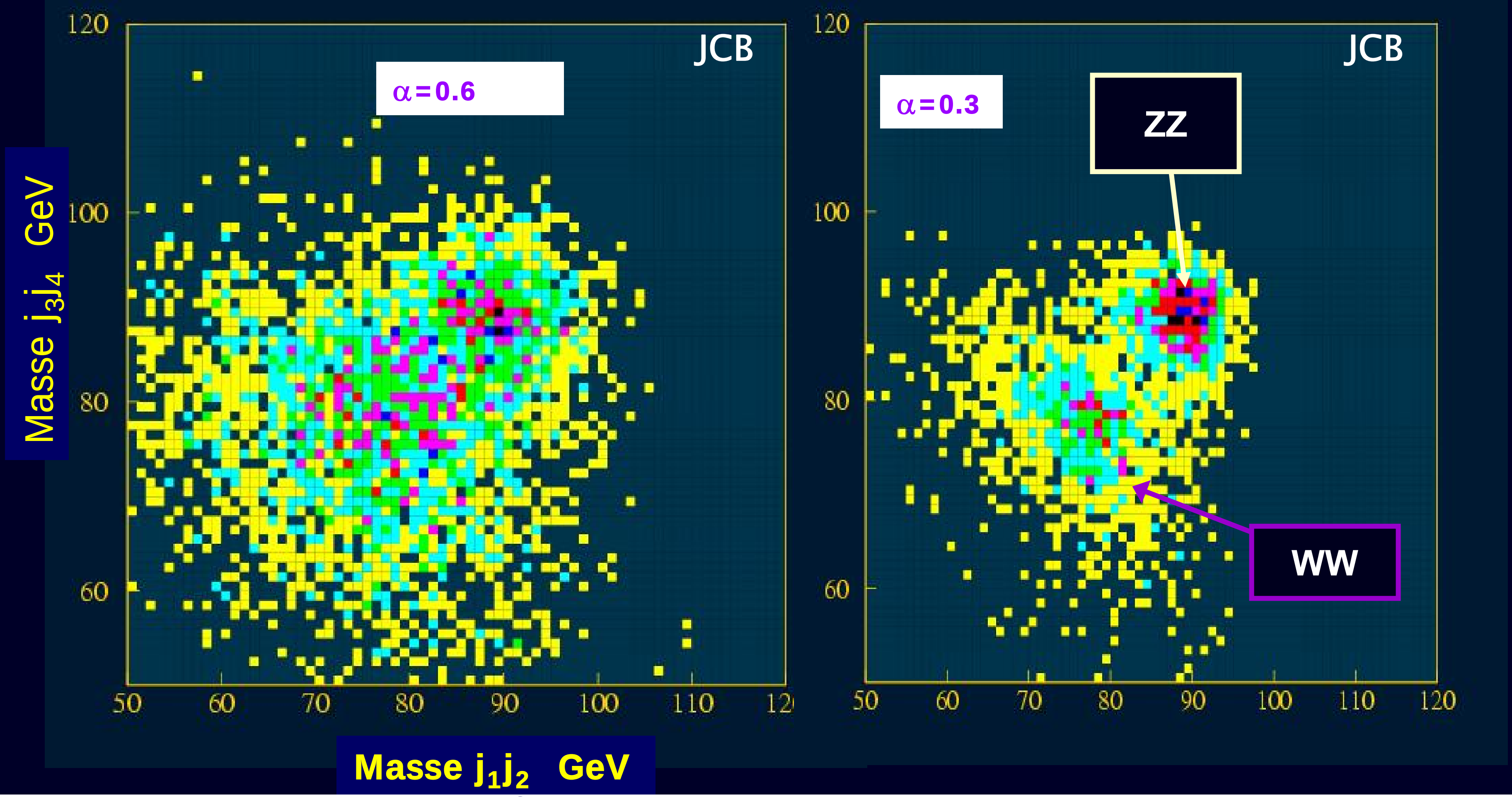
<u>ILC will probe the underlying theory</u> (turn on the light)

Why we need very good hadronic final state reconstruction ?

$\Delta E_{jet} \sim \alpha \sqrt{E_{jet}}$

If you didn't understand this plot, don't worry
Some people understand it

$e^+e^- \rightarrow \nu\nu W^+W^-, \nu\nu ZZ$ à $\sqrt{s}$=800 GeV



What is PFA - 1

What is For PFA

Geometrical , topological separation of energy deposited in the calorimeter

Allows to use the best sub-detector for each particle species

What is NOT PFA

> It is not Energy Flow (subtraction of deposition from one species to obtain the energy of another one

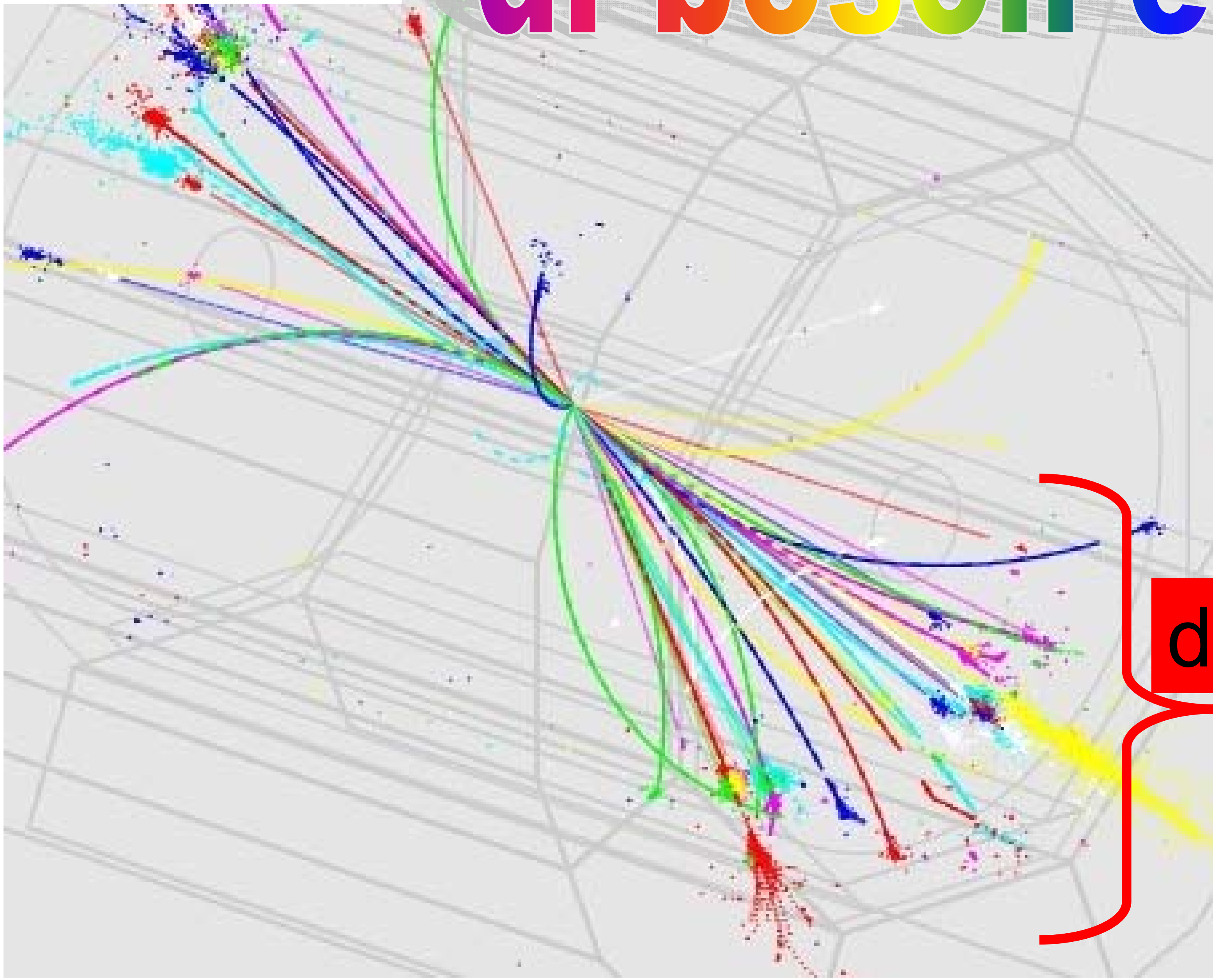
> It is not The jetology
(Rcone algorithm , DURHAM or JADE for e+e-, etc…)

> The fiducial volume
Mark Thomson's presentation at low angle is probably misleading

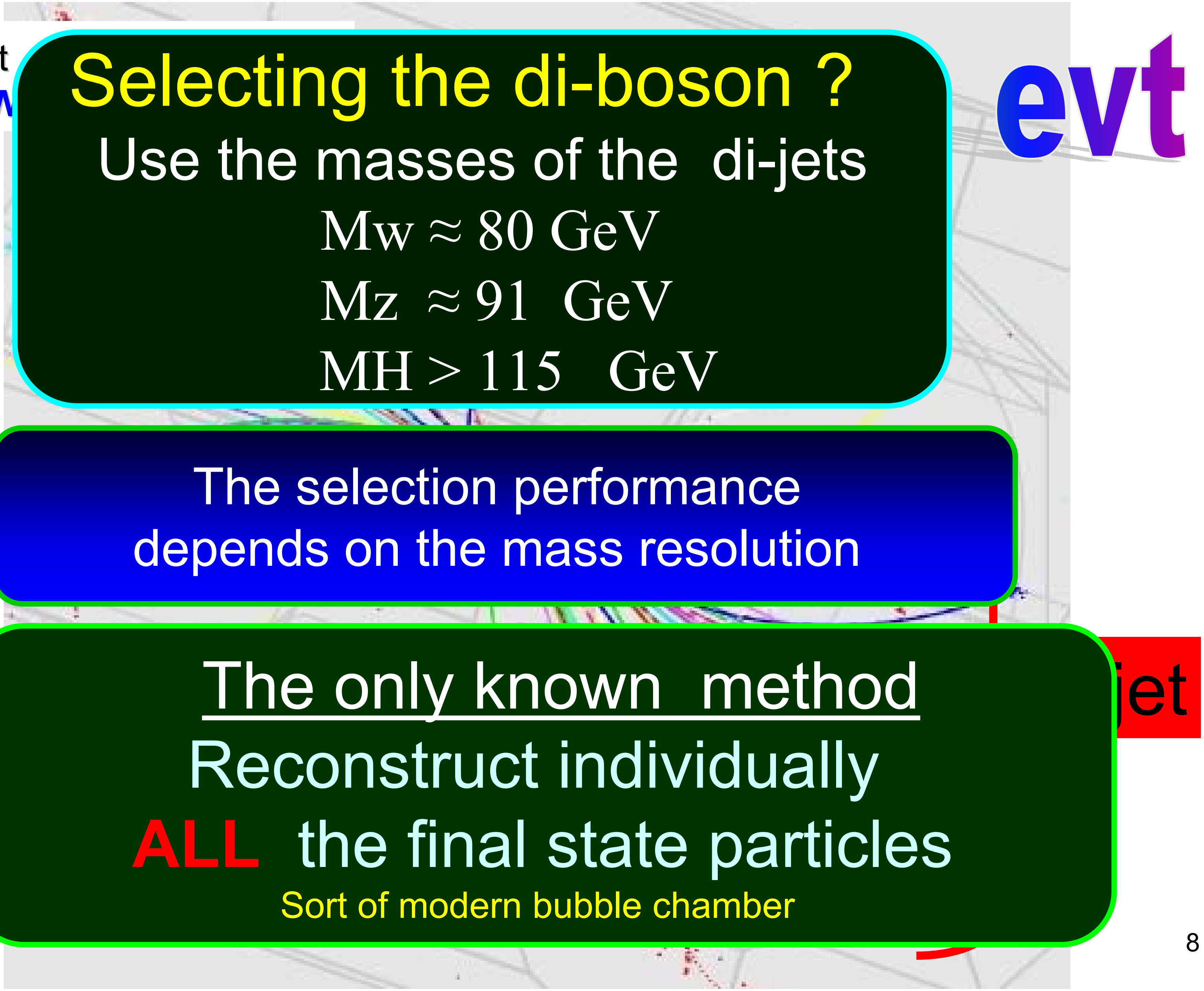
Talking of $\Delta E \sim 30\% \times \sqrt{E}$ on the energy resolution , It concerns the visible energy of the jet in the detector (the effect of the fiducial volume or of neutrino is outside of the discussion)

di-boson evt

Is it e^+e^- to
WW , **ZZ** , **ZH** , etc… ?



Is it
WW



Selecting the di-boson ?

Use the masses of the di-jets

$M_W \approx 80$ GeV

$M_Z \approx 91$ GeV

$M_H > 115$ GeV

The selection performance
depends on the mass resolution

<u>The only known method</u>

Reconstruct individually

ALL the final state particles

Sort of modern bubble chamber

What is PFA - 2

For jets

In our detectors, the charged tracks are better measured than the photon(s) which are themselves better measured than the neutral hadron(s)

Resolution on the charged track(s)	$\Delta p/p$	$\sim$ qq 10^{-5}
Resolution on the photon(s)	$\Delta E/E$	$\sim 12\%$
Resolution on the h°	$\Delta E/E$	$\sim 45\%$

$$E_{jet} = E_{charged\ tracks} + E_{\gamma} + E_{h^0}$$

fraction: charged tracks 65%, γ 26%, h^0 9%

With a perfect detector, no confusion between species and individual reconstruction

$$\sigma^2\ jet = \sigma^2 ch. \oplus \sigma^2\ \gamma \oplus \sigma^2\ h^0$$ gives about $(0.14)^2\ E_{jet}$

Real life and real detector →

- σ^2threshold → Energy threshold to be rec. (depend on species)
- σ^2efficiency → loss of particles (not reconstructed)
- σ^2confusion → Mixing between particles in the calorimeter

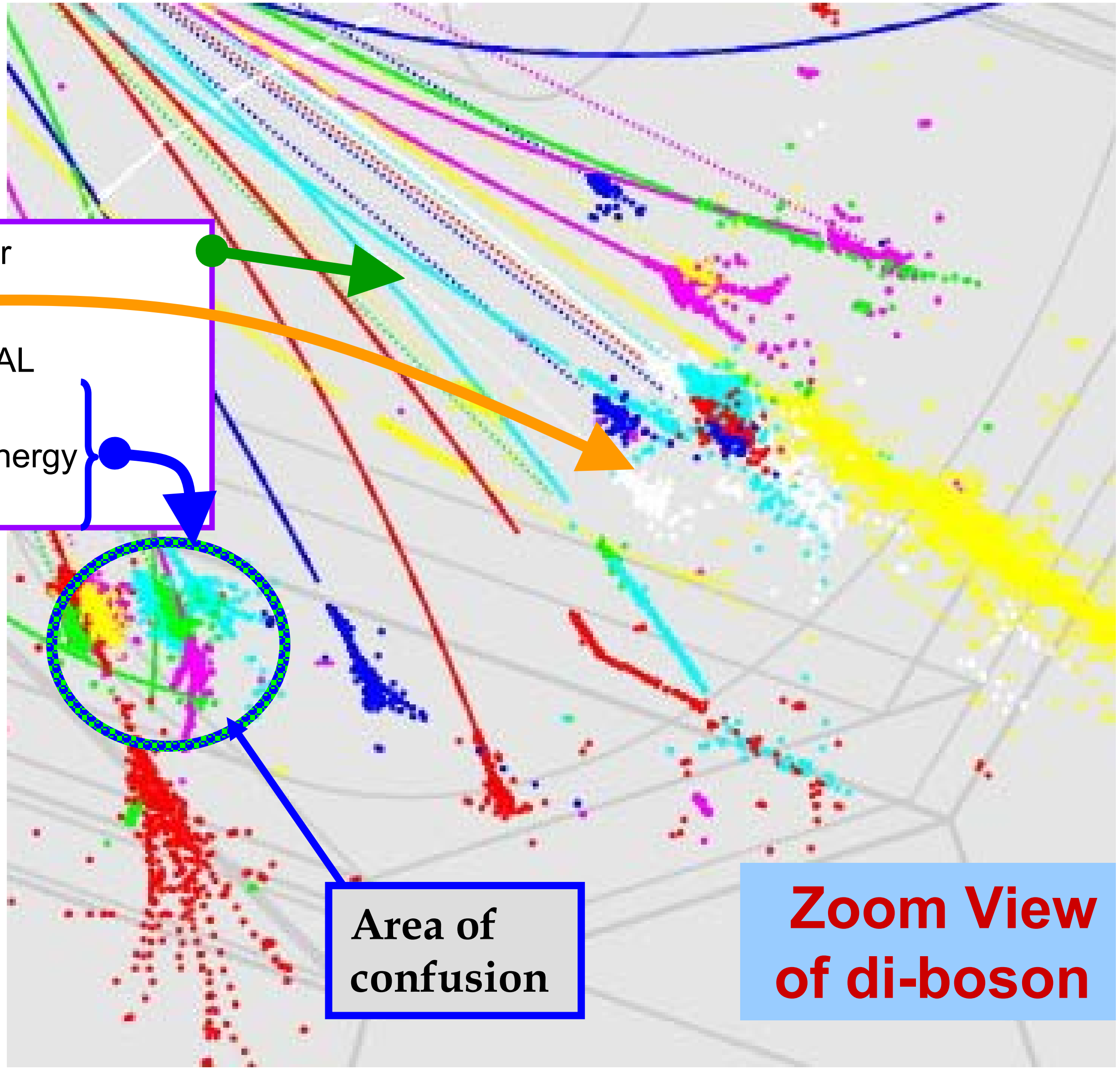
$$\sigma^2 confusion = \sigma^2\ \text{rate of wrong collection} \oplus \sigma^2 \text{clustering collection efficiency}$$

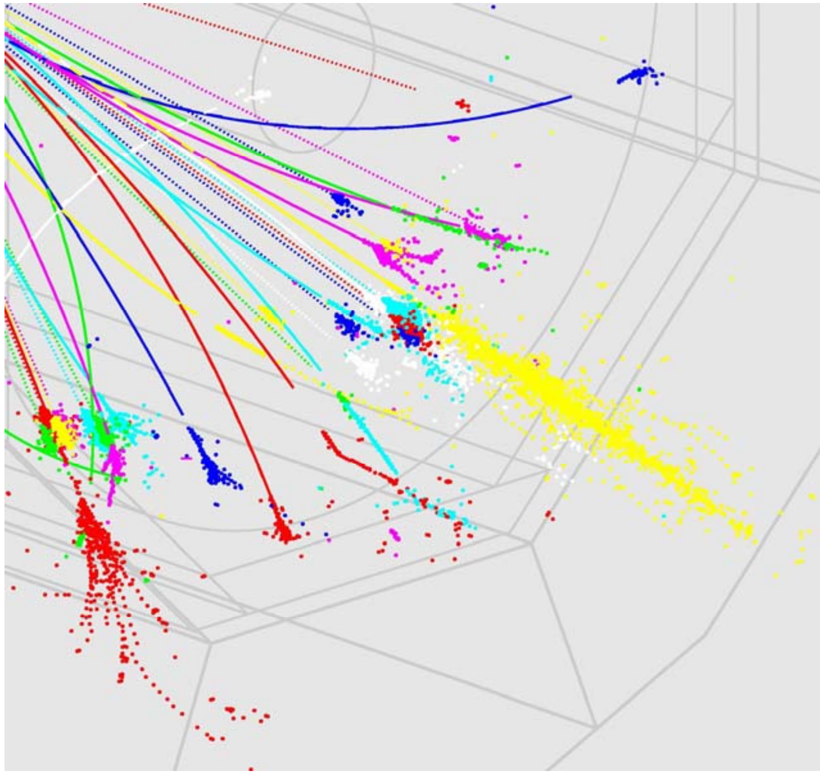
❶ find the charged particles in the tracker

❷ the photon(s) in the ECAL

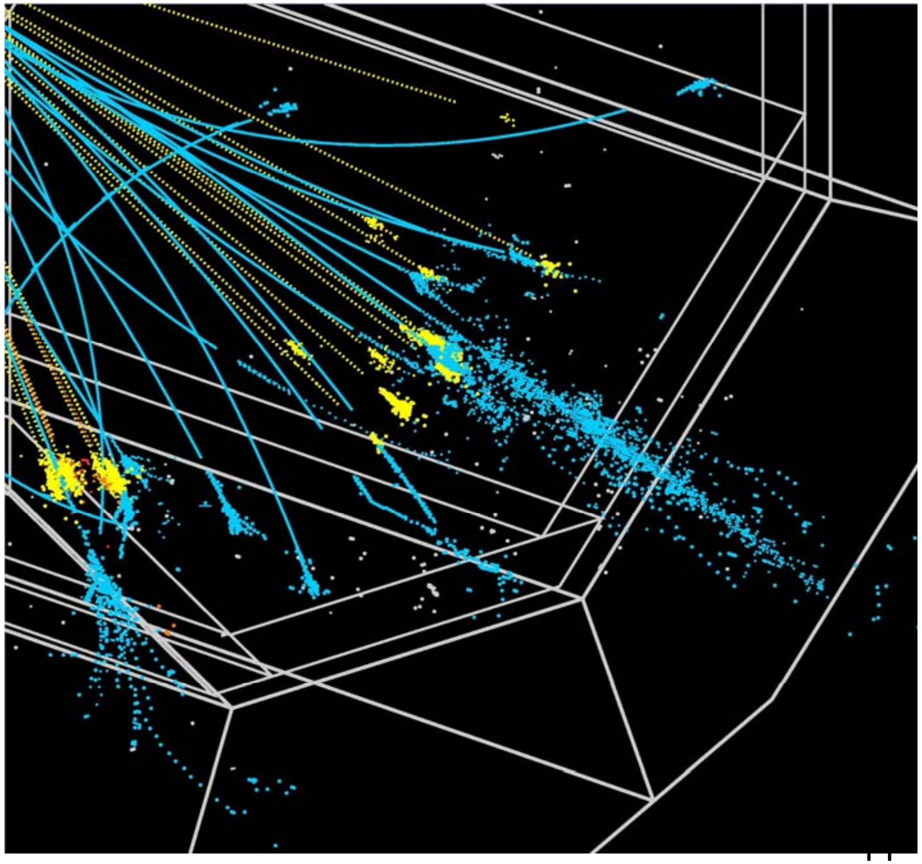
❸ the neutral hadron(s) in the ECAL, HCAL

Process ❷ and ❸ are possible only if there is no mixing between deposited energy from different particles





True for photons and charged tracks at simulation level

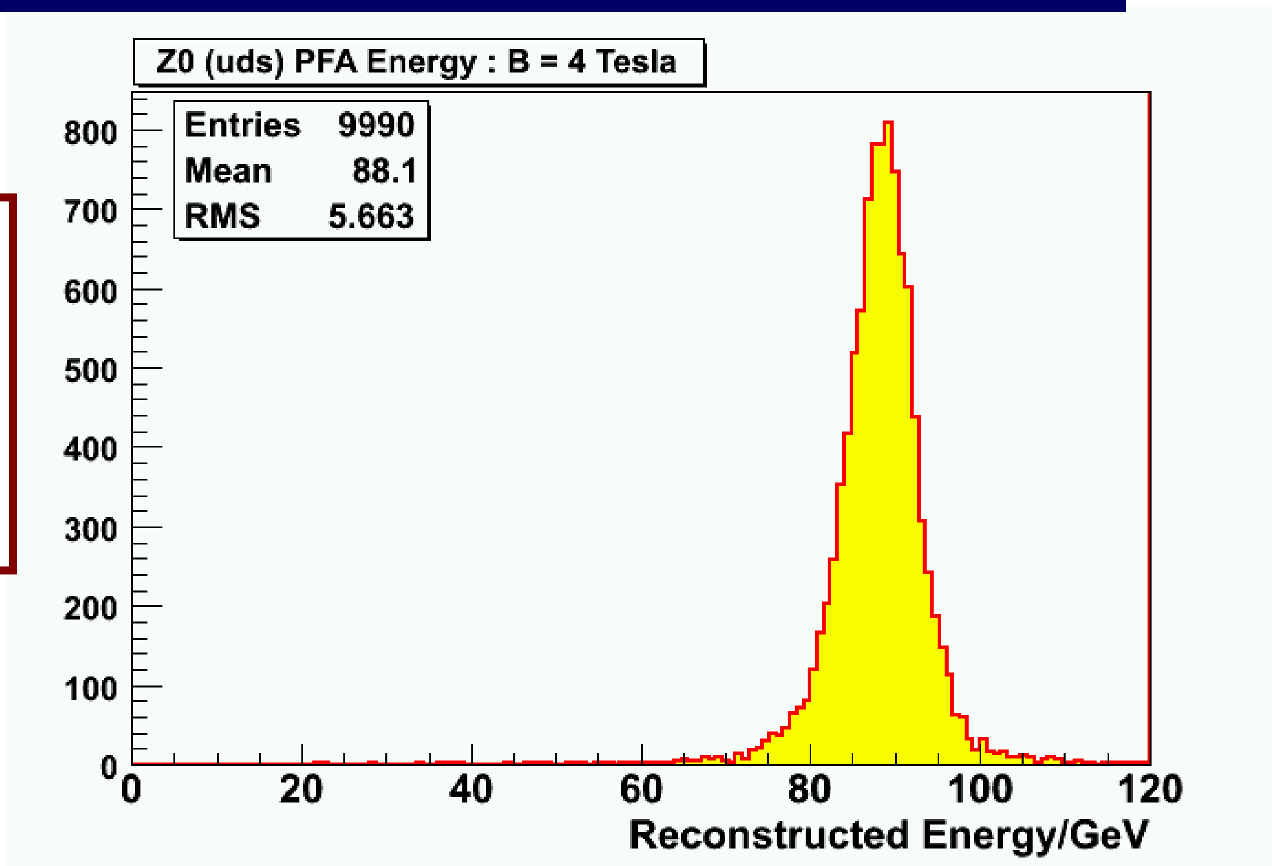


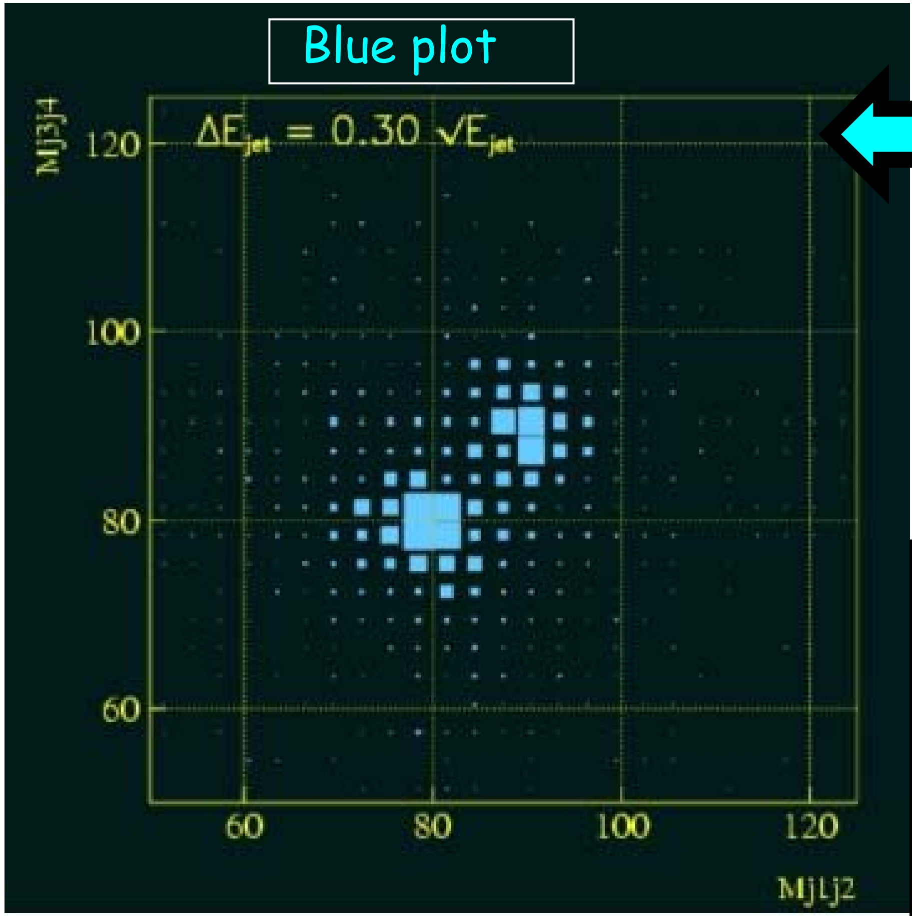
Full simulation and reconstruction on the LDC concept detector

a ~ 30-35%

And

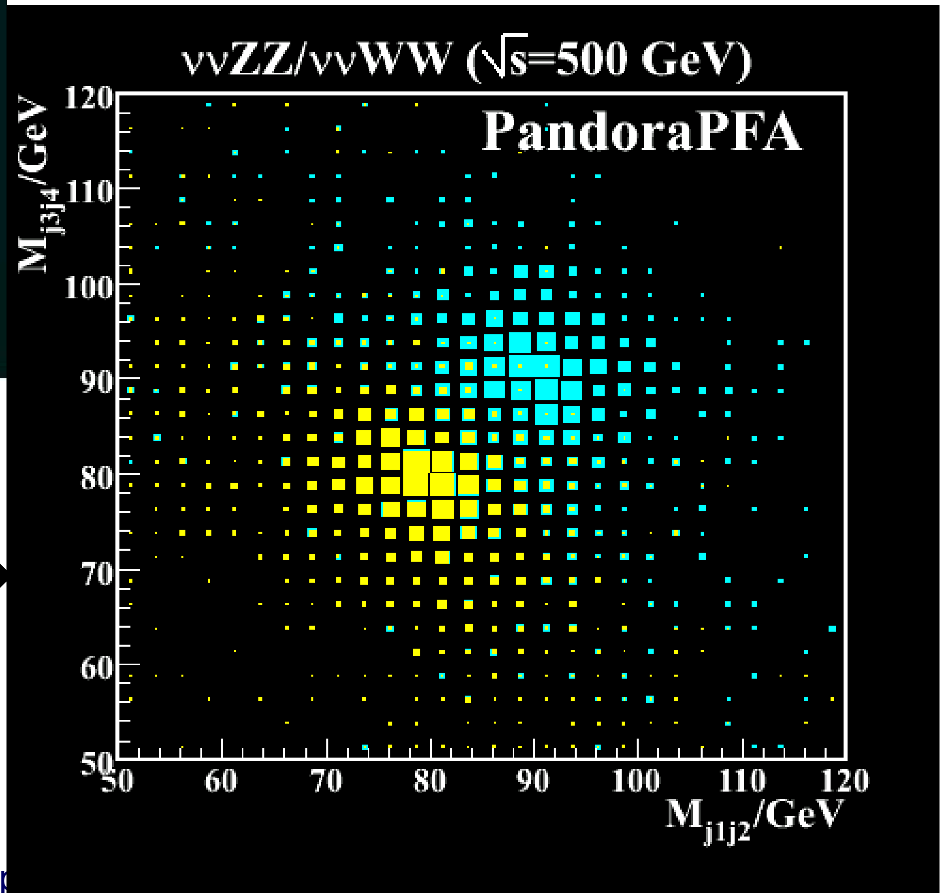
no angular effect





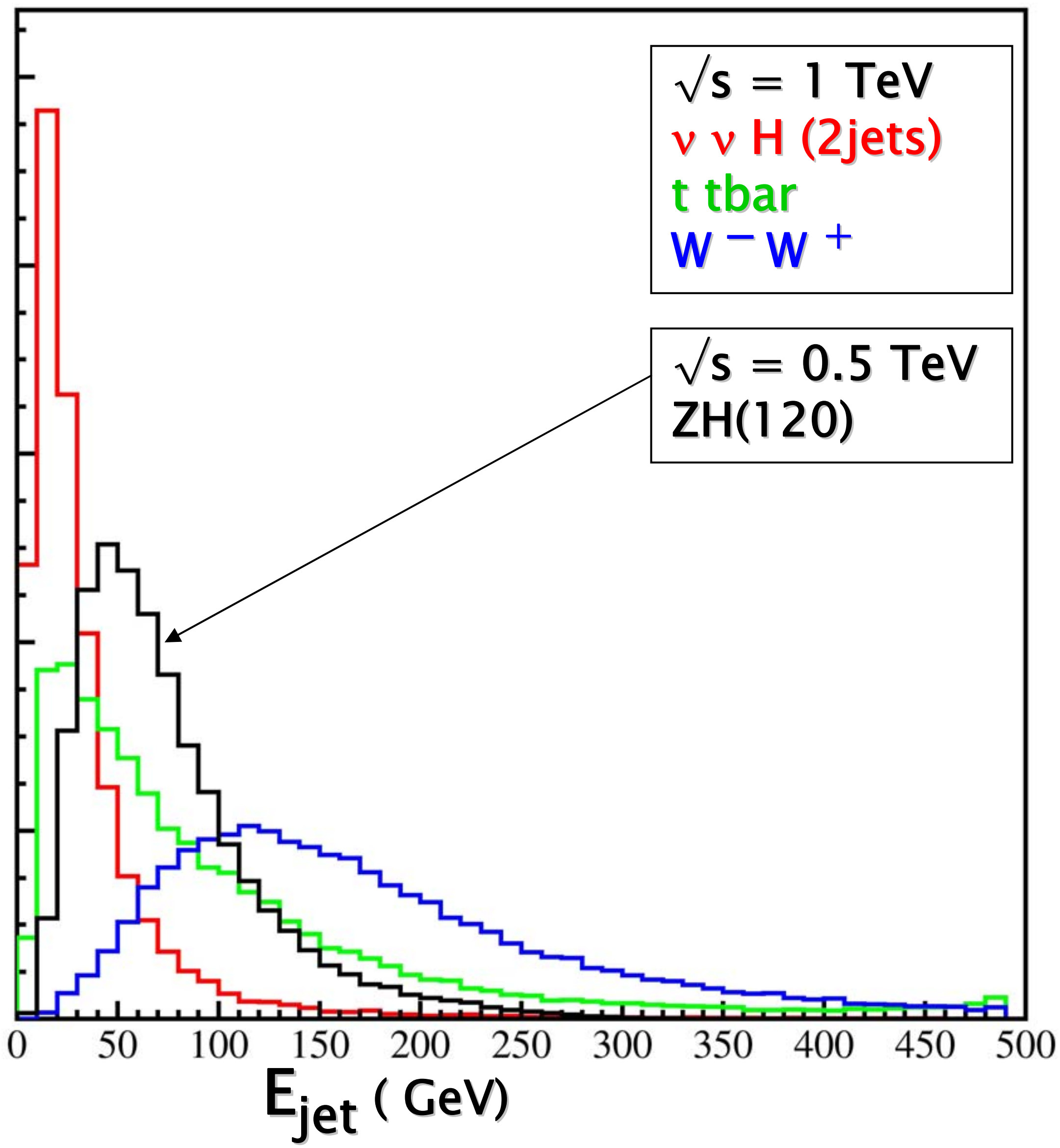
Simulate 4jets and
smear the jets before pairing

Preliminary result from
M.Thomson with full
PFA reconstruction



Range of interest for the jets energy

Distribution of the jets energy
For some physics processes



Comparing with other methods for jet

WARNING

The stochastic term is not the only parameter

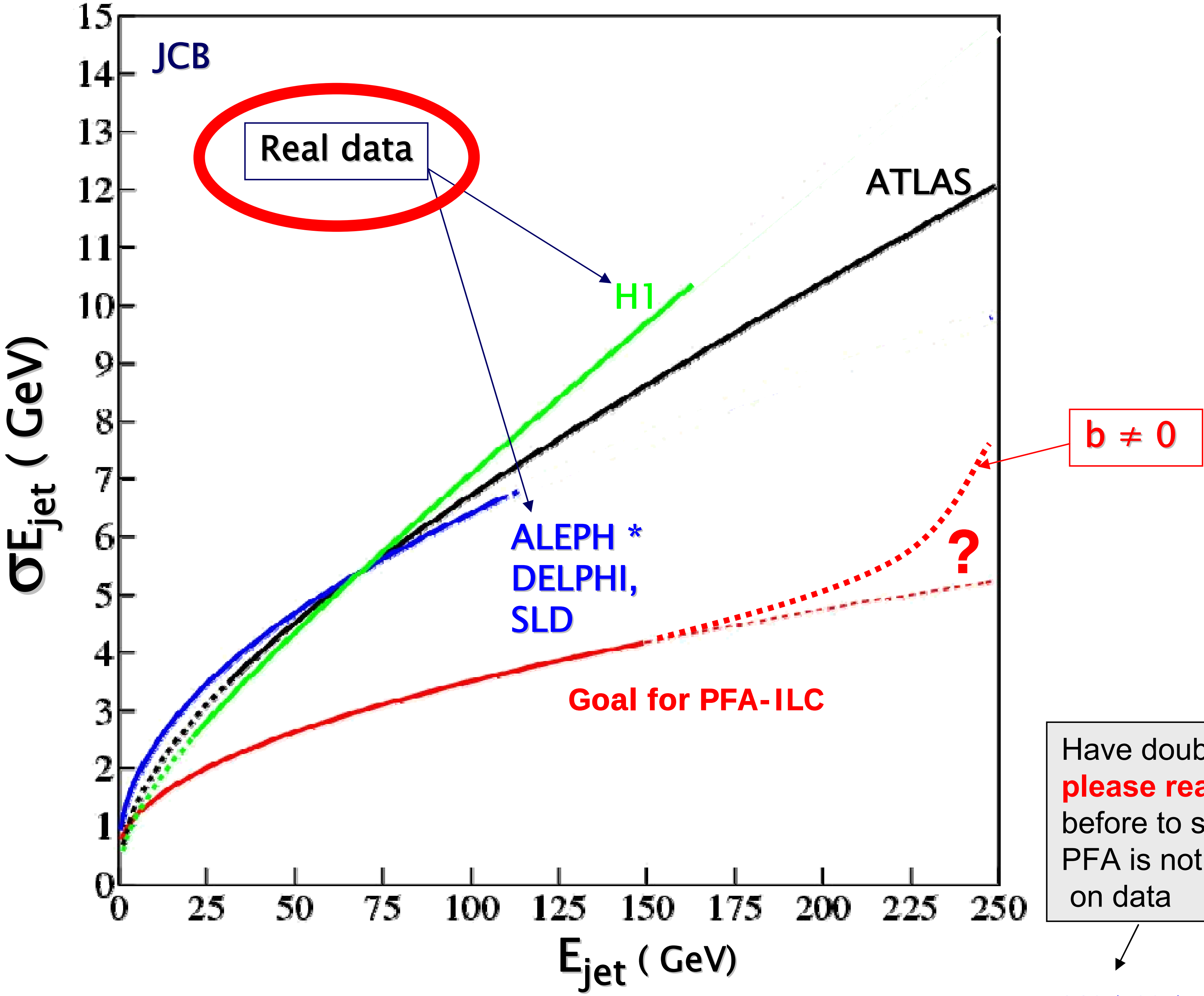
A more complete law

$\Delta E_J = a \times \sqrt{E_J} \oplus b \times E_J + c$

	a	b	c (GeV)
ALEPH method QPFLOW	0.59	0	0.6
ATLAS at best !!	0.6	0.03	0
H1	0.5	0.05	0
PFLOW–ILC	0.3	0	0.5

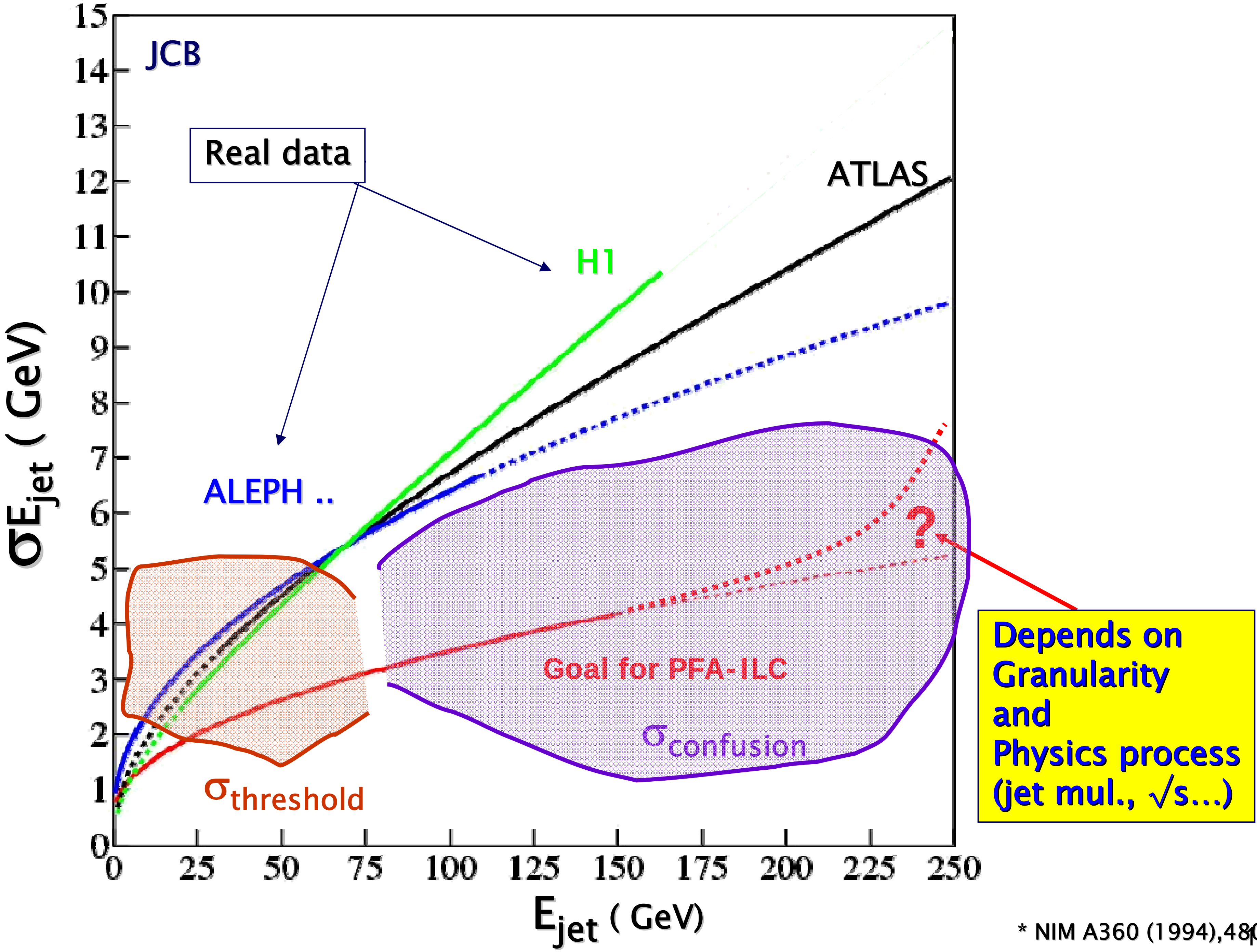
NIM A360 (1994),480

AND the Angular Dependence !!



Have doubts !
please read it
before to say
PFA is not proven
on data

* NIM A360 (1994),480



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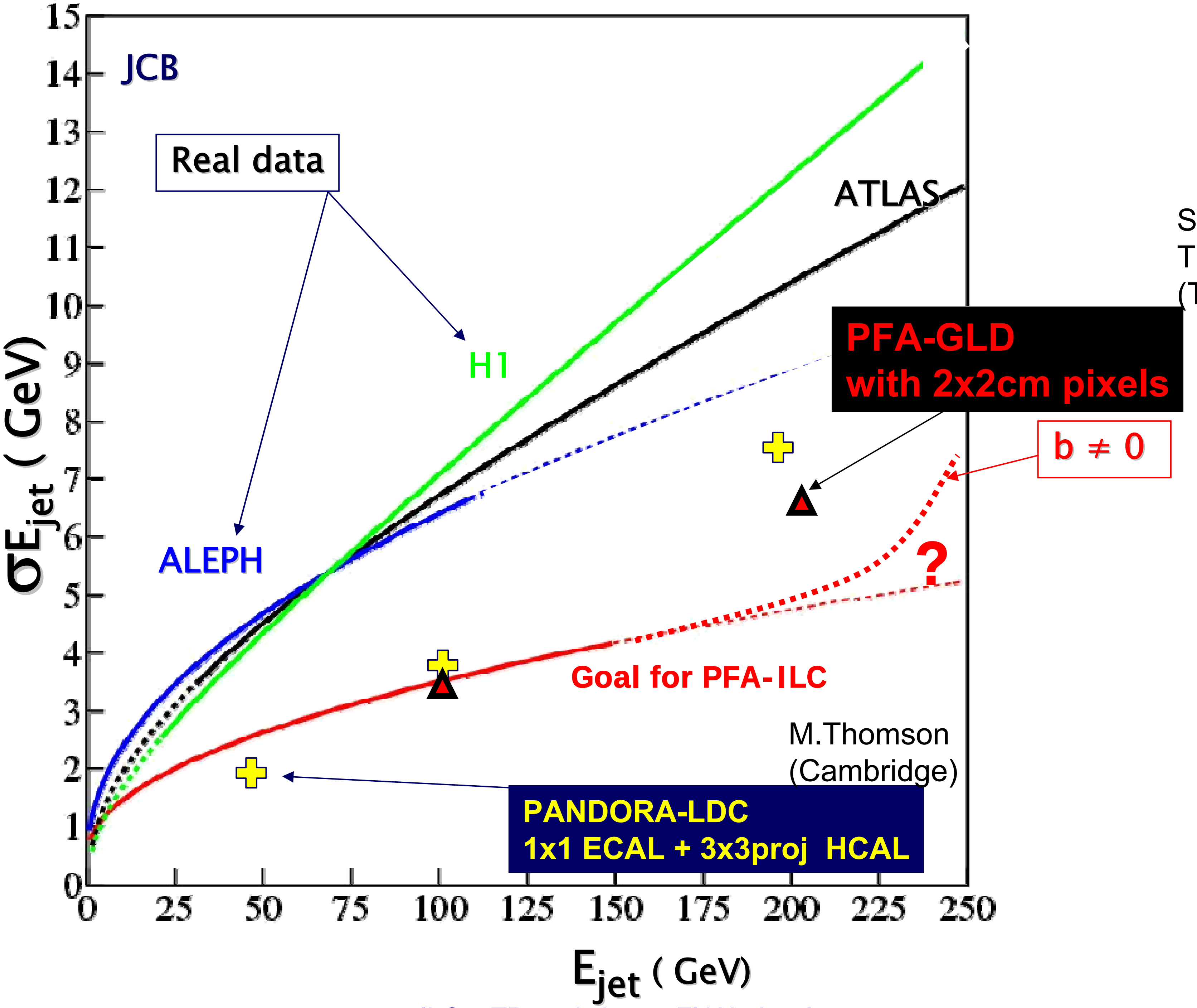
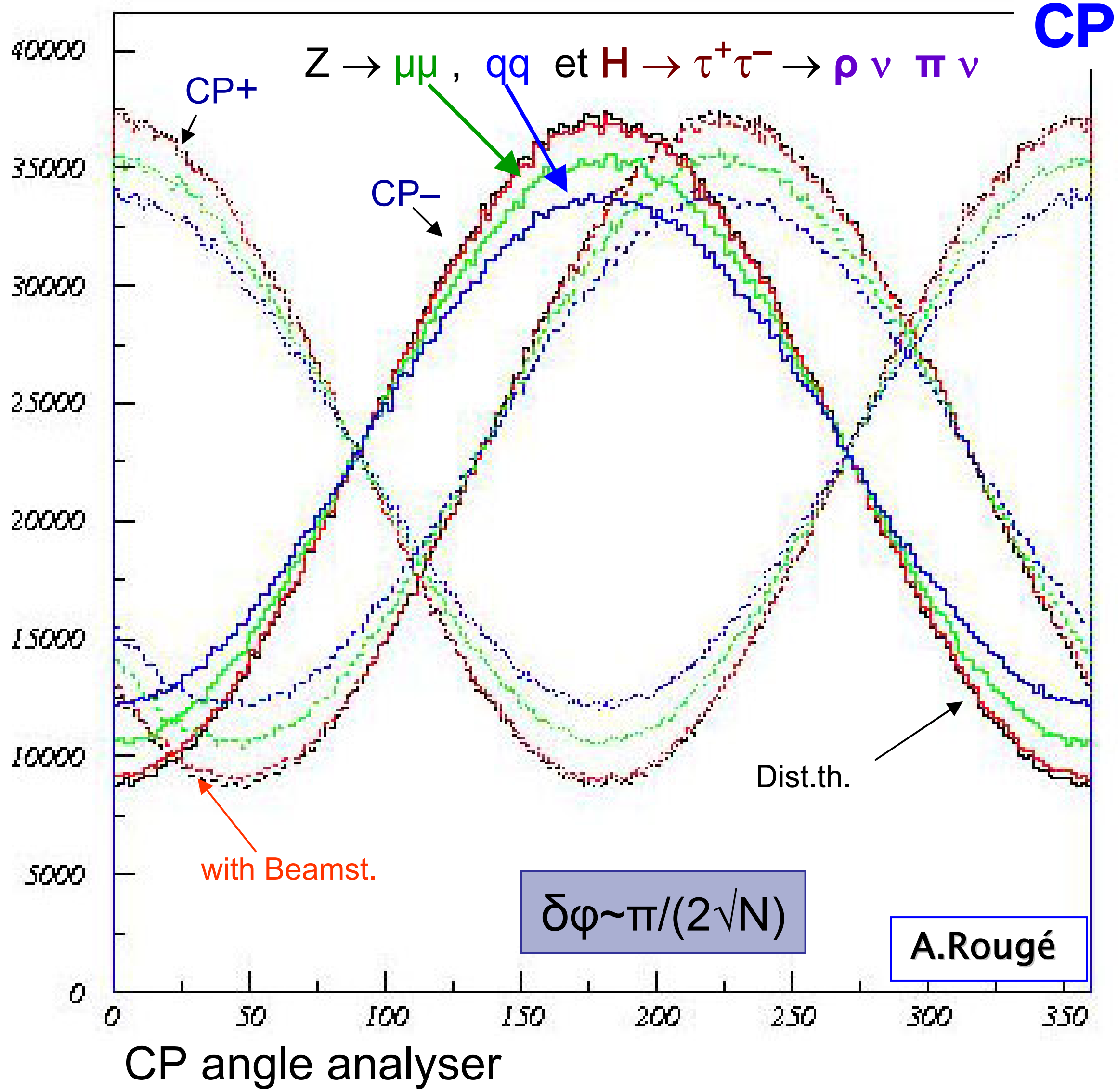


Study from
T.Yioshiaki
(Tokyo)

Where PFA could also play a role

CP violation, Higgs sector



$e^+ e^- \to ZH$

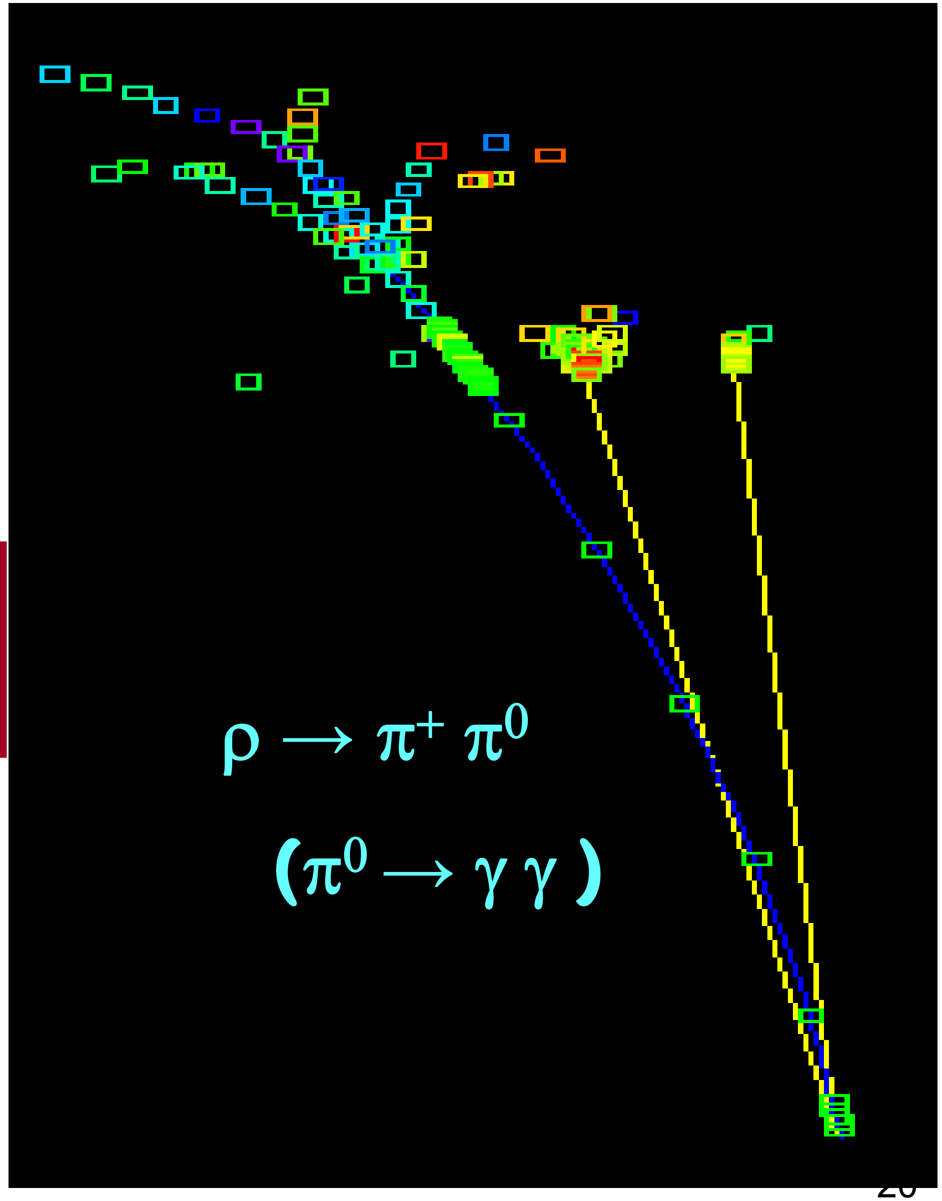
What PFA could do outside "jets"

For this analysis, it is mandatory to have

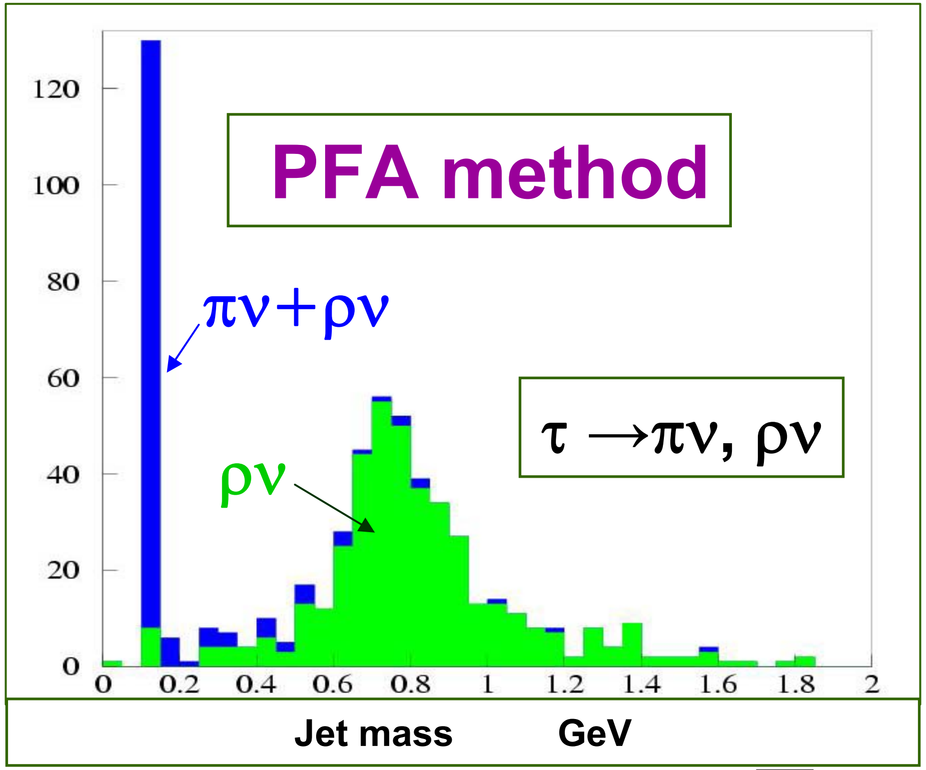
an ECAL and PFA which disentangle π, ρ, a_1 in the τ decays

PFA : It is not only the energy resolution

But also the number of objects !!



This PFA method allows to analyse the Taus decays
Leading to an excellent polarization analyzer



	Jet mass < 0.2 GeV	Jet mass in 0.2- 2 GeV
$\tau \to \pi\nu$	82%	17%
$\tau \to \rho\nu$	2%	90%

CP violation studies in the Higgs sector, means
Largely segmented ECAL !!!

What is PFA - 3

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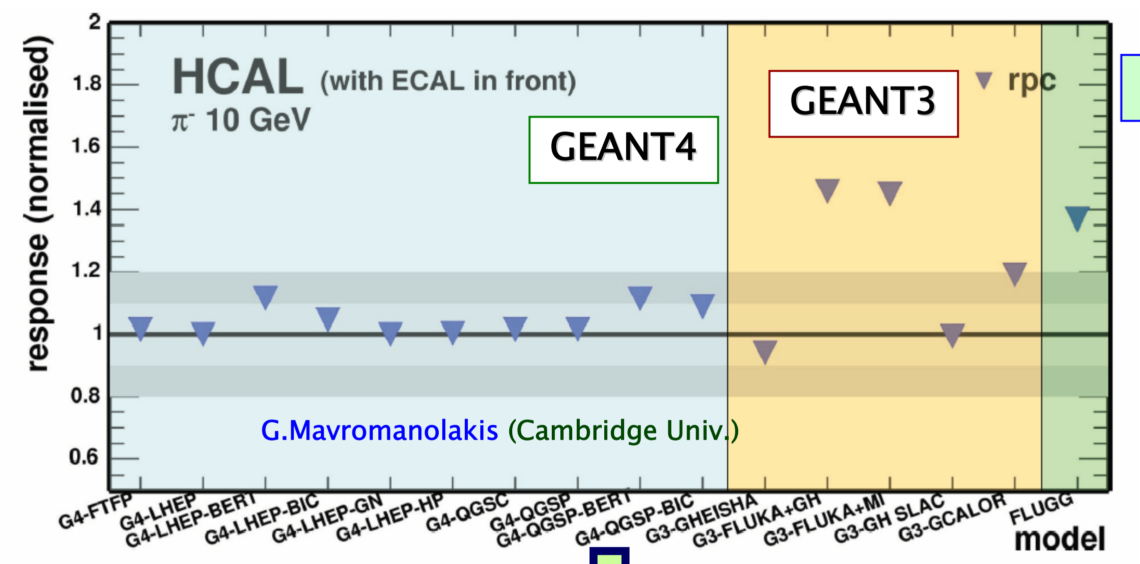
> There is no PFA test on jet with any kind of target in front of prototype…
(Pb of simulation of the interaction on target, core/peripheral , e/h different, etc …)

What could be tested in TB - 1

PFA and Hadronic shower

> **Tuning of GEANT4** simul. (MOKKA) for single particule
> Particle in the beam vs Simul (pi ,K , p, n, K_L,…)

Prediction of the hadronic shower simulator



FLUKKA

prototypes in test beam
are mandatory to constraint the hadronic shower simulation in GEANT4

Is there a perfect simulation model among them ??!! probably not

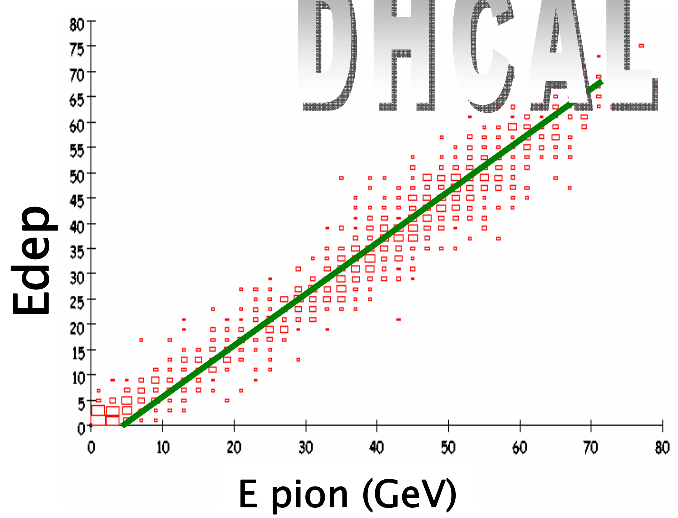
Is there a miracle variable able to tell you what the best simulation model ? probably not

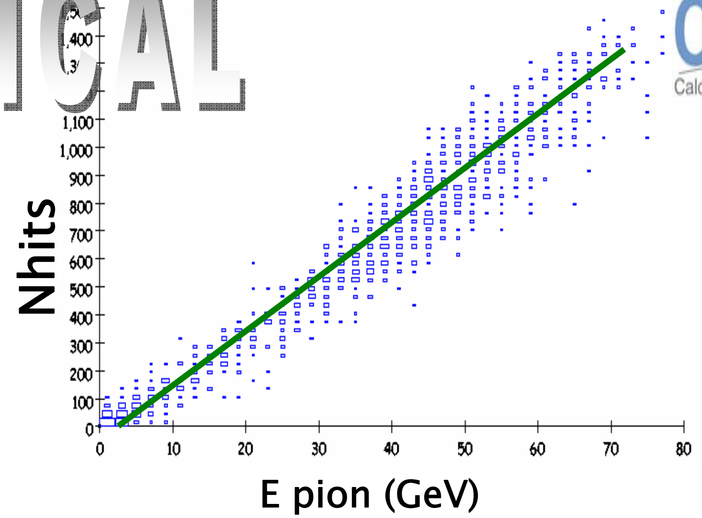
1 Constraint the hadronic shower model relevant for our detector through test beam with <u>prototype as close as possible</u> to the one of the final project *(the choice of the best model was usually correlated to the device … other detector, other choice)*

2 With detector prototype very close to the final one, one can test the PFA directly on test beam data

Our program/project is the design of ILC detector, we will try to use the best from GEANT4, but real test beam data with the relevant detector is for sure the ideal way to Use the best model for the design study

DHCAL vs AHCAL

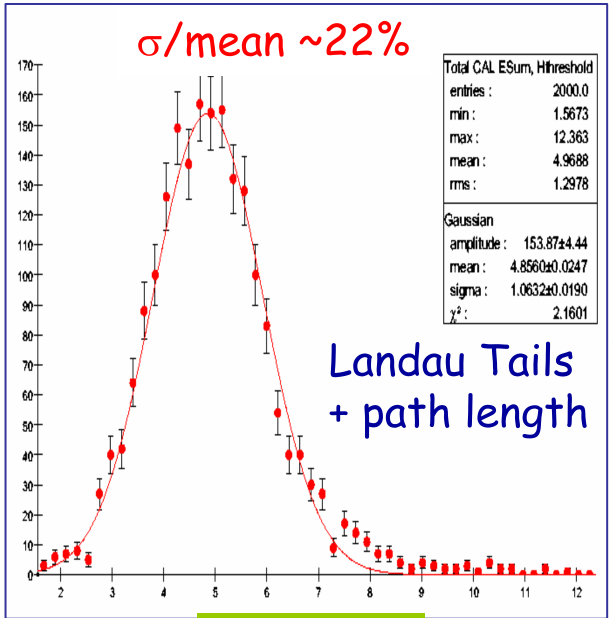




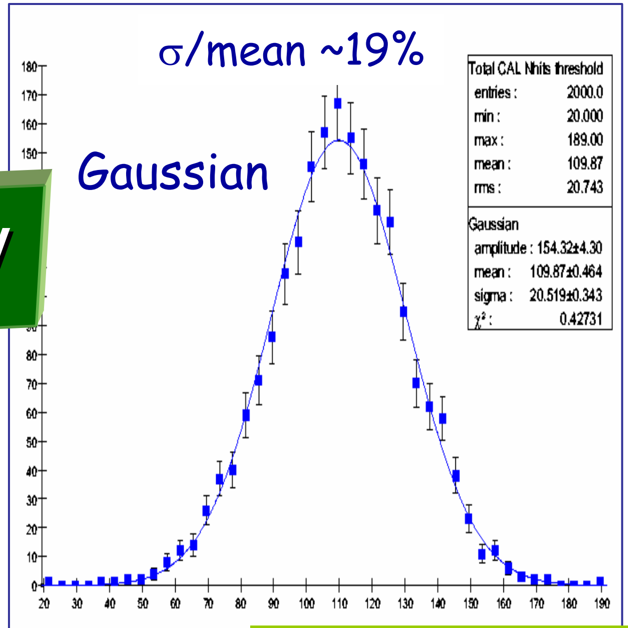
Analog

Digital

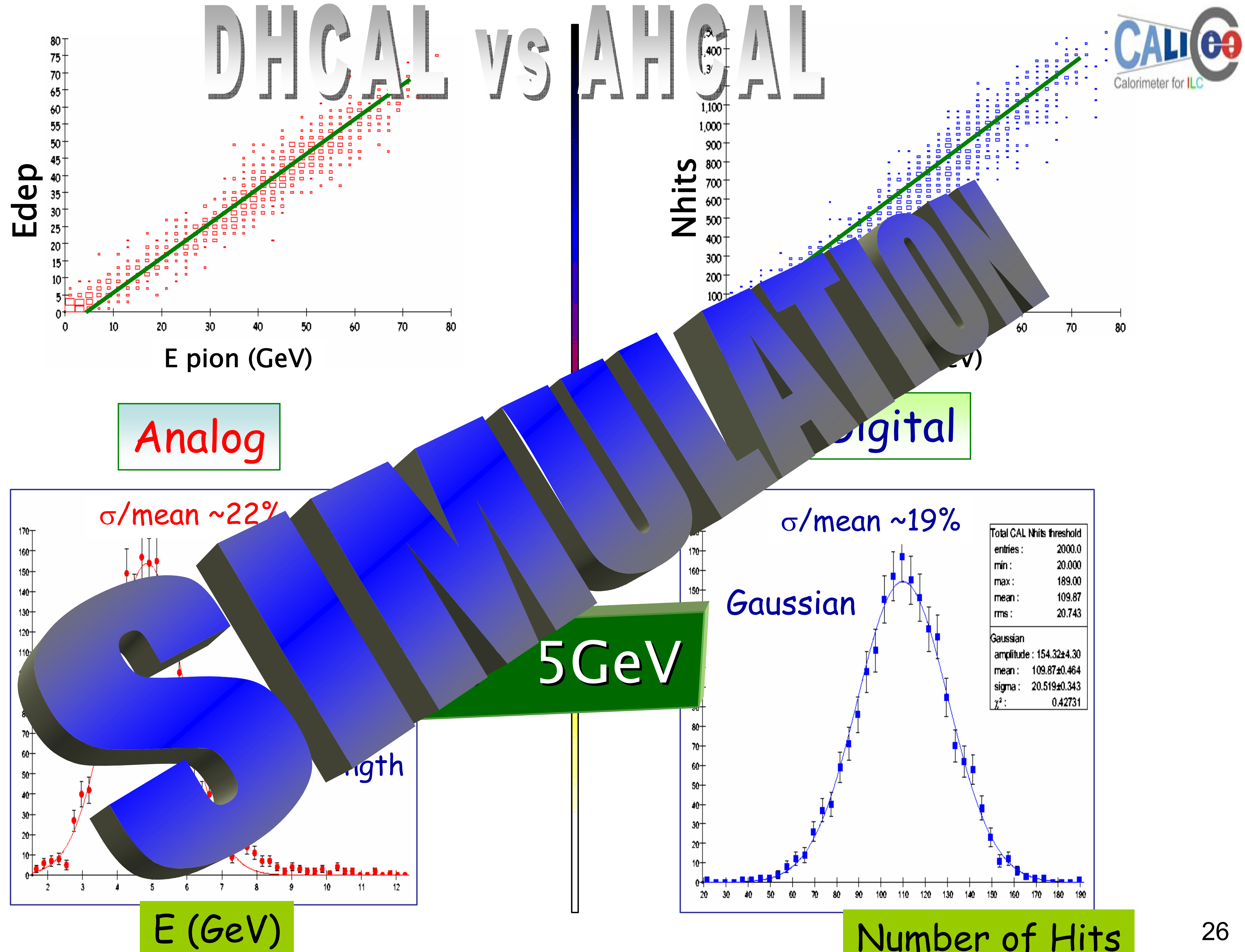
π^+ 5GeV



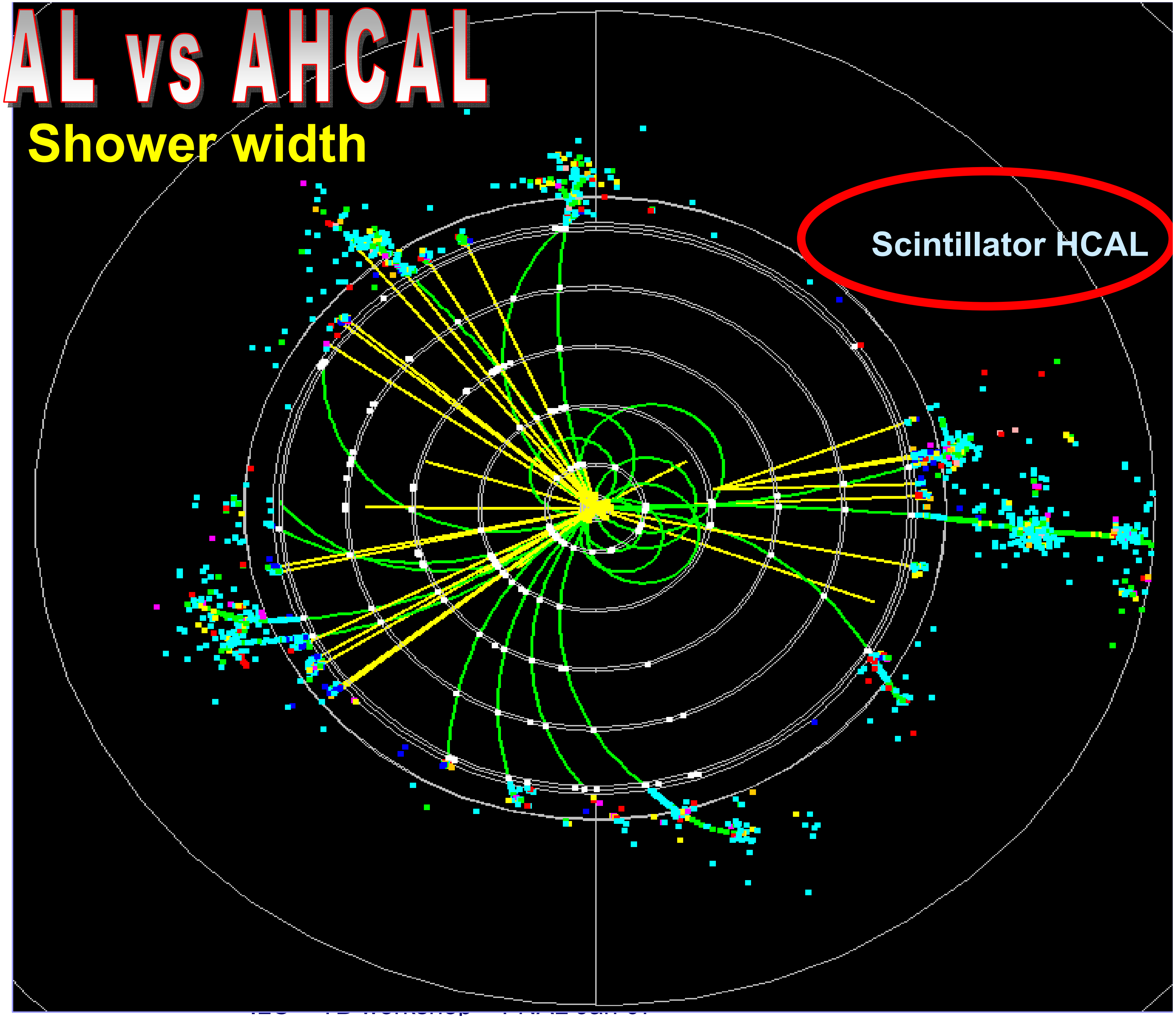
E (GeV)



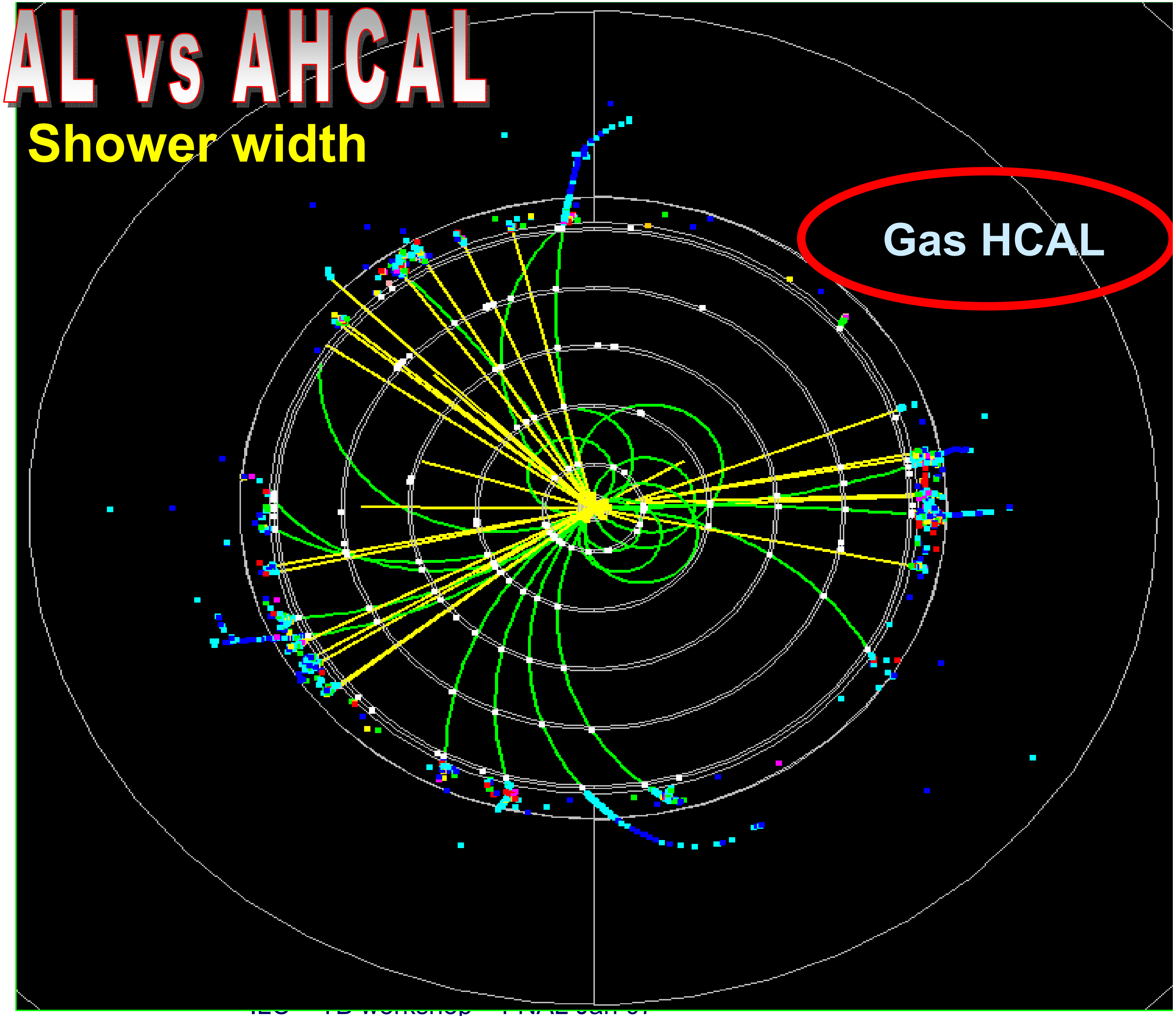
Number of Hits


DHCAL vs AHCAL
CALICE
Calorimeter for ILC
Edep
E pion (GeV)
Nhits
Analog
Digital
σ/mean ~22%
σ/mean ~19%
Gaussian
5GeV
E (GeV)
Number of Hits
Total CAL Nhits threshold
entries : 2000.0
min : 20.000
max : 189.00
mean : 109.87
rms : 20.743
Gaussian
amplitude : 154.32±4.30
mean : 109.87±0.464
sigma : 20.519±0.343
χ² : 0.42731
SIMULATION

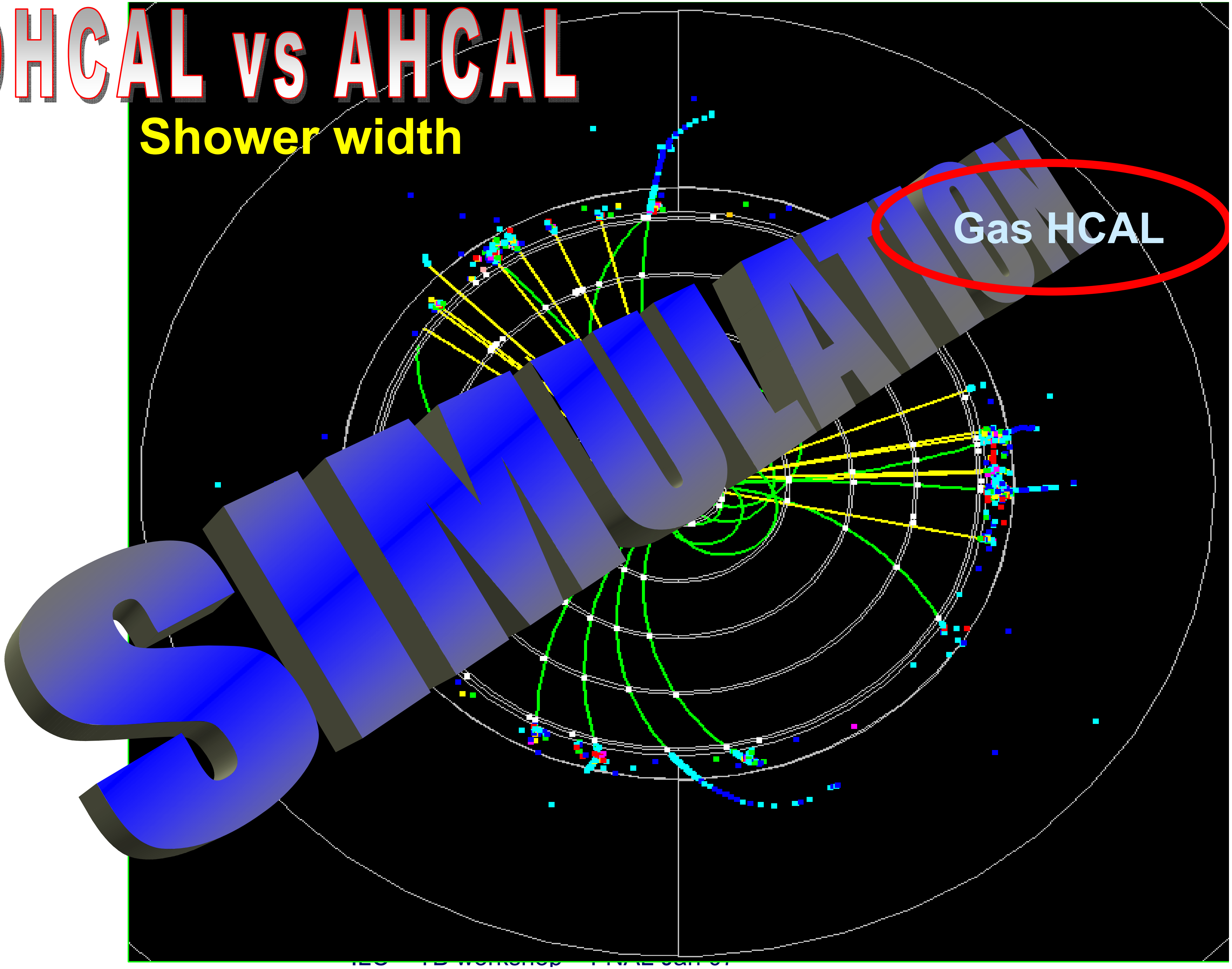
DHCAL vs AHCAL



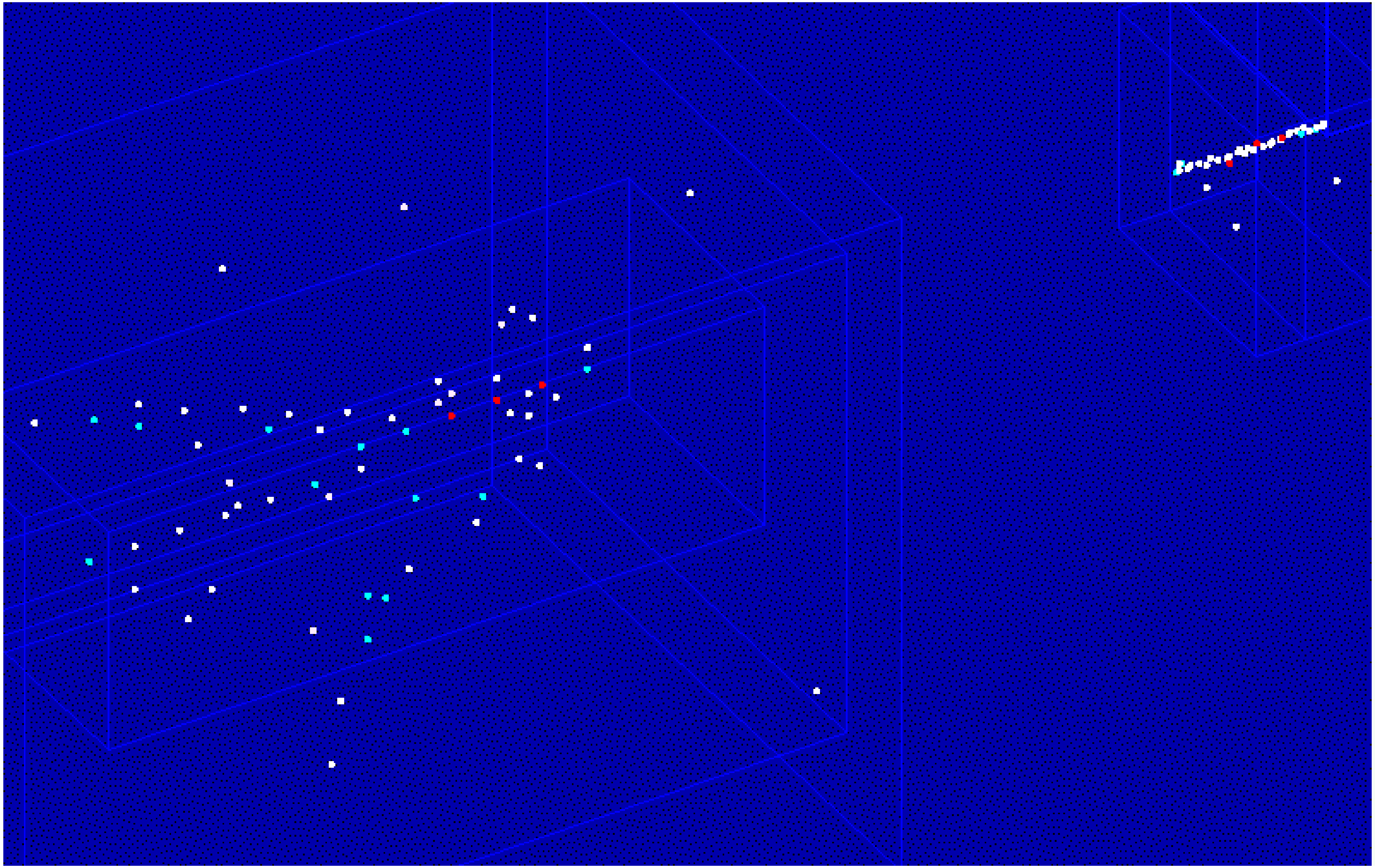
DHCAL vs AHCAL



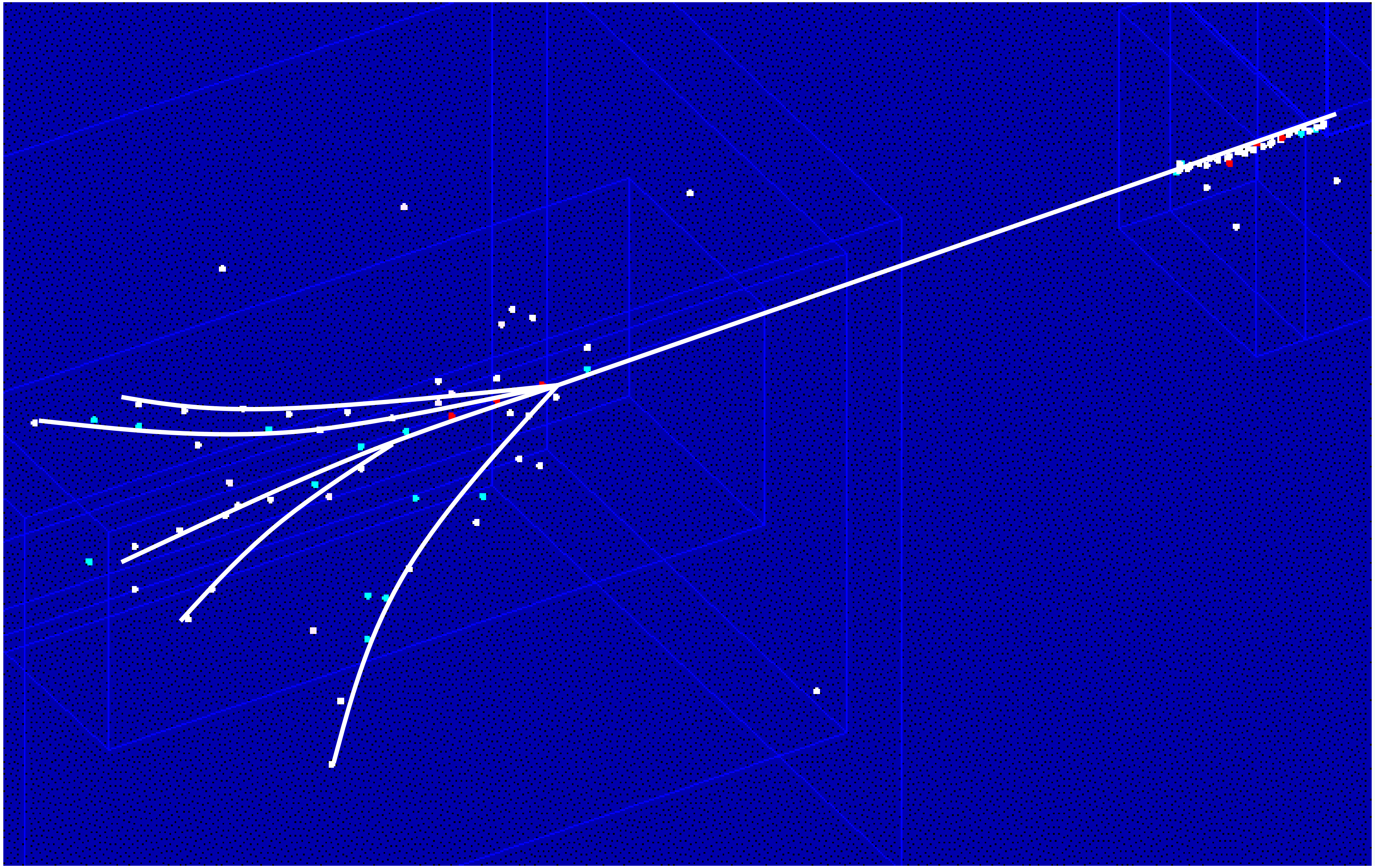
DHCAL vs AHCAL



PFA on hadronic shower in TEST BEAM

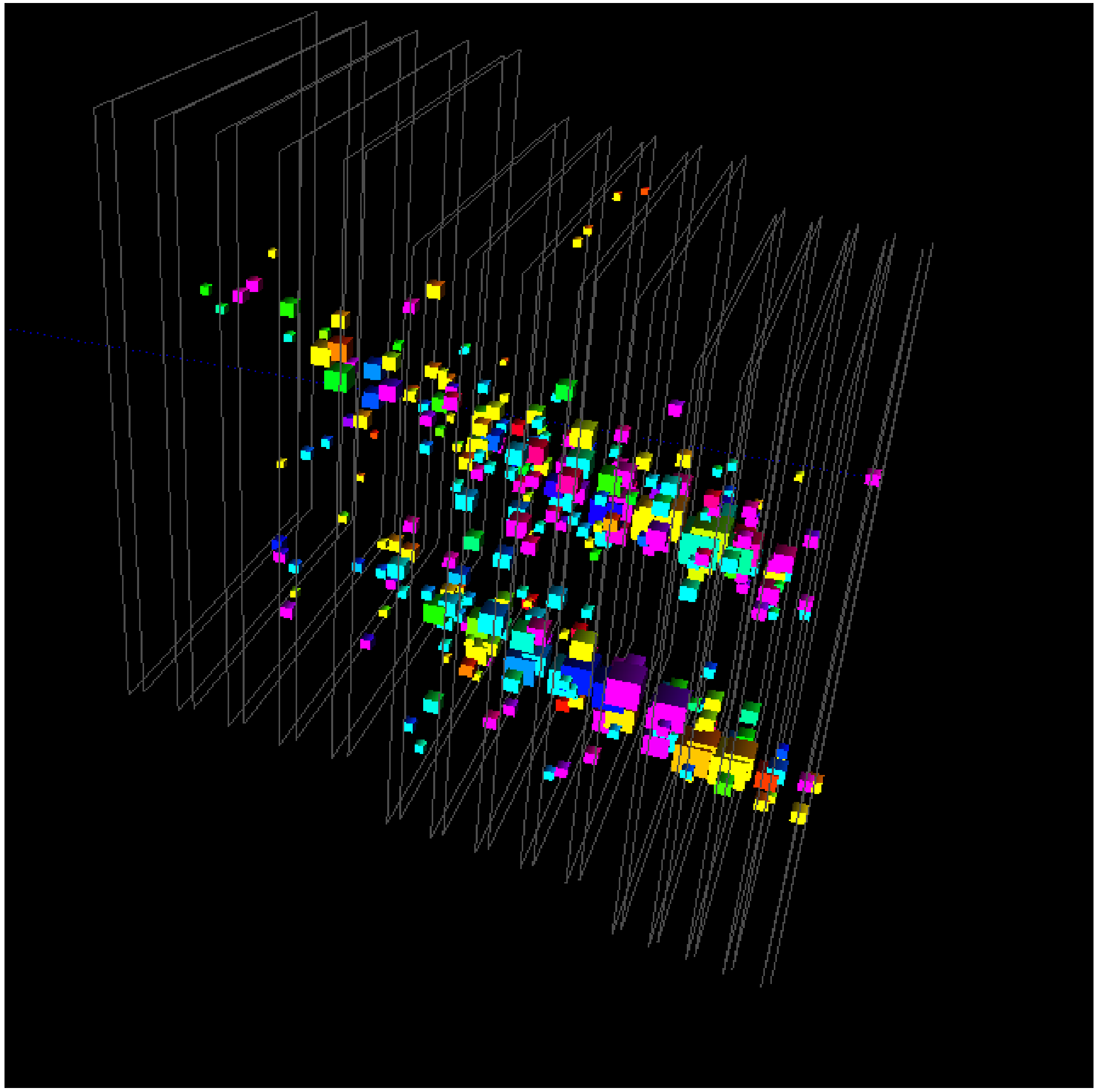


PFA on hadronic shower in TEST BEAM



Separability of close em shower !!

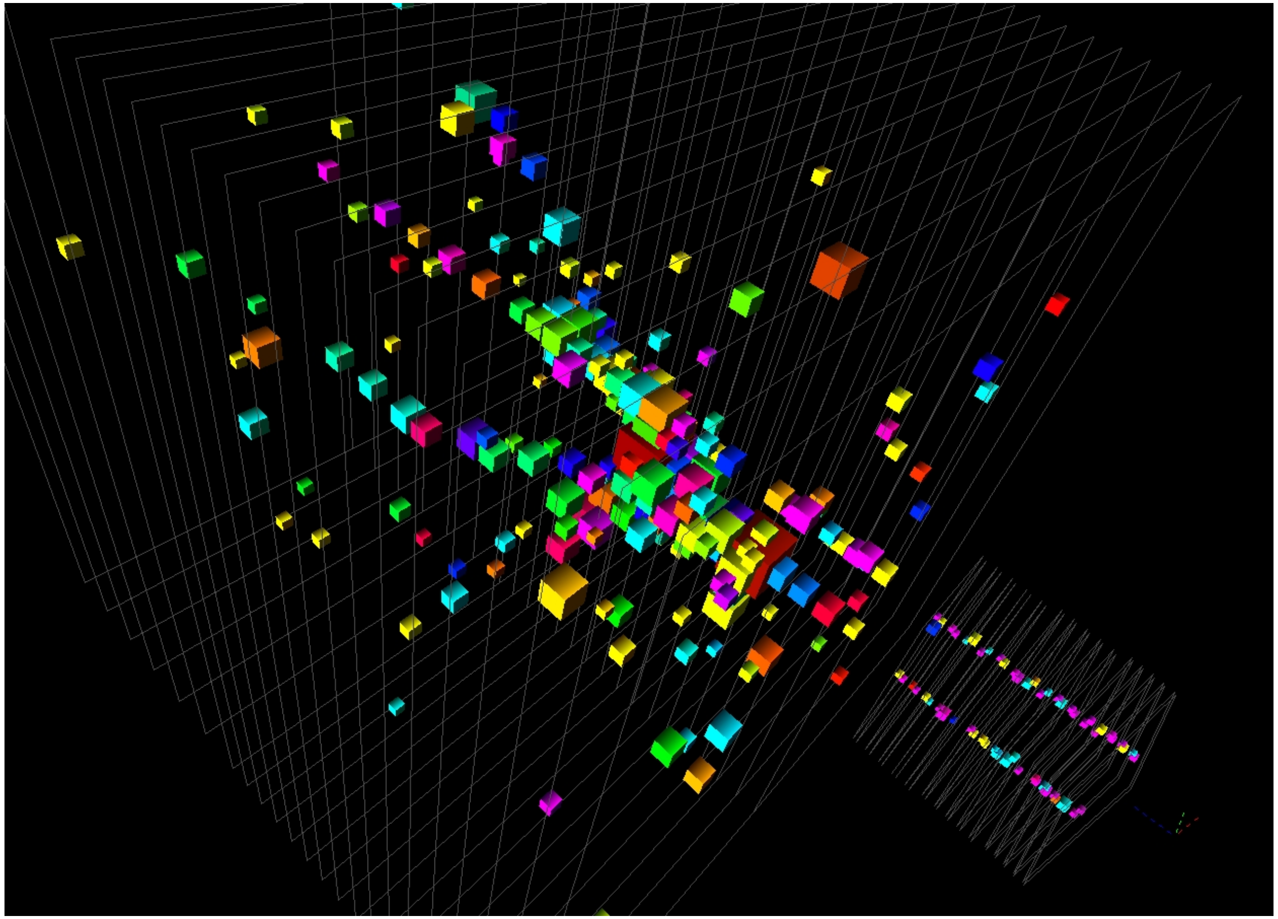
Example with CALICE detector CERN 2006



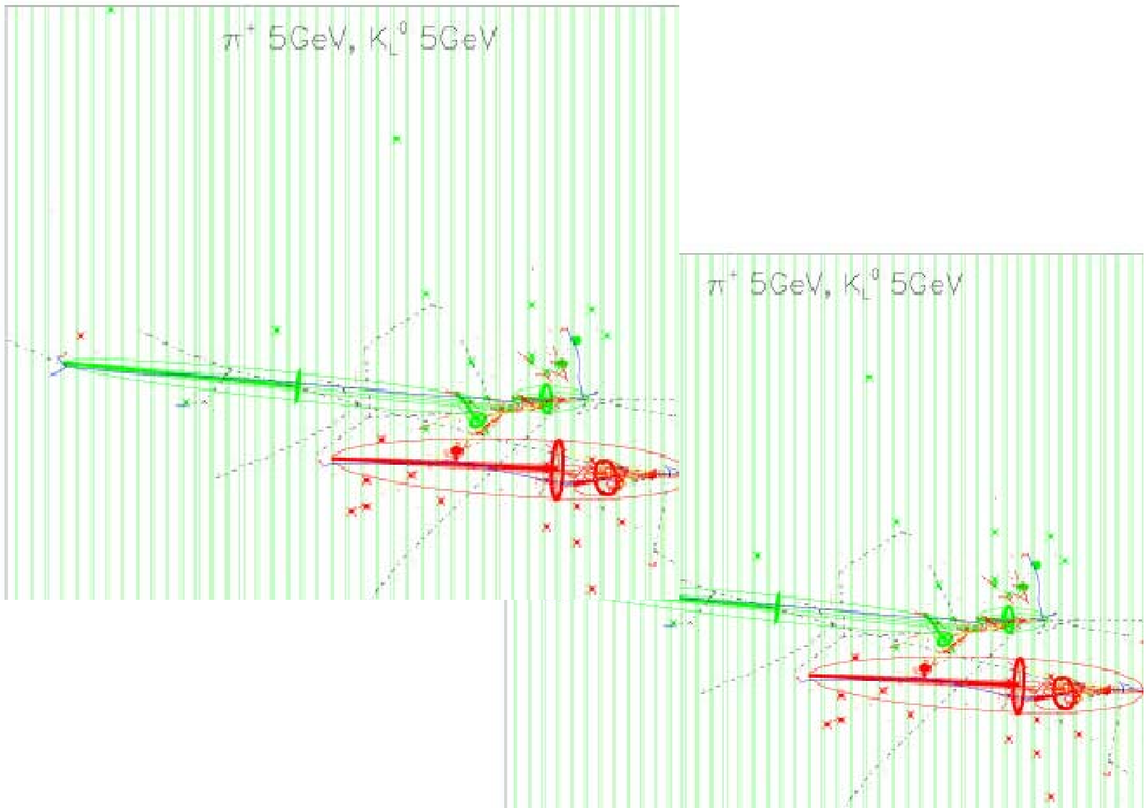
Much more difficult

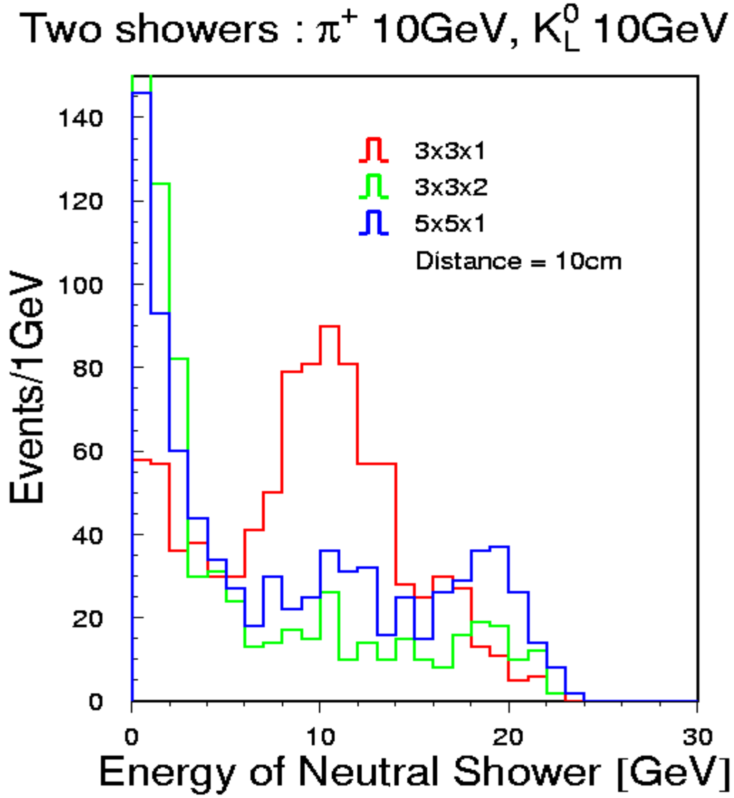
Separability of close hadronic shower !!

Example with CALICE detector CERN 2006



To quantify it, we can use the technique of events overlay from test beam data
Then data vs MC could measure the “realism “ of the PFA





Example of simulation study by A.Raspereza

What could be tested in TB - 2

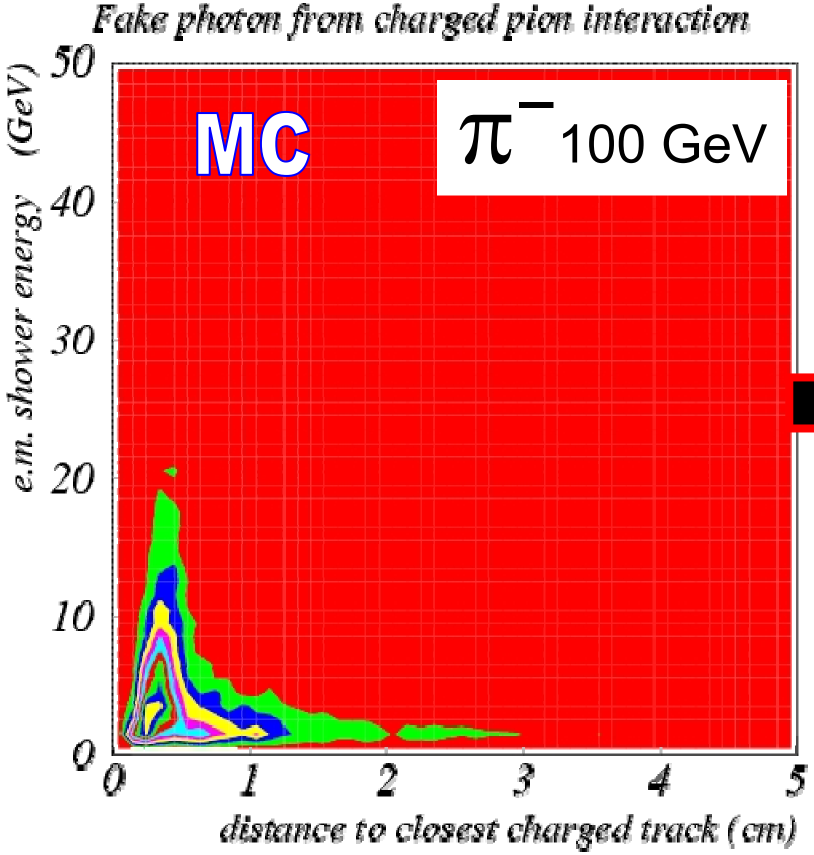
PFA and Clustering

σ^2confusion $= \sigma^2$ rate of fake collection $\oplus$ σ^2clustering collection efficiency

fragments of charged interaction in the neutral list

The rate of fake particle as a function of charged particle energy, distance and type
Test MC versus real data **!!**

Example with Photons reconstruction



Same distribution with test beam will gives the picture for real data

What could be tested in TB - 2

PFA and Clustering

$$\sigma^2_{confusion} = \sigma^2_{wrong\ collection\ rate} \oplus \sigma^2_{clustering\ collection\ efficiency}$$

- From shower lateral/longit. Development
- From clustering algorithm and shower ID.

Clustering on real shower

It plays a direct role on **the energy resolution**

Typical example, neutron energy in scintillator calor.

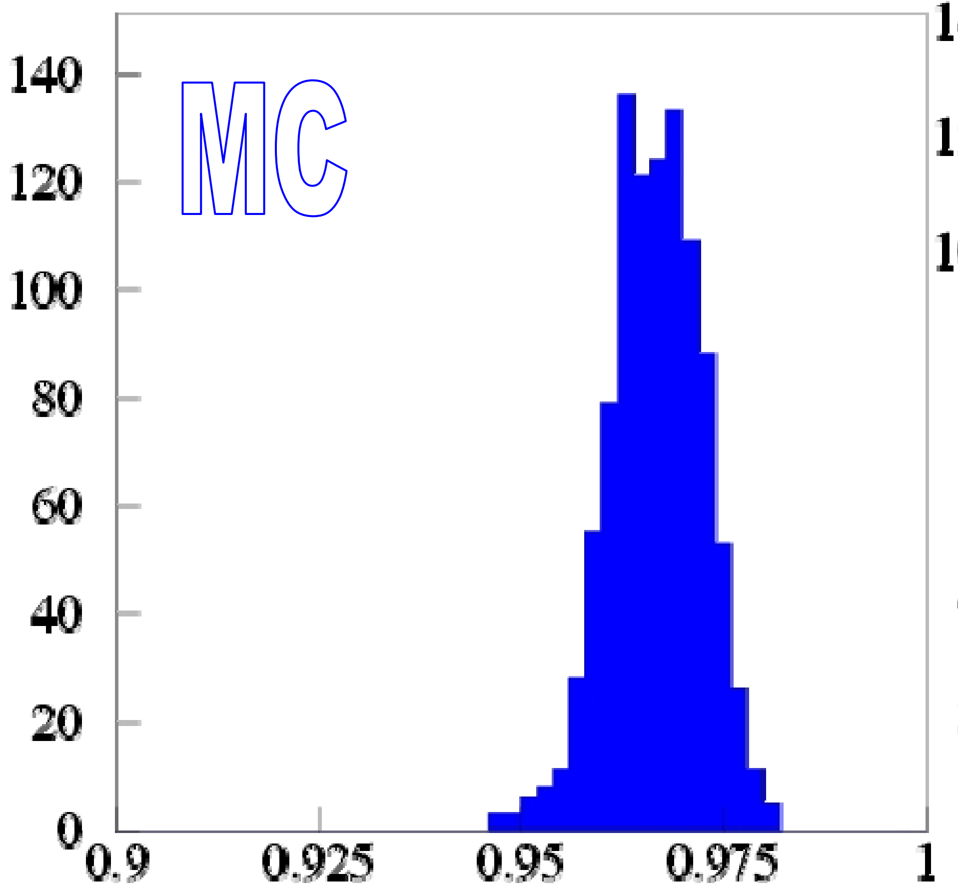
Very difficult to collect in shower -> possible impact on resolution

-> Need to use the same clustering in real shower and PFA studies

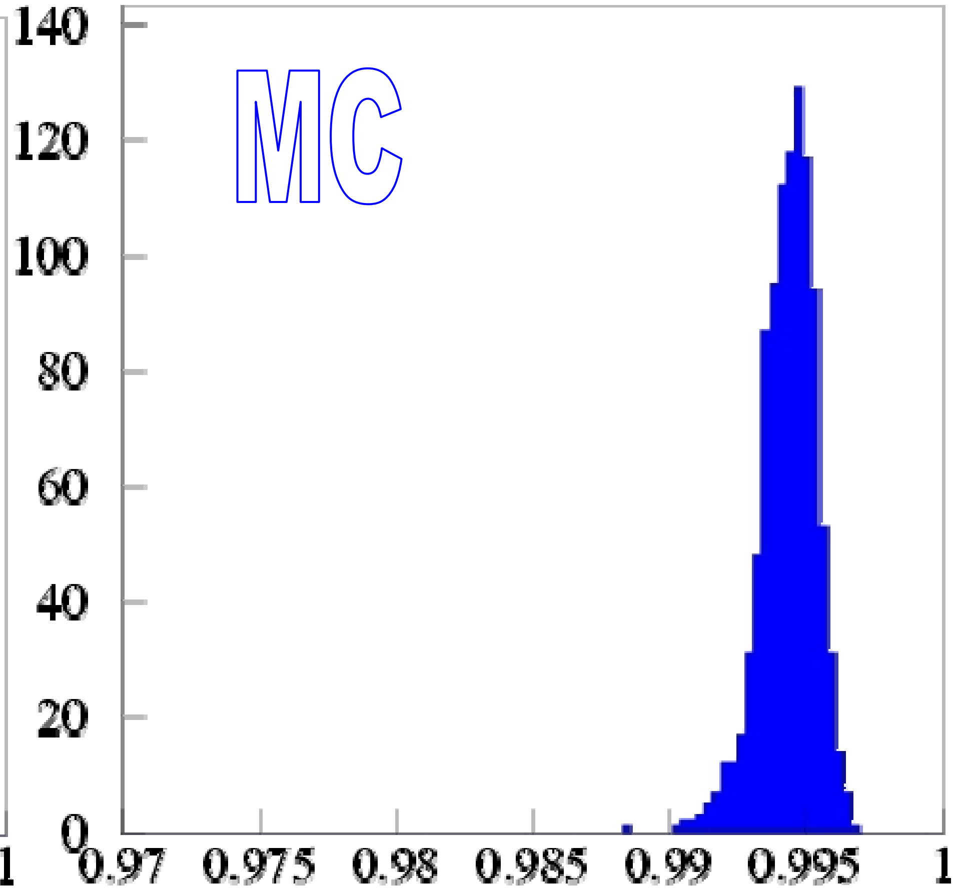
But also effectb from

- Noisy cells
- Readout imperfections
- separability test on double particle in beam

One example of clustering at 500 GeV



Fraction of collected pads



Fraction of collected energy

Quid for real data ??

A non-exhaustive list of PFA tests with test beam data

♦ Is it true that large segmentation give us smaller constant term than LHC calorimeter ?

♦ Is it true that pixels counting for ECAL give us a good stochastic term at low energy ?

♦ Is it true that we can separate em shower at very small distance (mandatory for tau decays identification) ?

♦ At which distance we reconstruct em shower to an hadronic shower Data vs MC ?

♦ What is the effect of neutrons component of the hadronic shower for PFA ? (link between core of the shower and neutrons components)

♦ for each device and particle species , what is the energy resolution AFTER clustering !!!

♦ Verification on data of the software compensation shower/shower observed with GEANT4

♦ Effect of K/pi/p/n unknown id. on energy resolution with particle energy

Conclusion

- The calorimeter test beam has begun at DESY,CERN in 2006

- Following MC studies, the reached energy resolution on jet by PFA, is already much better than calorimetric standard approach

  in order to increase our confidence in this results,
  TB results are mandatory.

- Some of the essential inputs for GEANT4 and more directly for PFA could be tested with the collected data

Like it was on real data (see ALEPH results vs calor. approach)