MC simulation of LXe detector

(presented by)
Giovanni Signorelli

INFN sez. di Pisa and Scuola Normale Superiore di Pisa

•The simulation of the calorimeter is embedded in the GEANT 3 simulation of the full detector

•All major characteristics of all sub-detectors are included

•Many kinds of events can be generated

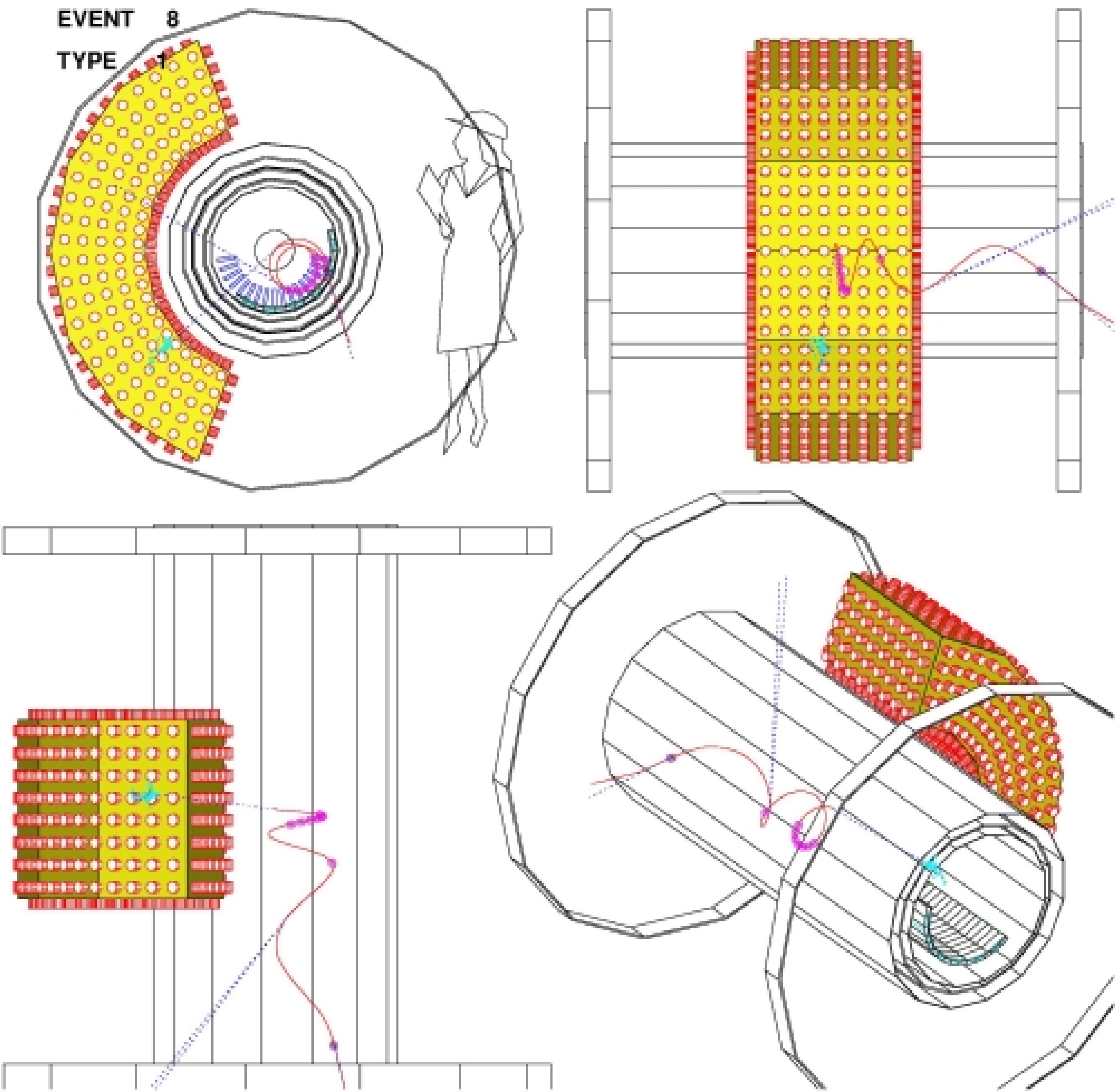
Type of event	ITYPE Code	Routine
e^+ - gamma signal	1	EVESIG
e^+ - gamma radiative decay	2	EVERDE
e^+ - gamma accidental background; 1st kind	3	EVEACC
e^+ - gamma accidental background; 2nd kind	4	EVEACC

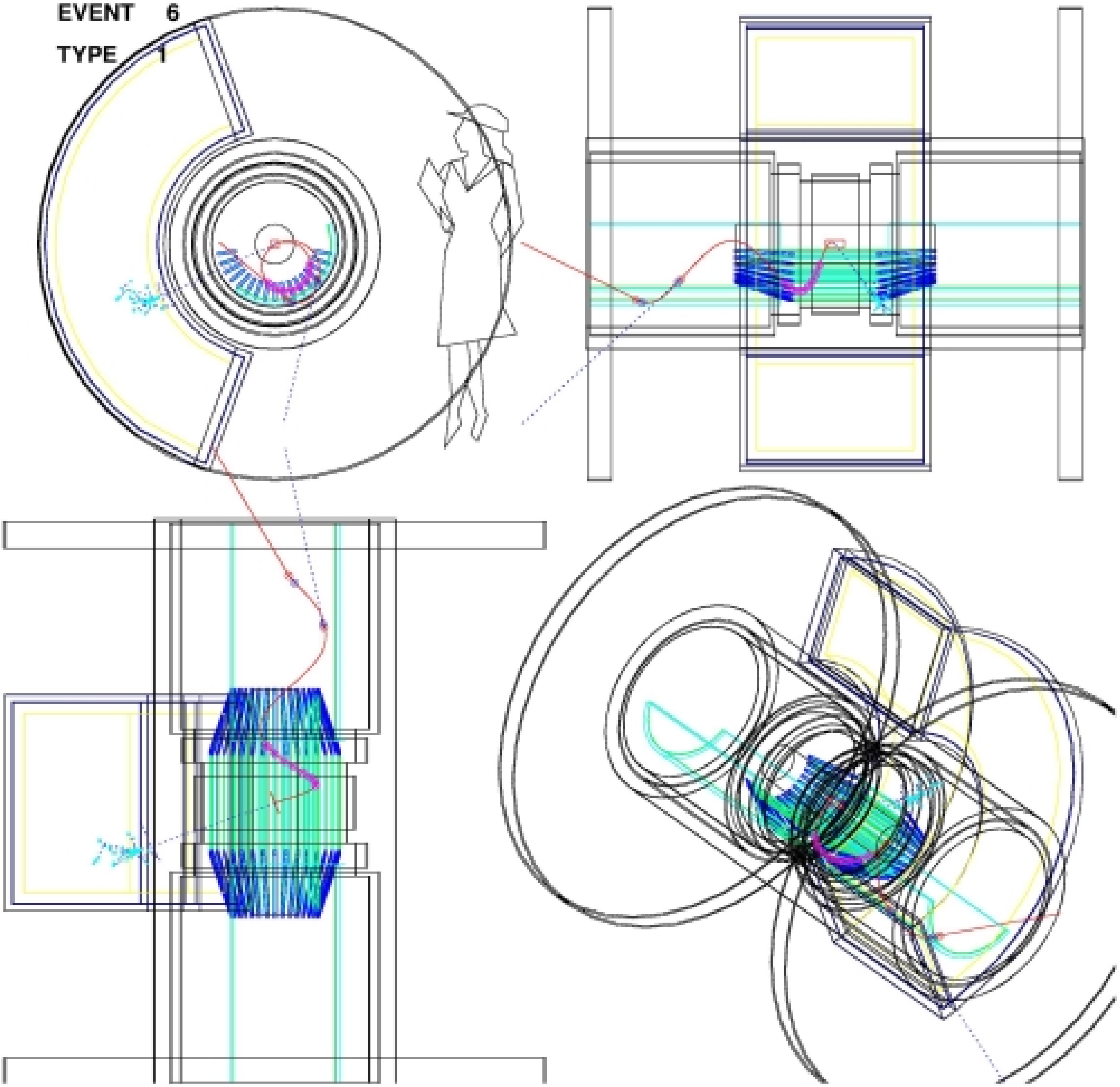
[…]

•A simulation of the Large Prototype exists

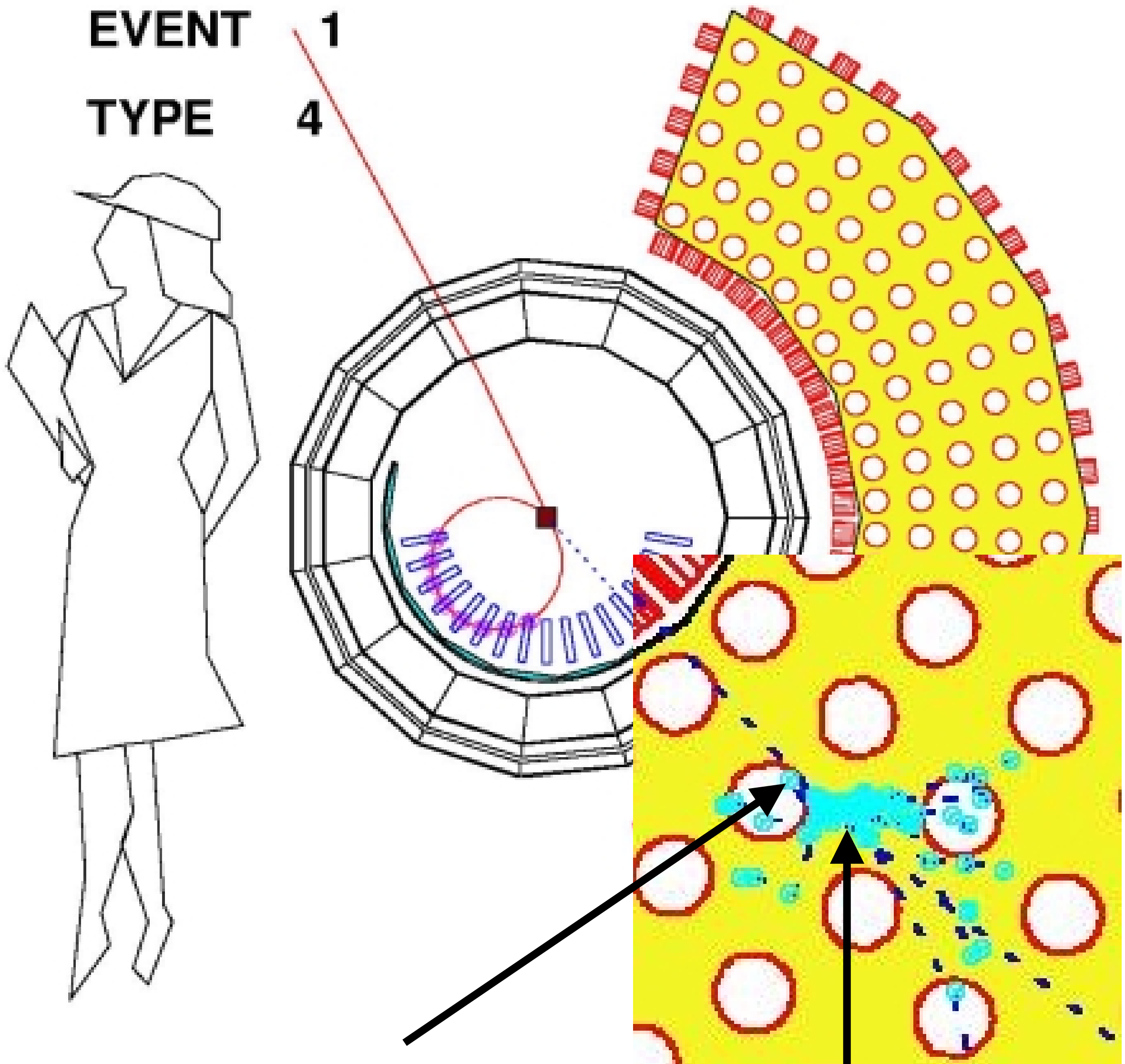
(http://meg.psi.ch/subprojects/pisamc/doc/doc.html)

An example of the $\mu \to e\,\gamma$ decay




EVENT 6
TYPE 1

MC simulation of the LXe calorimeter



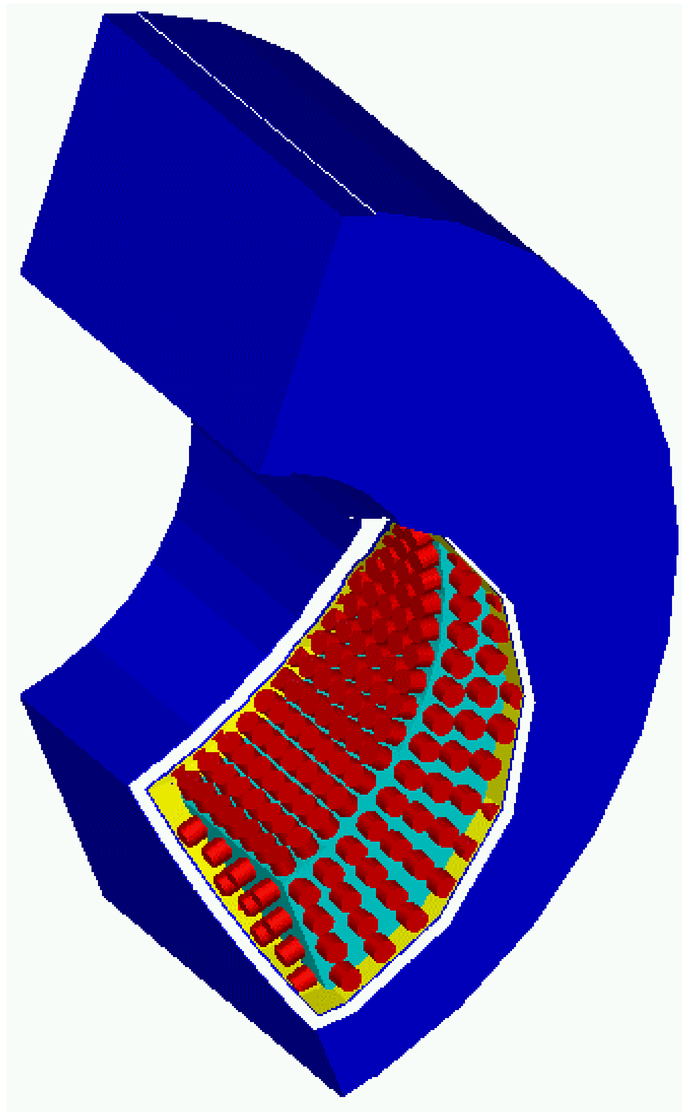
Interaction point

θ, φ, z, t

Energy deposit

E

There exist at present two simulation codes which agree

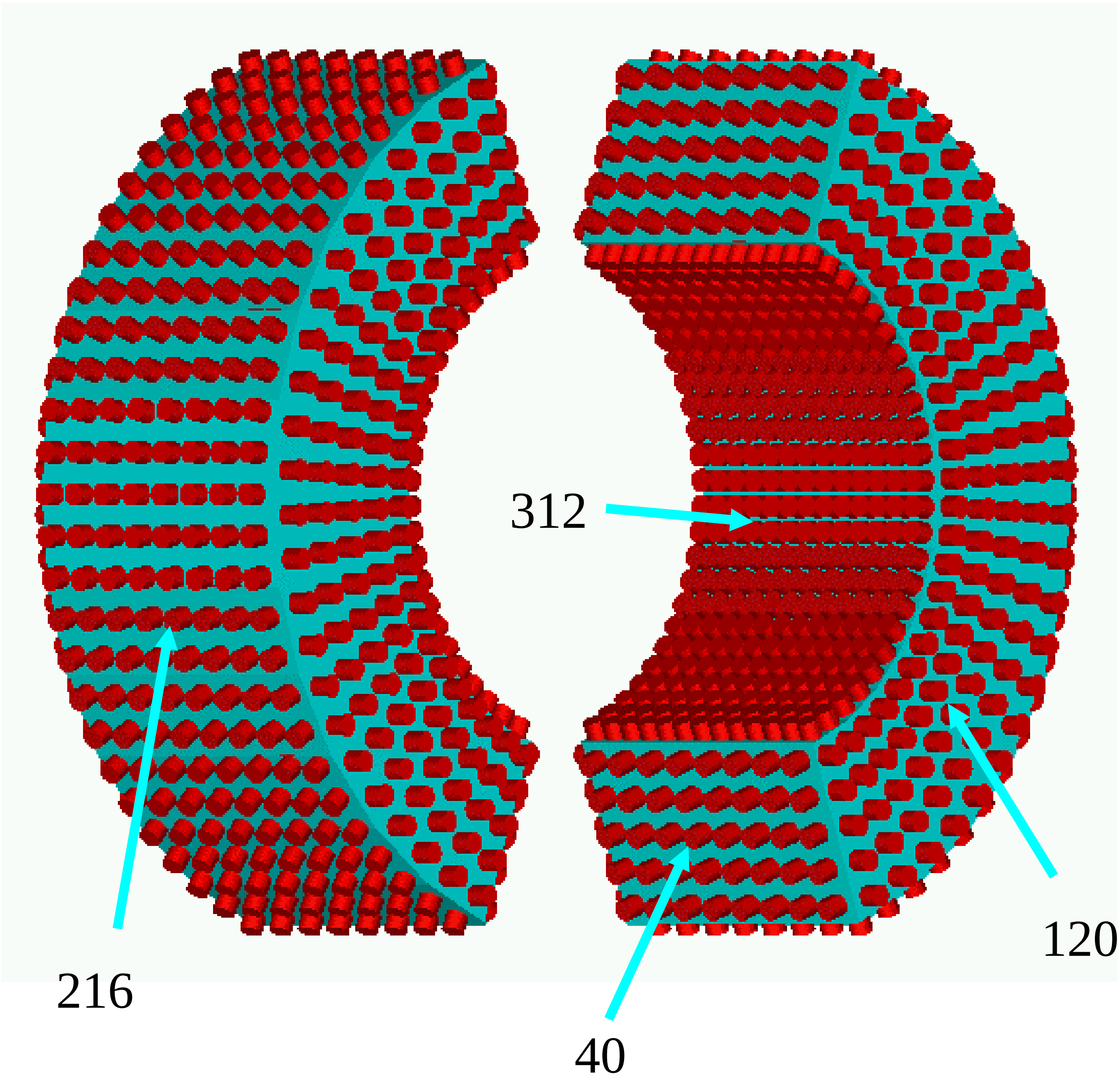


Proposed detector

- $0.8\ m^3$
- 848 PMTs (312 FF)
- $65 < r < 112$ cm
- $|\cos\theta| < 0.35$
- $|\varphi| < 60^o$

- PMT coverage as high as possible on the FRONT FACE
- Complete material simulation (efficiency)

A view of all 848 photomultipliers



Coverage ~ 30 % $\Rightarrow$ PMT positions not definitive

It is necessary to understand the basic characteristics of a 52.8 MeV photon shower in LXe

- GEANT 3.21 and tracked secondaries down to 10 keV

- Properties of LXe:

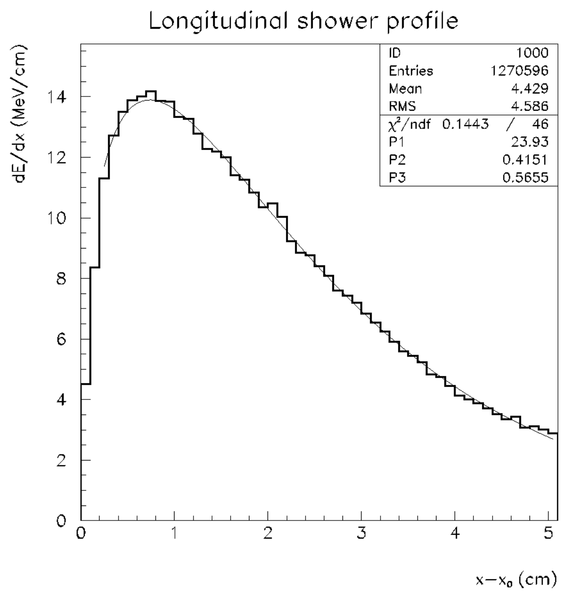
Density	3 g/cm^3
Light yield	42,000 ph/MeV
$\lambda_{Rayleigh}$	30 cm (variable)
$\lambda_{Absorption}$	100 cm (variable)
X_0	2.77 cm

- PMT characteristics

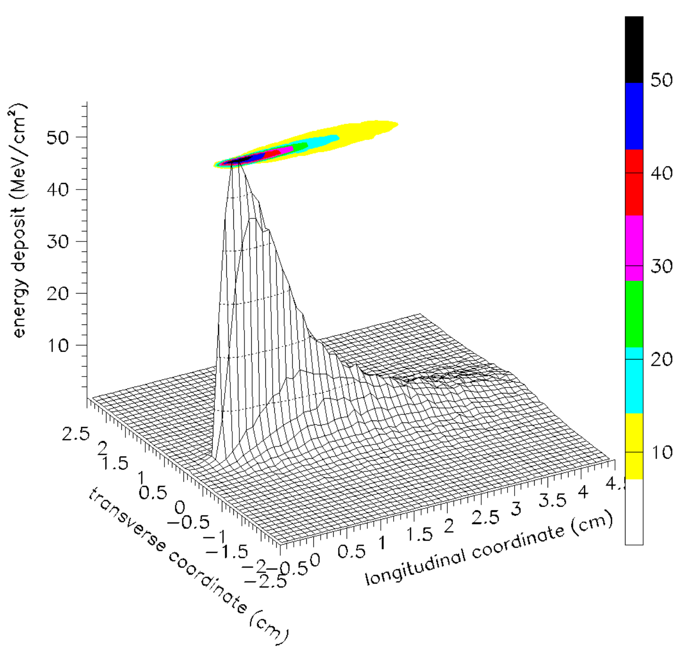
Radius	2.54 cm
Window	fused silica
Q.E.	10% $\rightarrow$ 5%

What are the main characteristics of the simulated showers in LXe?

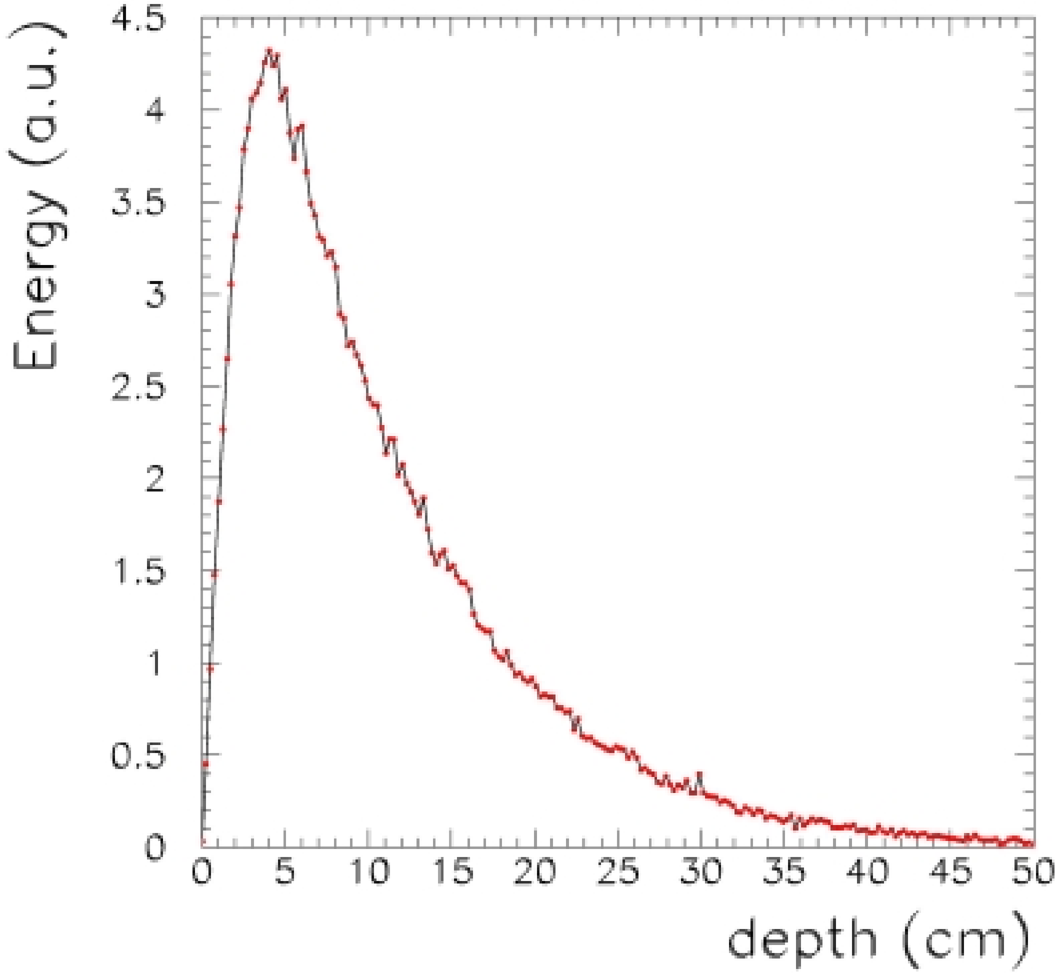
Average over 1,000,000 events



- Relative to conversion point
- Longitudinal spread ~ 5 cm
- Max energy deposit after 1 cm



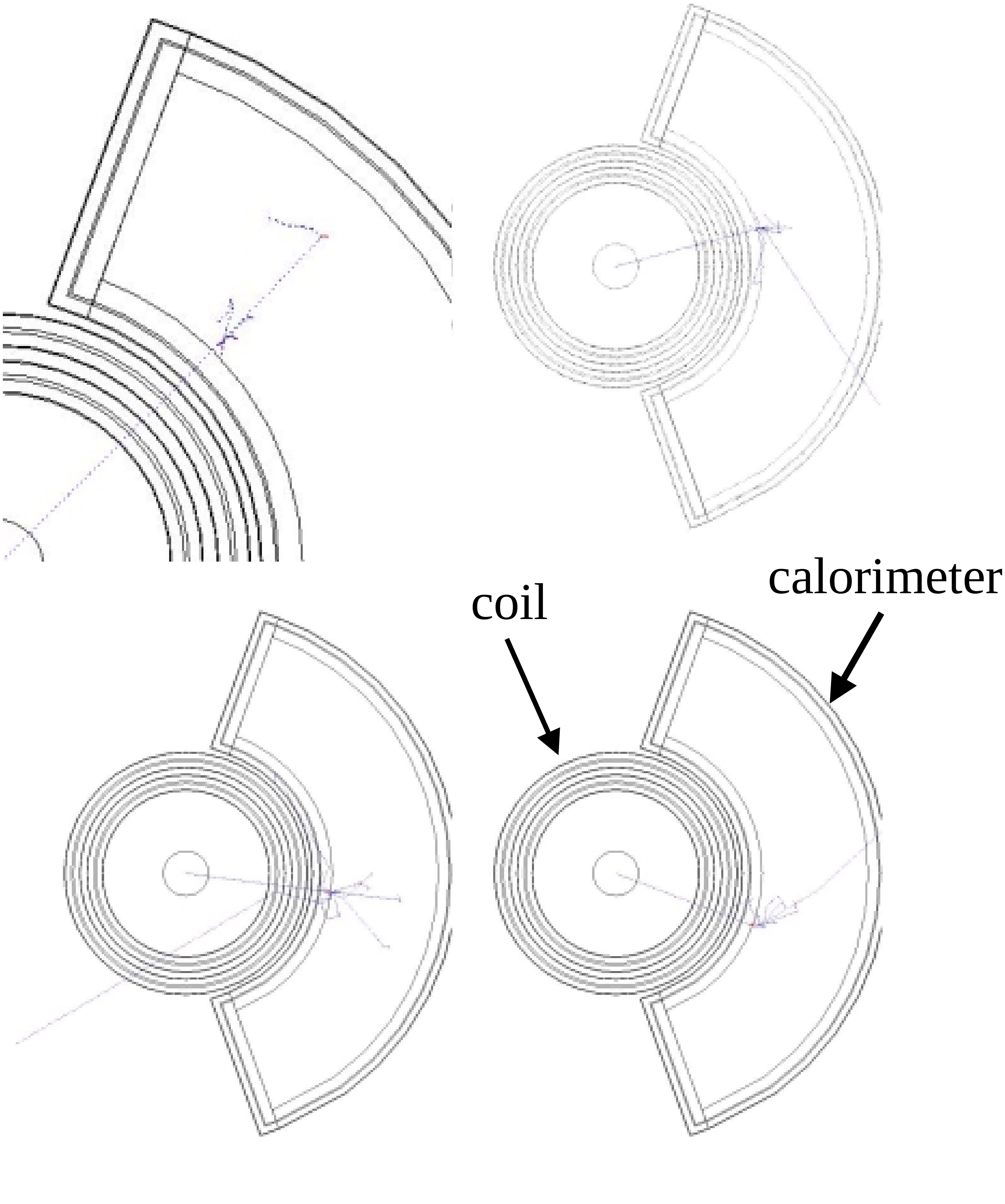
- Lateral spread ~ 1 – 2 cm
- Relative to conversion point



Energy deposited in LXe by a 52.8 MeV γ

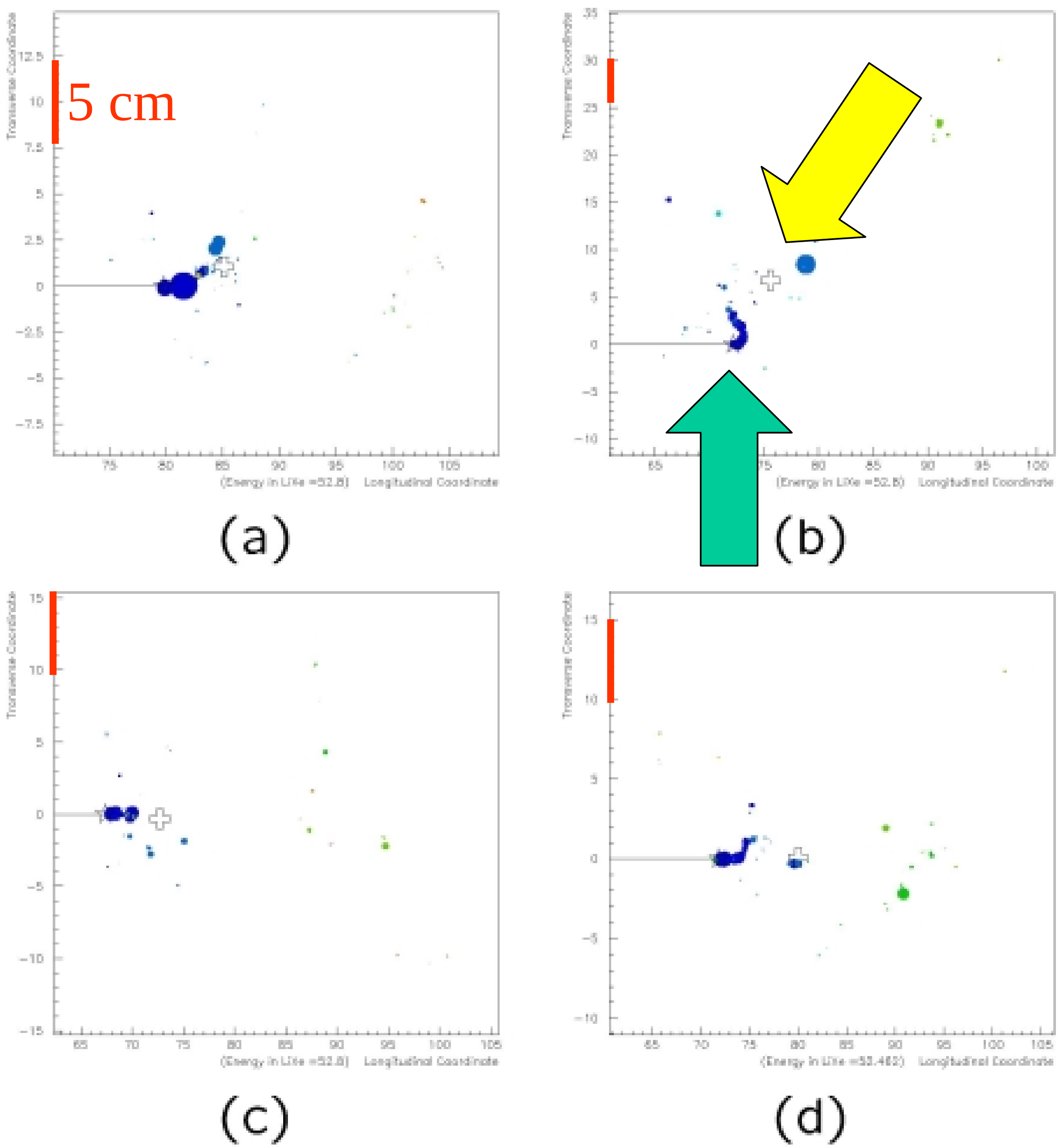
despite those mean properties…

…There are large fluctuations

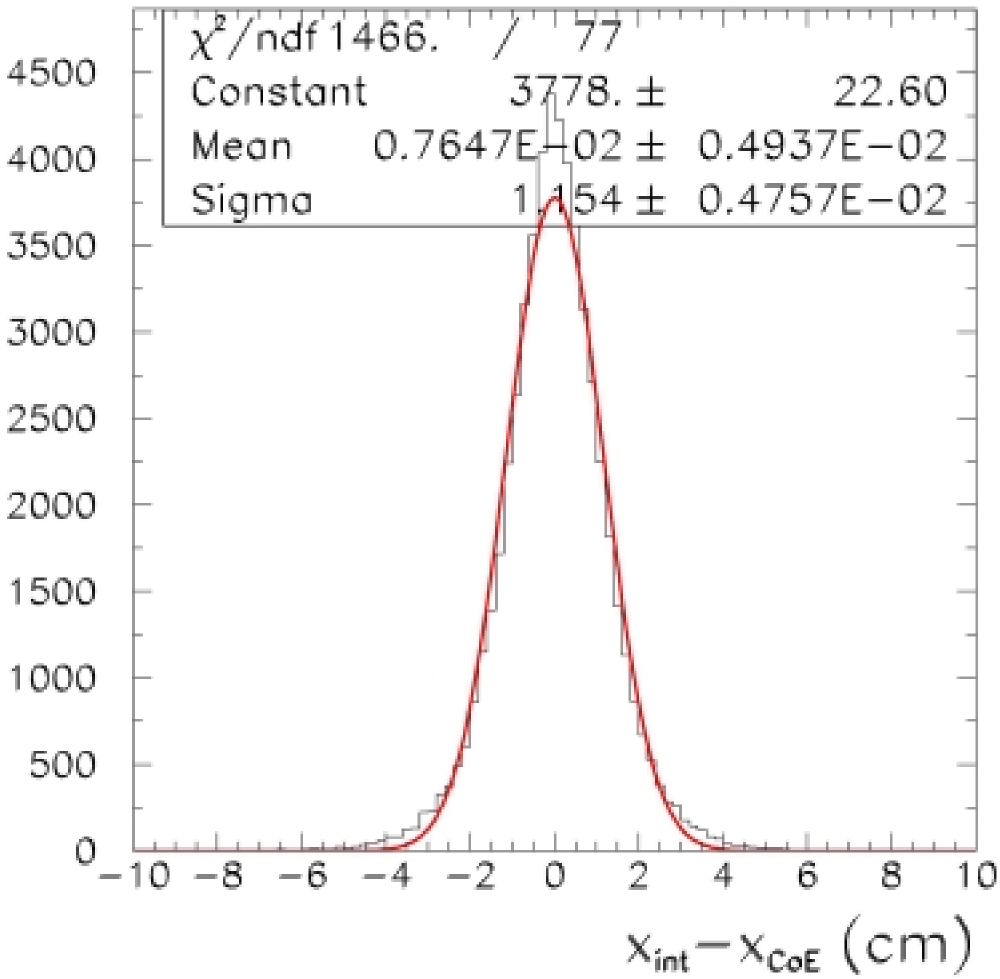


Center of energy

INTERACTION POINT



Distribution of ($x_{interaction} - x_{Center\ of\ Energy}$) MC



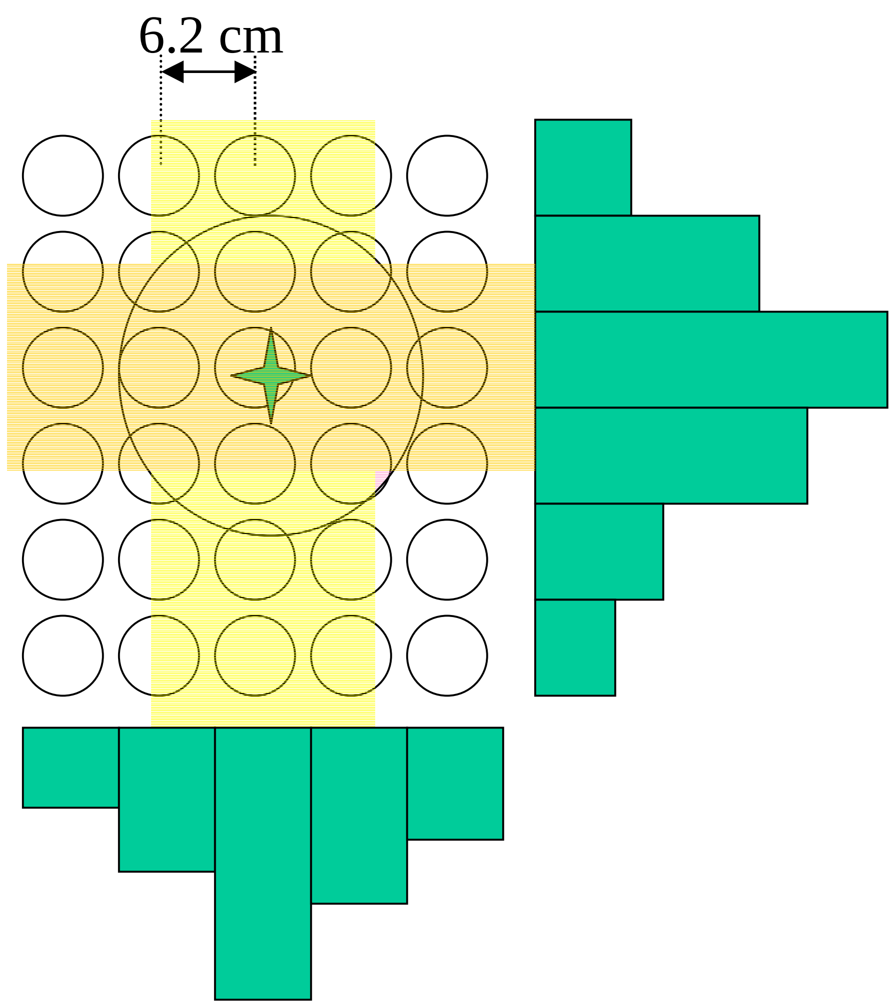
$\sigma \approx 1$ cm!

Position reconstruction

We want x_{int} *not* x_{CoE}

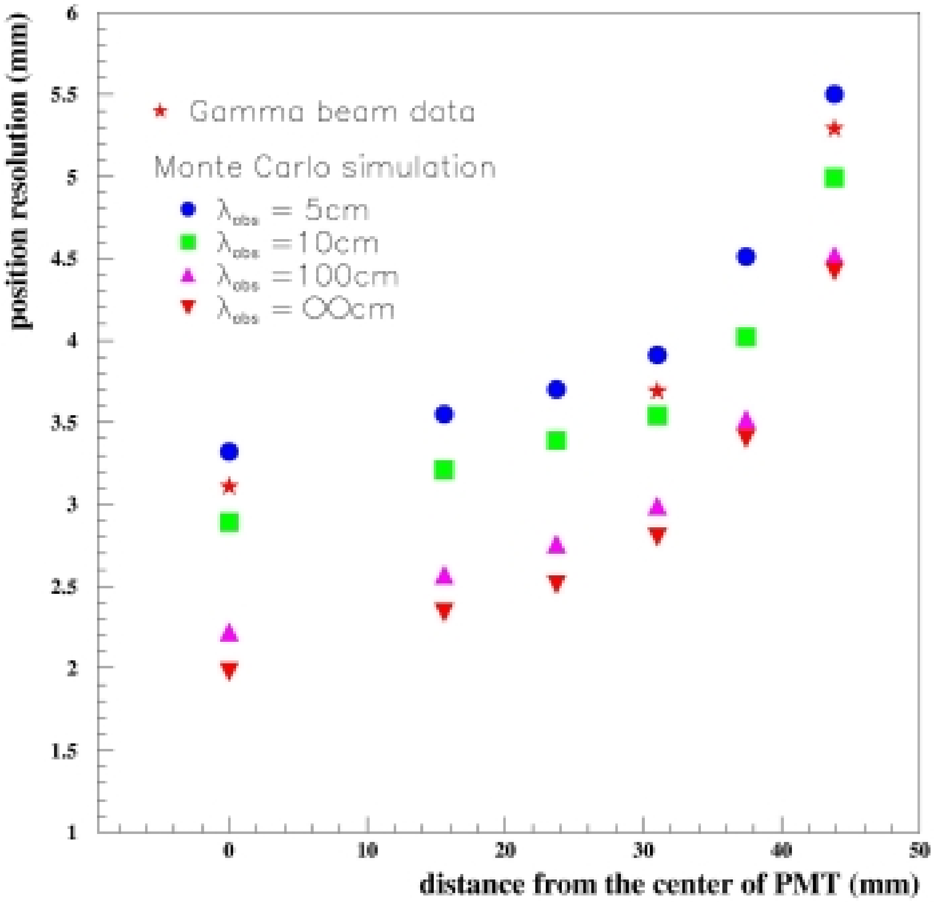
⇒Use the information of the **FRONT FACE**

1st method: Weighted average (bias)



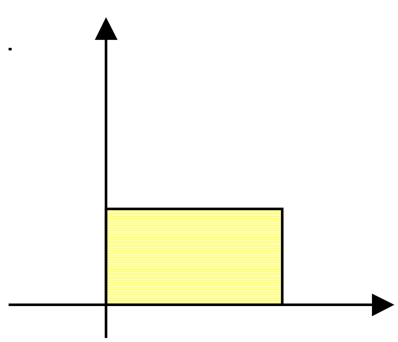
•Use only PMT in a circle and iterate

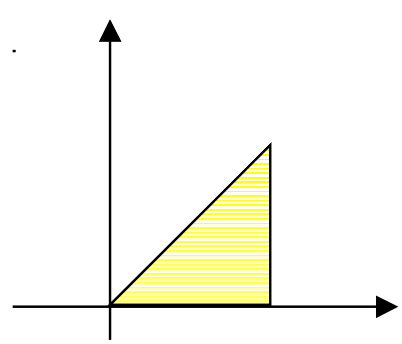
Position resolution as a function of the photon hit position



~4mm

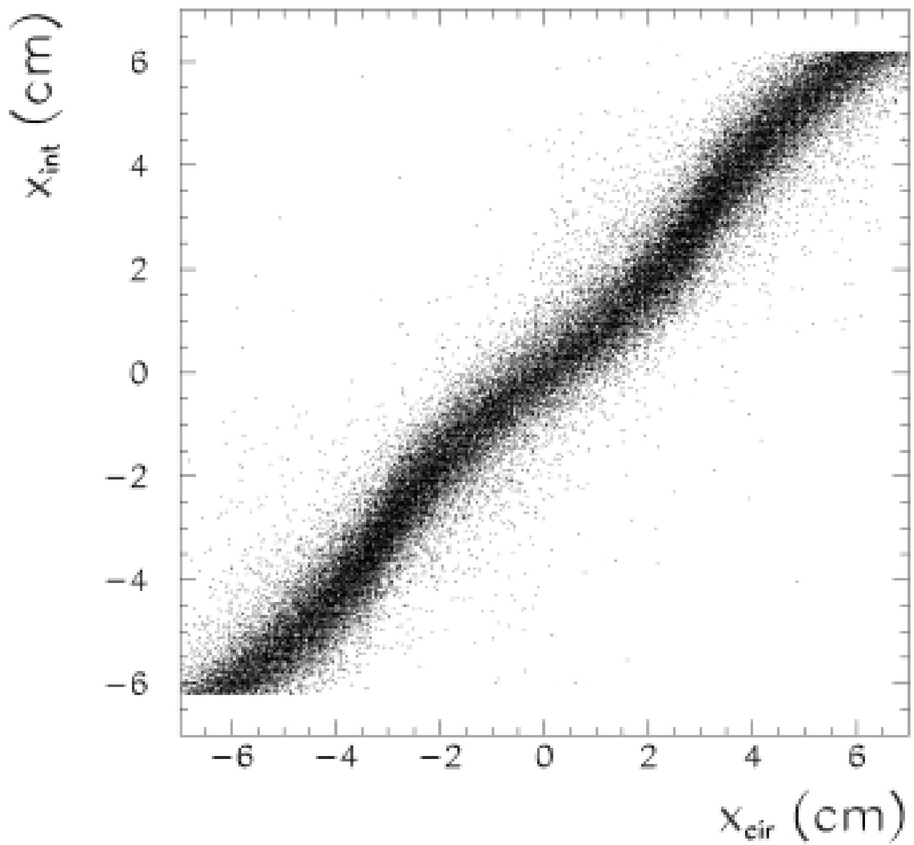
$$\mathrm{d}n = \rho\,\mathrm{d}x\,\mathrm{d}y \;\rightarrow \mathrm{d}n = 2\pi\rho\, r\,\mathrm{d}r$$





next

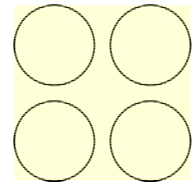
Nice recontruction but tends to “collapse” on certain points



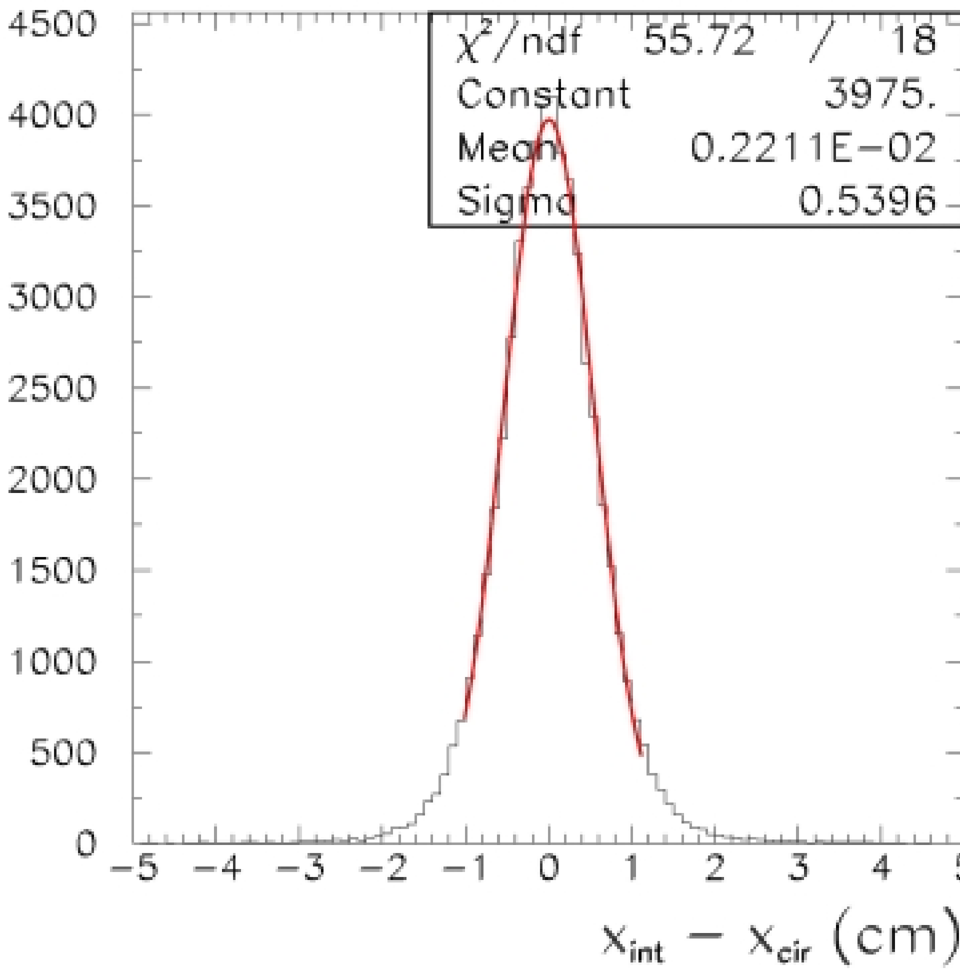
~ 10 % of the photons interact before reaching the xenon

(xjwa)

All results shown are obtained shooting a 52.8 MeV photon normally on a 2 x 2 PMT window, uniformly



Results of **CIRCLE AVERAGE**:

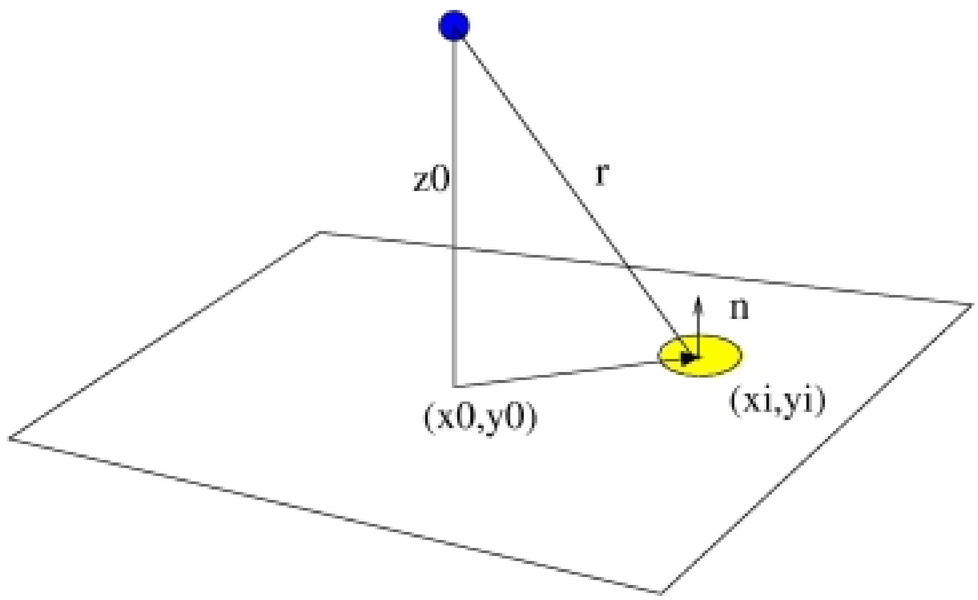


Which corresponds to an angular resolution of 8.3 mrad.

2^{nd} method:

•Fit of the expected-observed light from a point-like source

•$Q_{exp} \propto$ solid angle



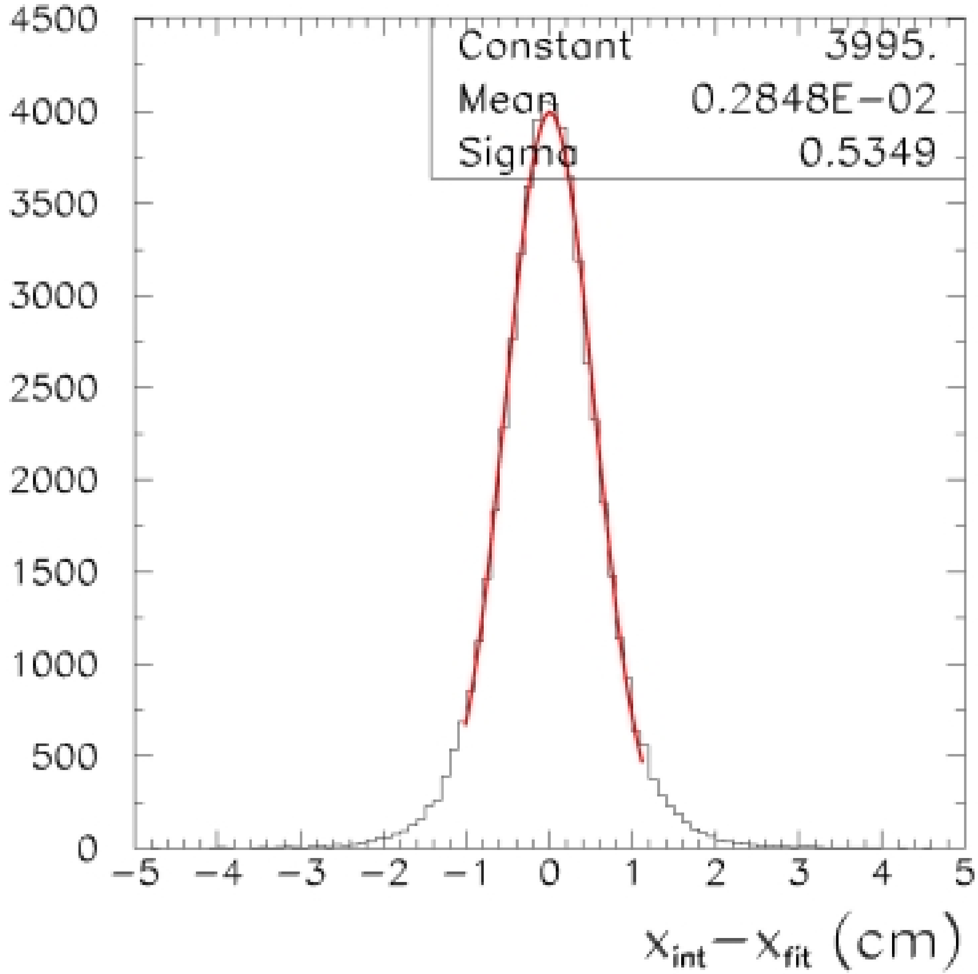
•Minimize

$$\chi^2 = 2 \sum_{i=1}^{N} \frac{(Q_i^{exp} - Q_i^{meas})^2}{(Q_i^{exp} + Q_i^{meas})}$$

•Works also with missing/broken PMTs

next

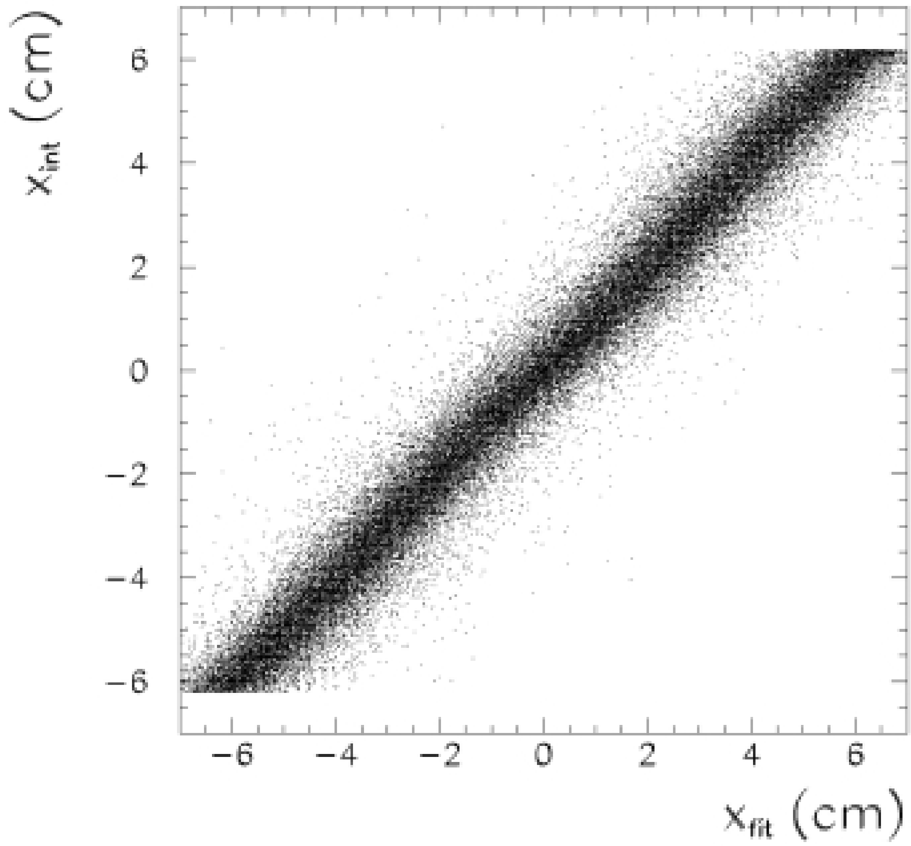
Results of **FRONT FIT**:



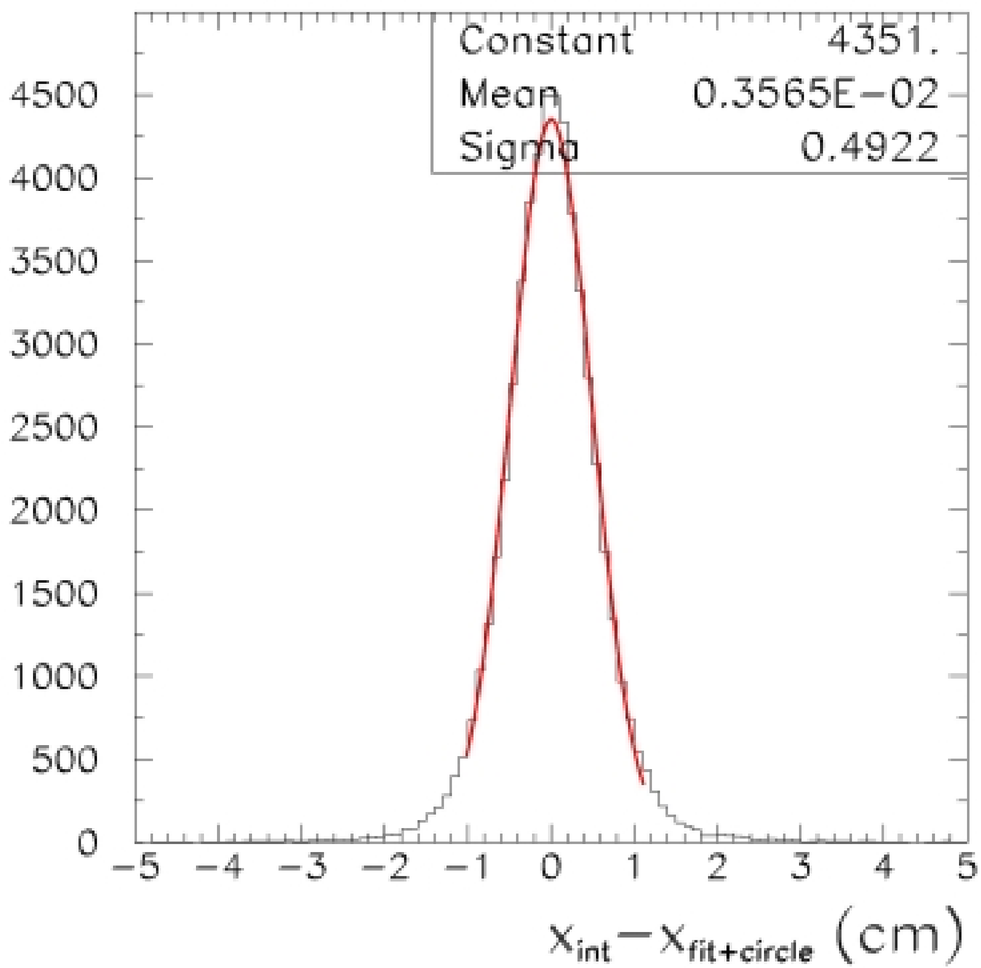
Angular resolution = 8.1 mrad (sigma)

(Slightly different from the previous note because of different Q.E.)

The fit reconstruction has a better behaviour (though not perfect)



Result of the **FRONT FIT** on a **CIRCLE**:



Angular resolution = **7.5** mrad (sigma)

(z constant from FRONT FIT)

Peaks….

The resolution is limited by

1. Shower fluctuations
2. PMT dimensions

In fact:

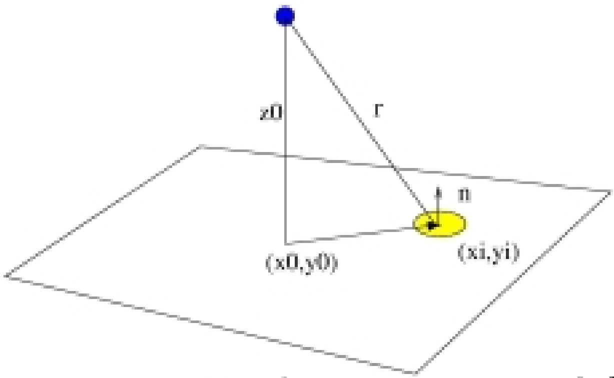
1. Pointlike source and 2'' PMTs

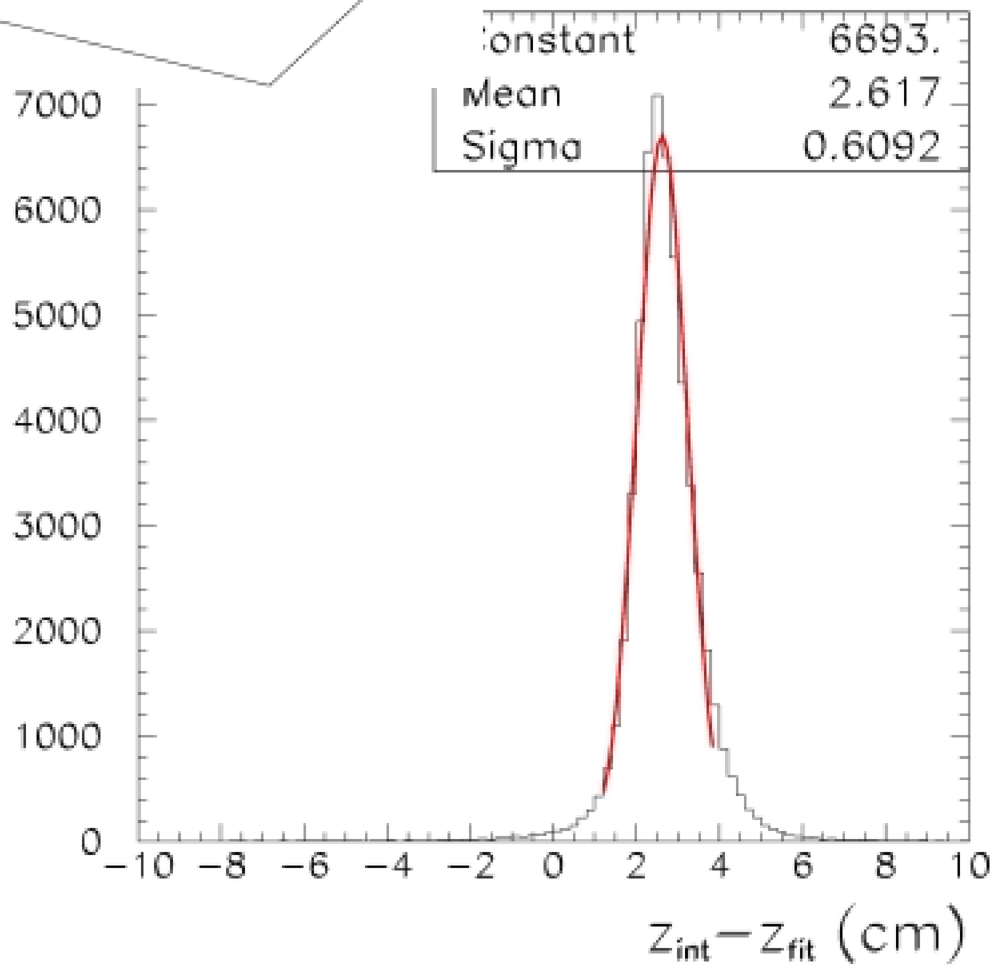
   $\Rightarrow$ 1.0 mm sigma   (1.5 mrad)

2. Real event and 1'' PMTs

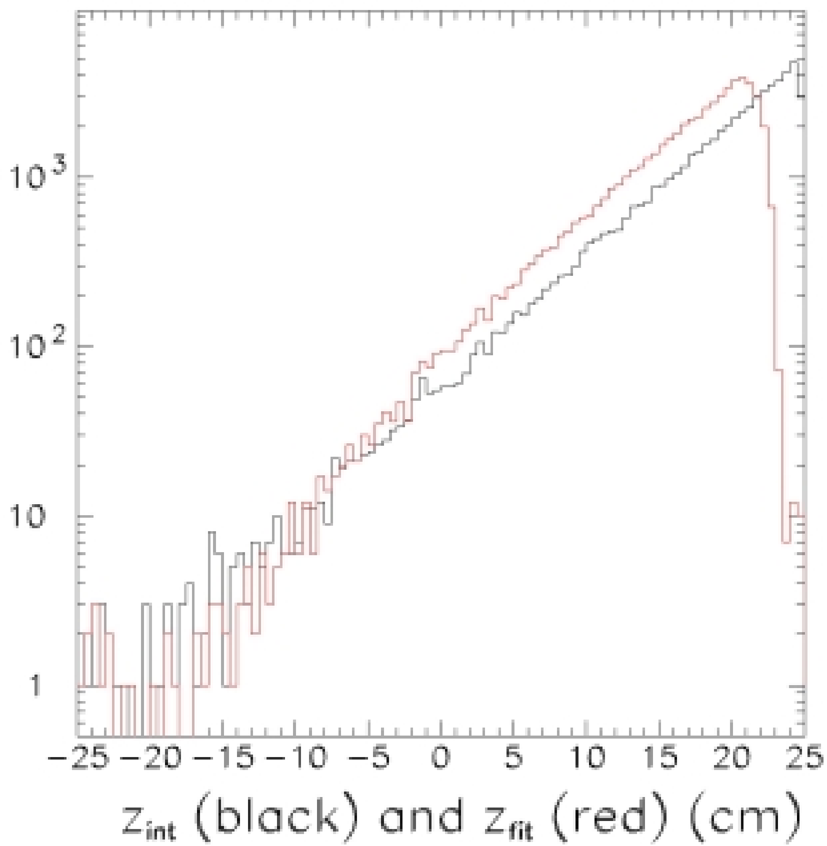
   $\Rightarrow$ 3.5 mm sigma   (5.4 mrad)

From the FRONT FIT one gets also the depth (***z*-coordinate)** of the conversion point.

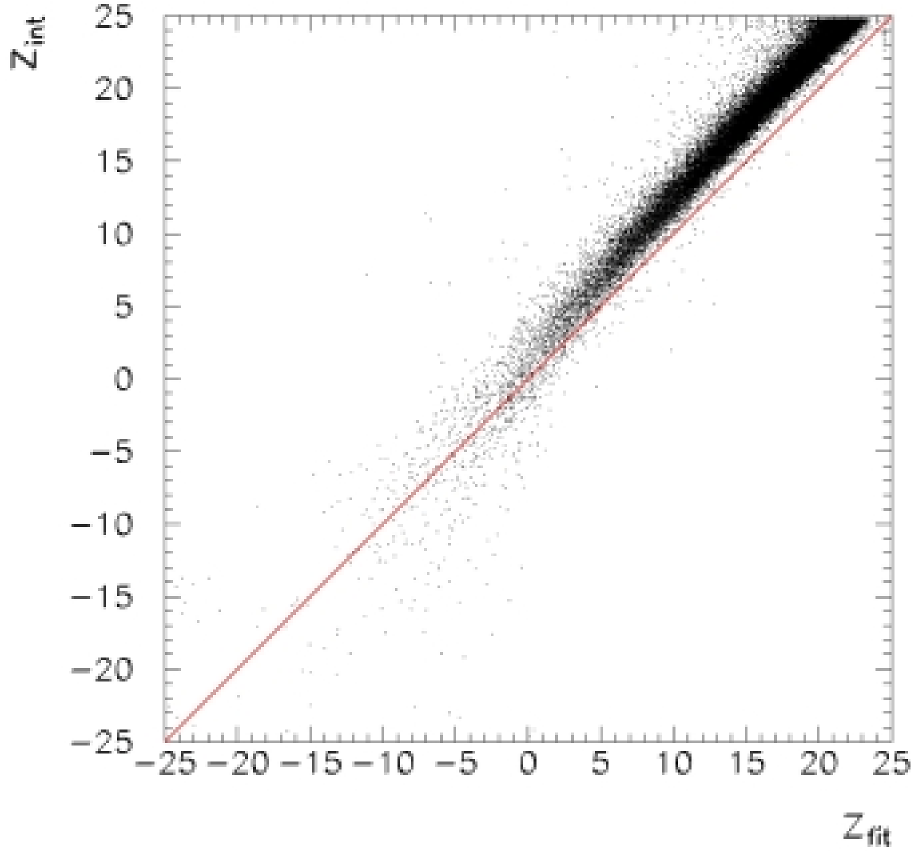




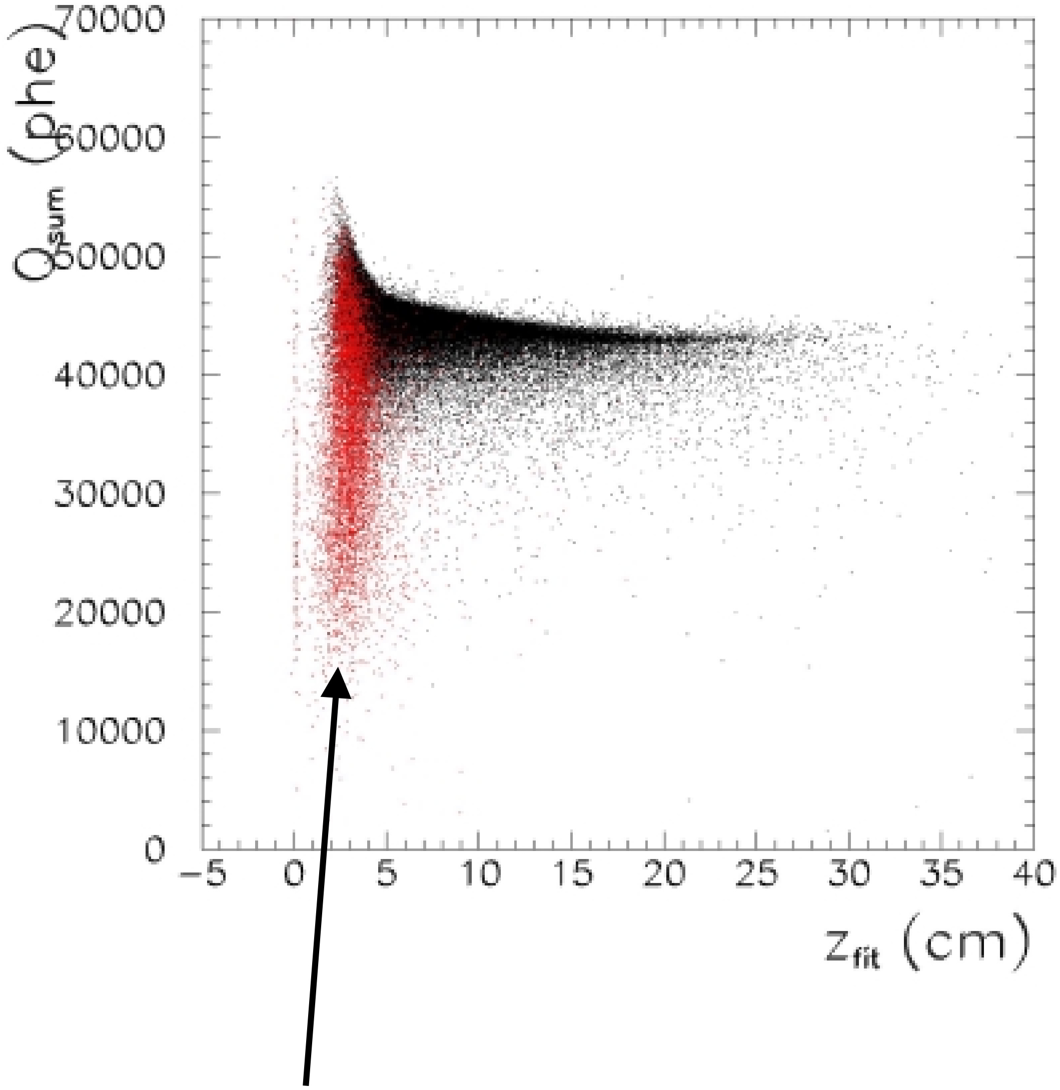
Corresponding to ~ 85 psec intrinsic FWHM



1
10
10 2
10 3
−25 −20 −15 −10 −5 0 5 10 15 20 25
z_int (black) and z_fit (red) (cm)



z_int
25
20
15
10
5
0
−5
−10
−15
−20
−25
−25 −20 −15 −10 −5 0 5 10 15 20 25
z_fit

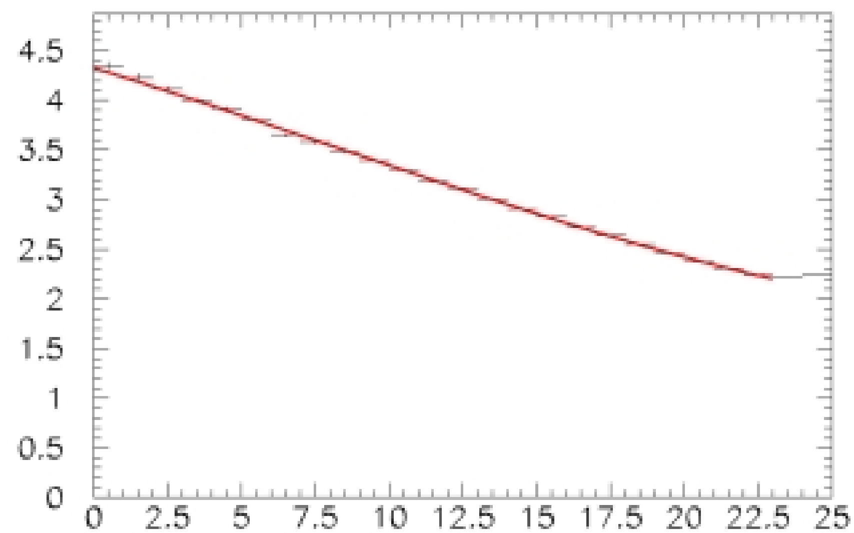


Converted before xenon

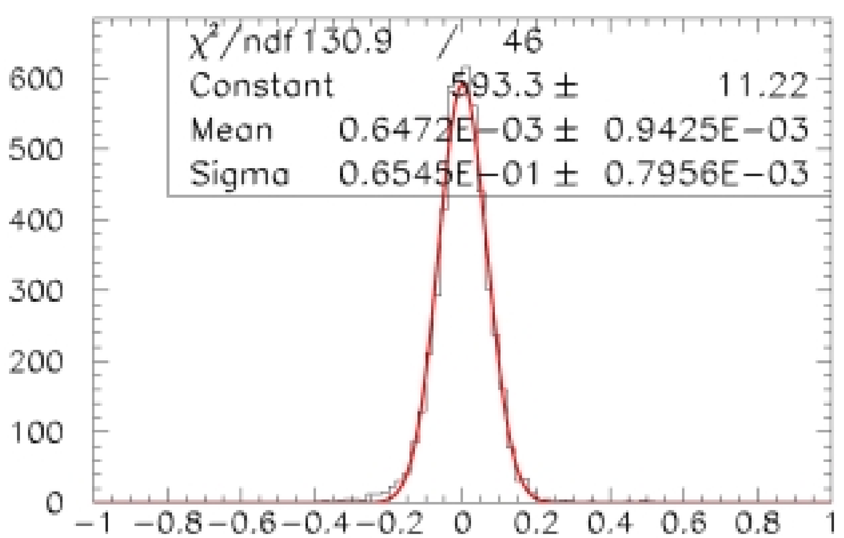
Rough evaluation of timing performance

Minimum time on the front face corrected with the reconstructed z

t_{min}



z_{fit}



~ 150 ps FWHM but uses only one PMT

Energy reconstruction

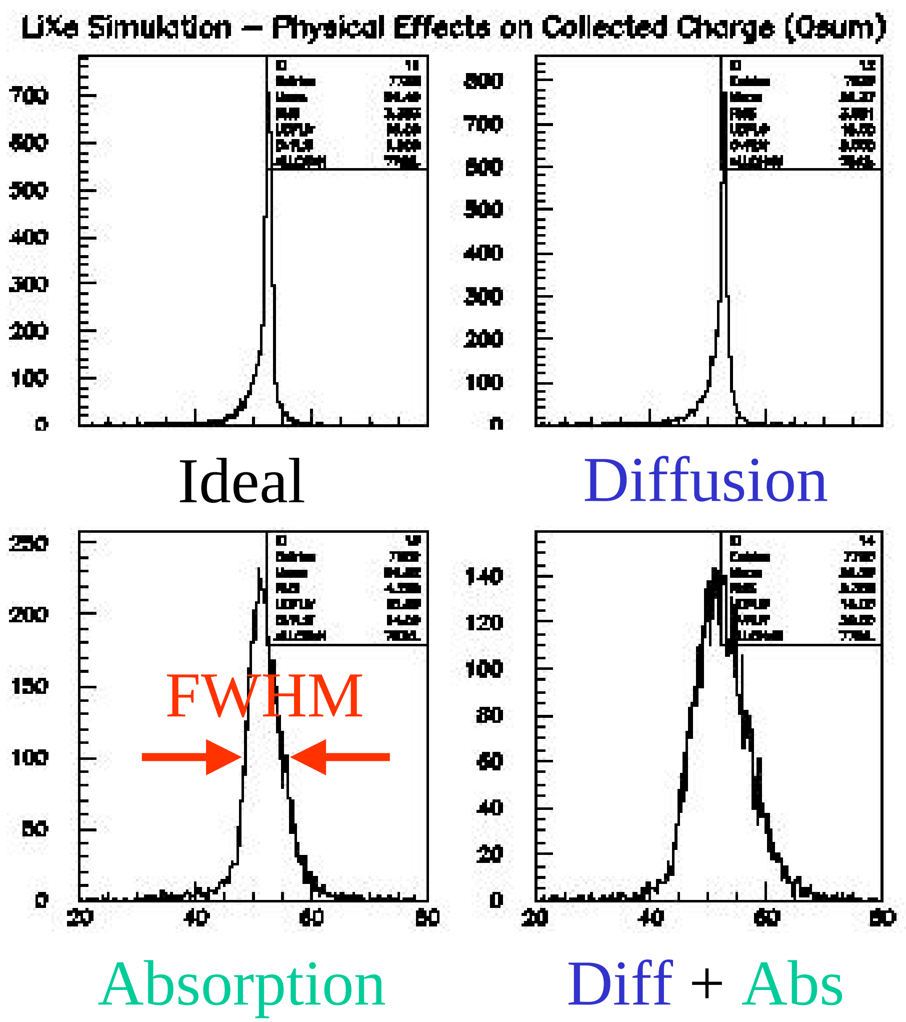
•The *ideal* case is simple:

$$E \propto \sum_i Q_i w_i = Q_{\mathrm{sum}}$$

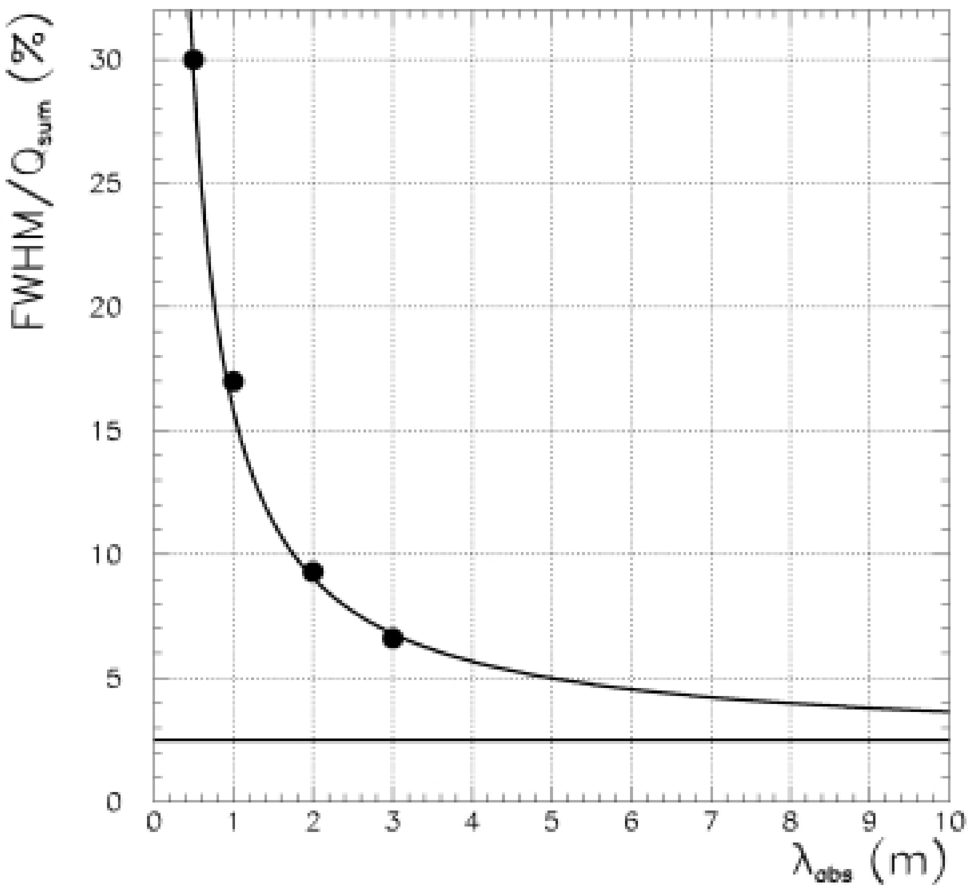
w_i = density of PMTs on various faces

~ 2.5 % FWHM

•Physics effects ($\lambda_{Ray}<\infty$, $\lambda_{Abs}<\infty$) worsen the energy resolution:



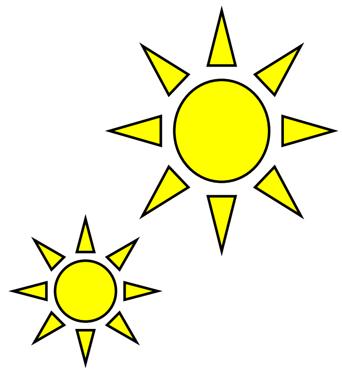
Energy resolution using Q_{sum} worsens rapidly with increasing absorption (not corrected for z_{int})



⇒ We need different algorithms to guarantee a good resolution in presence of absorption

Dipole model

•Shower =



“CoE”

“conversion”

Two lamps of relative position and intensity fixed, to mimic the true shower.

•MINUIT reconstruction

•(θ,φ) ~ 10 mrad

•Better than Q_{sum}u at small λ_{Abs}

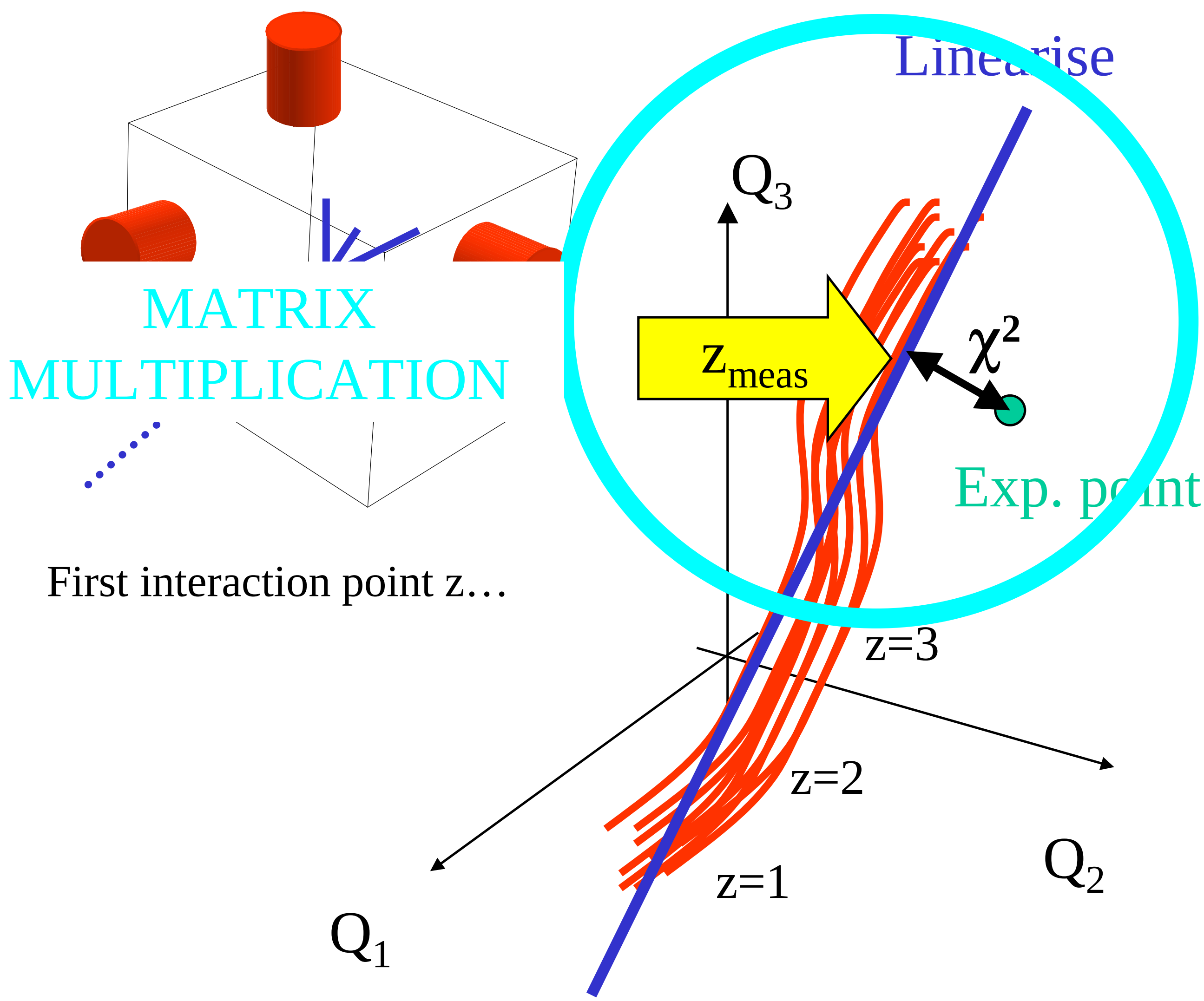
•FWHM 8% for λ_{Abs} 50

6.5% for λ_{Abs} 300 cm

Principal component analysis

- A vector of parameters $\{p_i\}$ = E, θ, φ, z…
- A vector of observables $\{q_j\}$ = PMT charges

$$\{q_j\} \rightarrow \{p_i\}$$



All in a linearised way $\Rightarrow$ fast

Linearisation

Here are the formulas:

$$p_i = w_{ij}(q_j - q_j^0) + c_i$$

Generate a sample of MC events and find the best hyper-plane:

Minimize (analytically) the deviation between the linear approximation and the true p_i values (ONCE AND FOR ALL)

$$q_j^0 = \frac{1}{N} \sum_{events}^{N} q_j$$

$$\mathbf{M}_{kl} = \left\langle (q_k - \bar{q}_k)(q_l - \bar{q}_l) \right\rangle$$ Covariance matrix

$$w_{ij} = \frac{\mathbf{M}^{-1}}{N-1} \left[\sum_{events}^{N} p_i q_j - \frac{1}{N} \sum_{events}^{N} p_i \sum_{events}^{N} q_j \right]$$ Analytical

$$c_i = \langle p_i \rangle - \langle w_{ij} q_j \rangle$$ Average on MC events

Algorithms details: CERN EP 81-12/ReV

CDF/DOC/TRIGGER/PUBLIC/3108

SVT

Silicon Vertex Tracker

TECHNICAL

DESIGN REPORT

Version 2.1 – November 22, 1994

The following people have contributed to the development of the SVT Project and to the writing of this document:

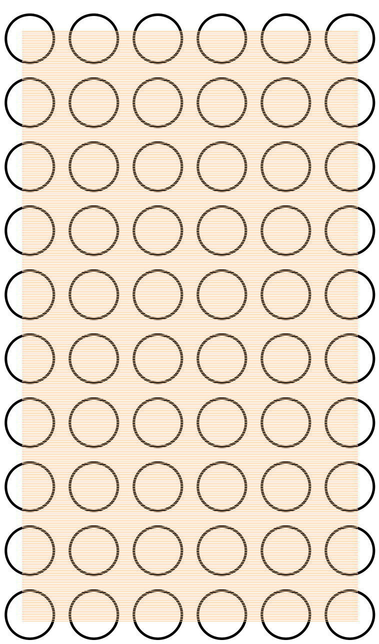
S. Belforte, M.Dell'Orso, S.Donati, G.Gagliardi, S.Galeotti, P.Giannetti, N.Labanca,F.Morsani,D.Passuello,G.Punzi, L.Ristori,G.Sciacca,N.Turini,A.M.Zanetti

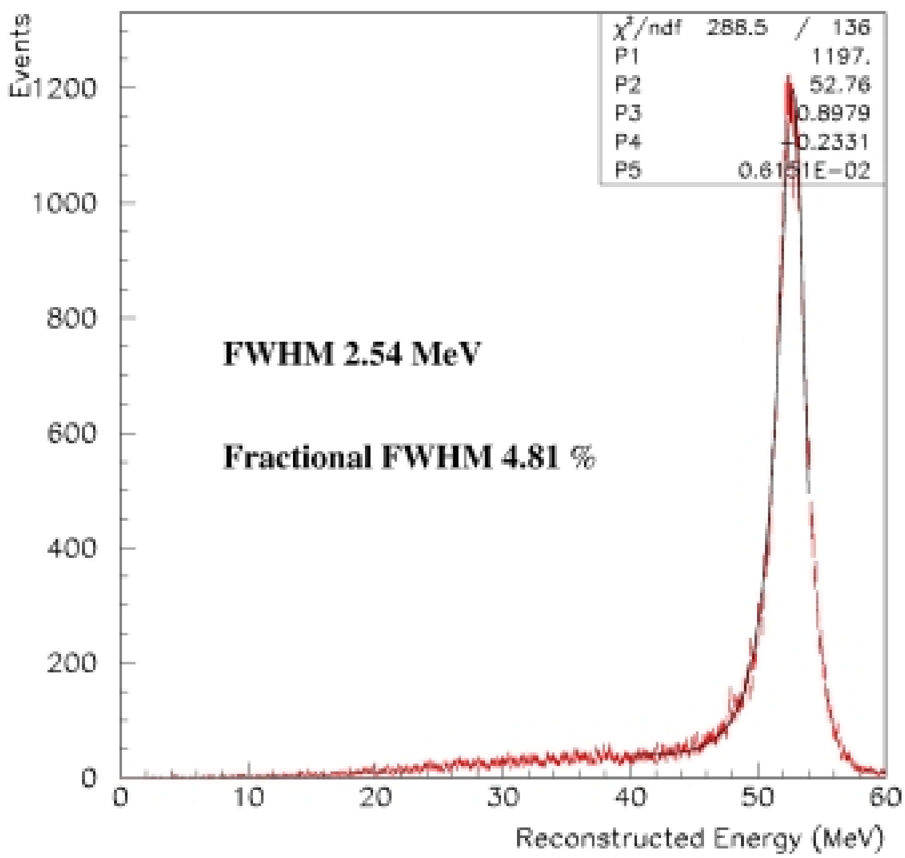
INFN - Pisa

Results for energy:

- λ_{Ray} = 30 cm
- λ_{Abs} = 100 cm
- One set of constants for all the detector

$$\left.\frac{\Delta E}{E}\right|_{52.8\,\mathrm{MeV}} = 4.8\%$$



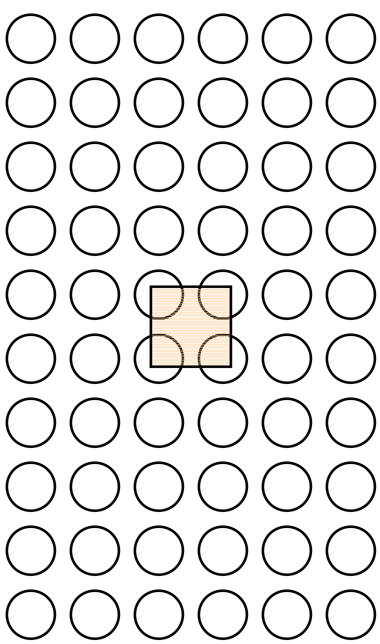


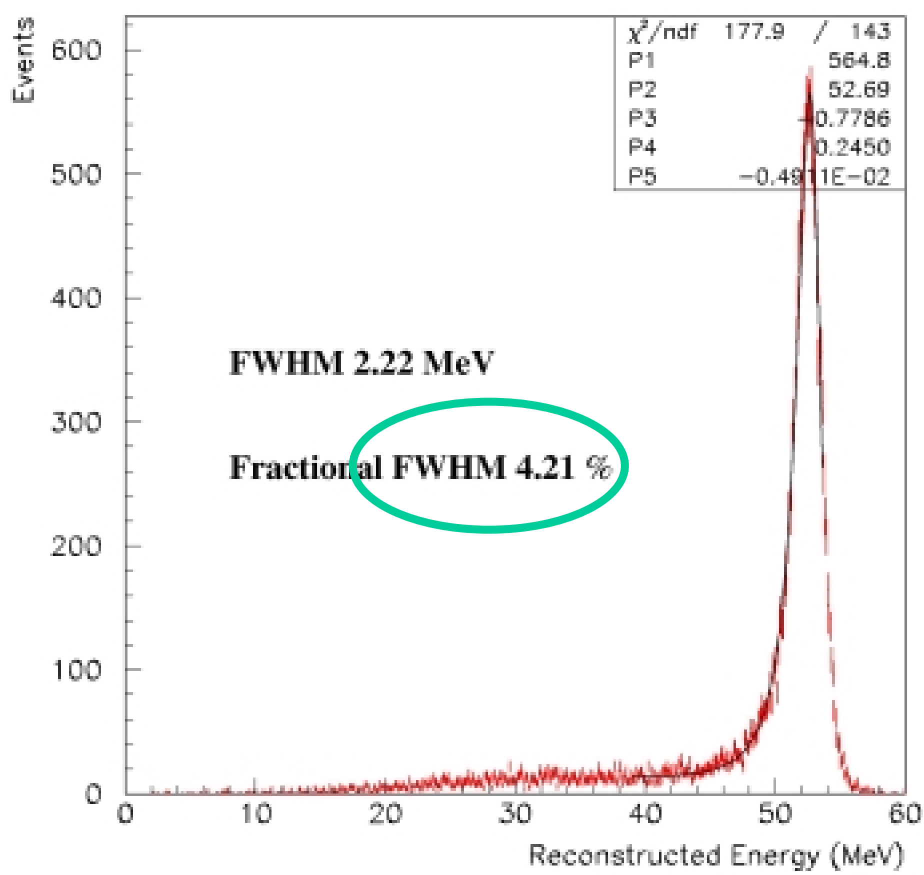
λ_{Abs} = 100

Knowing the interaction point (from INNER FIT)

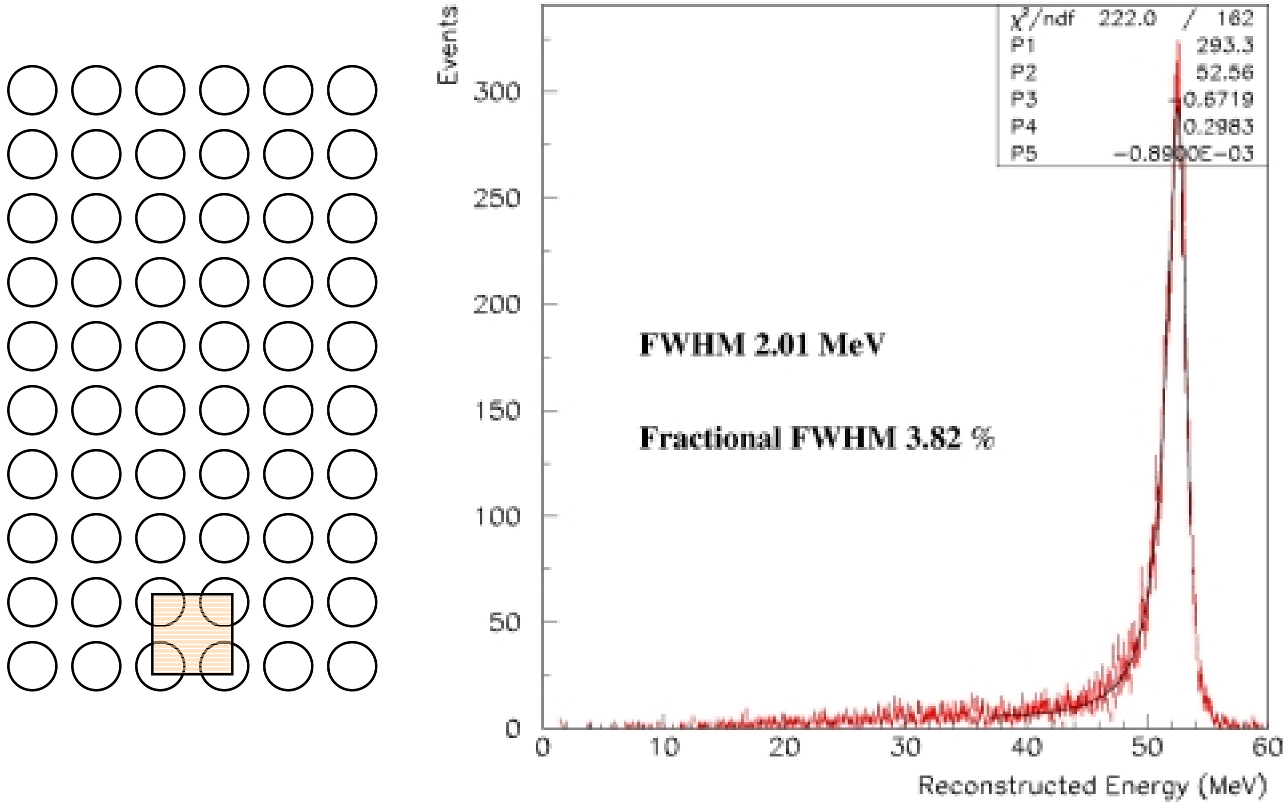
Different set of constants:

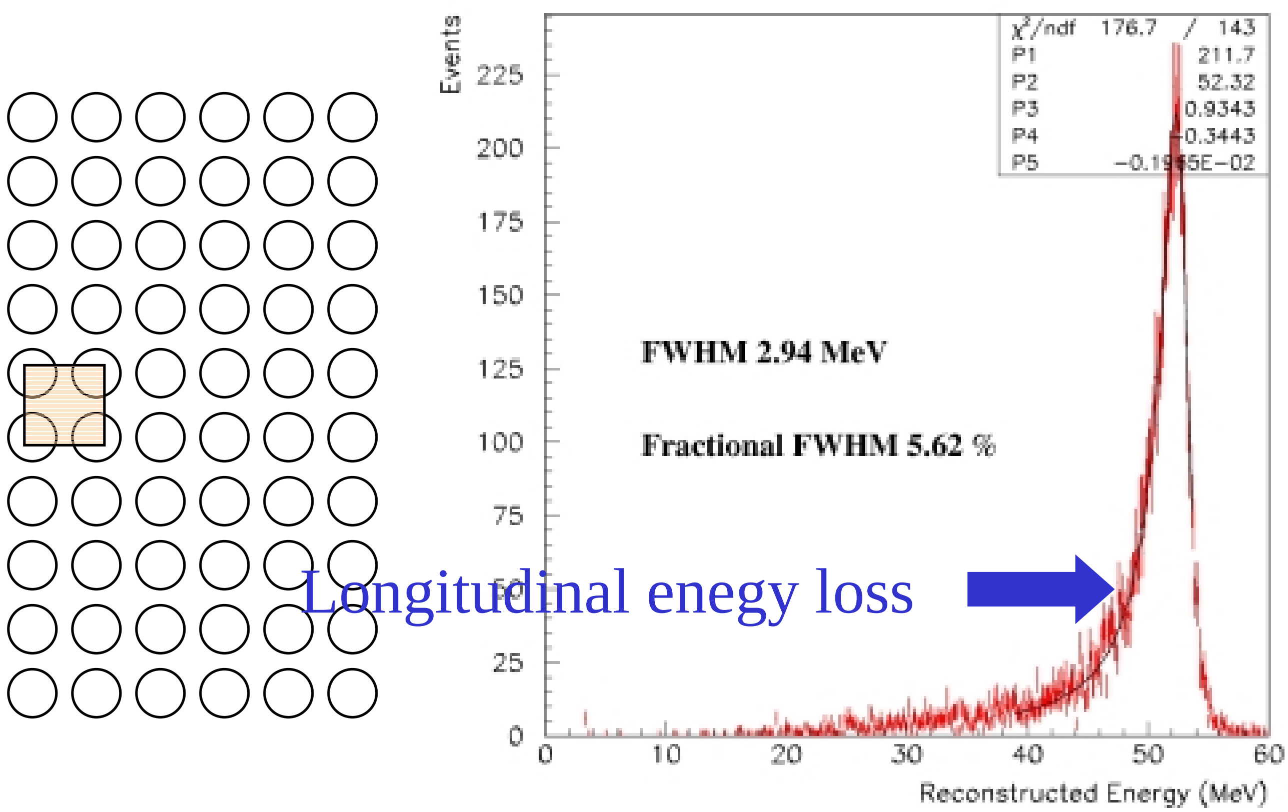
square of 5-σ edge around the reconstructed position





$\lambda_{Abs} = 100$



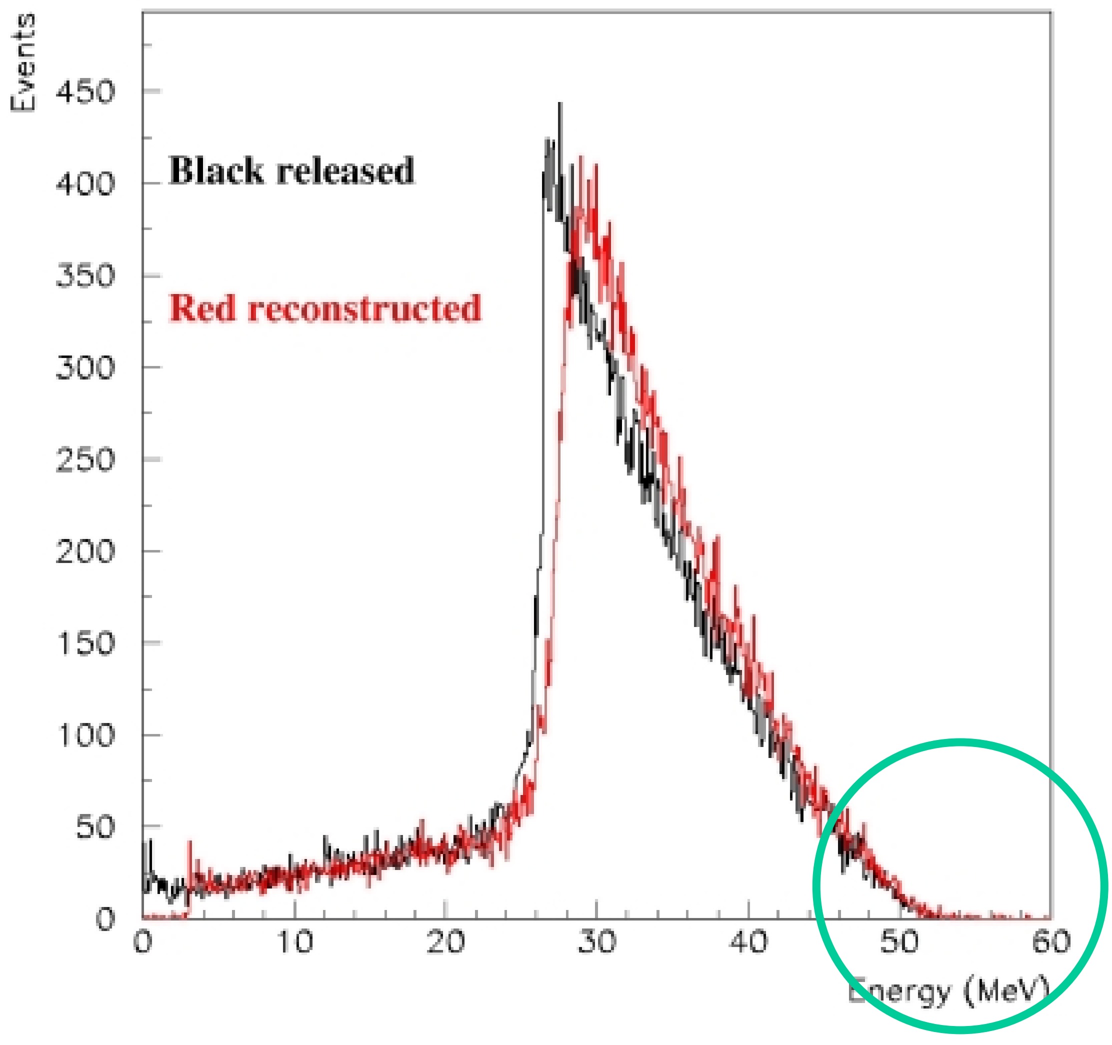


$\lambda_{Abs} = 100$

Background reconstruction:

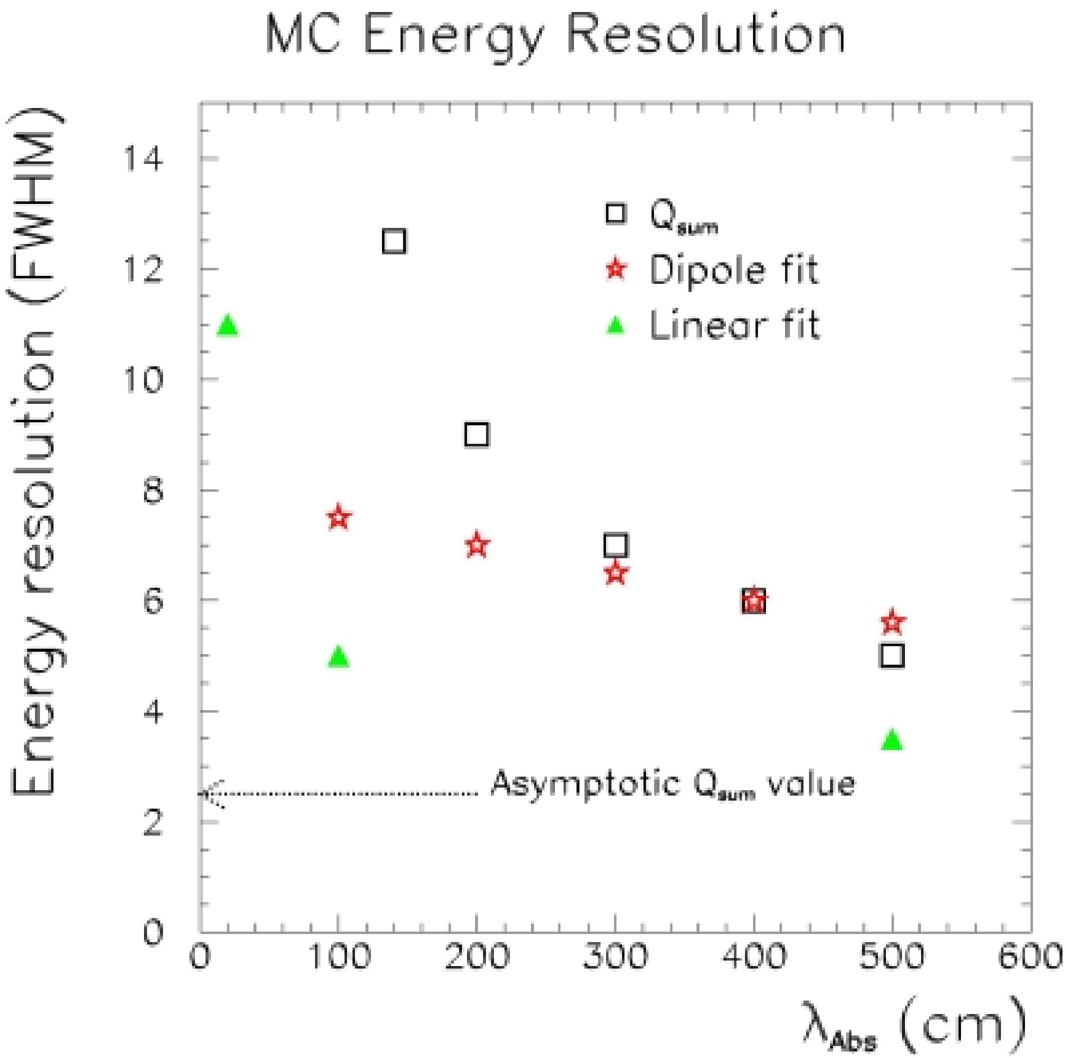
•Radiative decay

•Constants computed using signal events



$\lambda_{Abs} = 100$

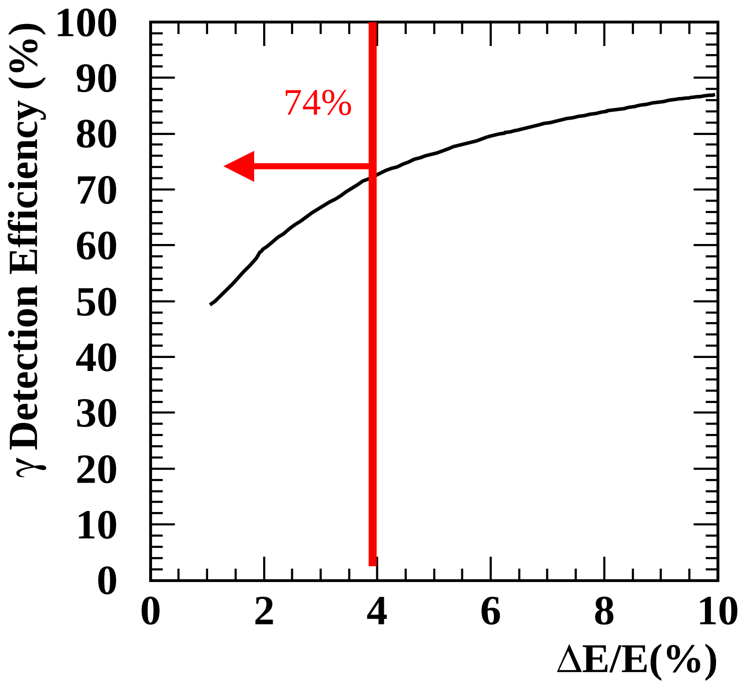
Absorption dependence



Expected Performance

- Detector Efficiency

Detector		Radiation thickness X_0
Magnet	Coil	0.153
	Cryostat	0.048
Photon Detector	Outer wall	0.03
	Honeycomb	0.068
	PMT+holder	0.21
Total		0.482



– 74% with ±4% energy cut
– Reconstruction efficiency is not know yet.
– A possible inefficiency may result from gamma conversions very close to the PMT surface.

SUMMARY

•A MC simulation of the final calorimeter is embedded in the simulation of the complete detector

•We studied γ shower in LXe

•The position can be reconstructed on the whole detector with a resolution

FWHM ~ 4/5mm - 6/7.5 mrad

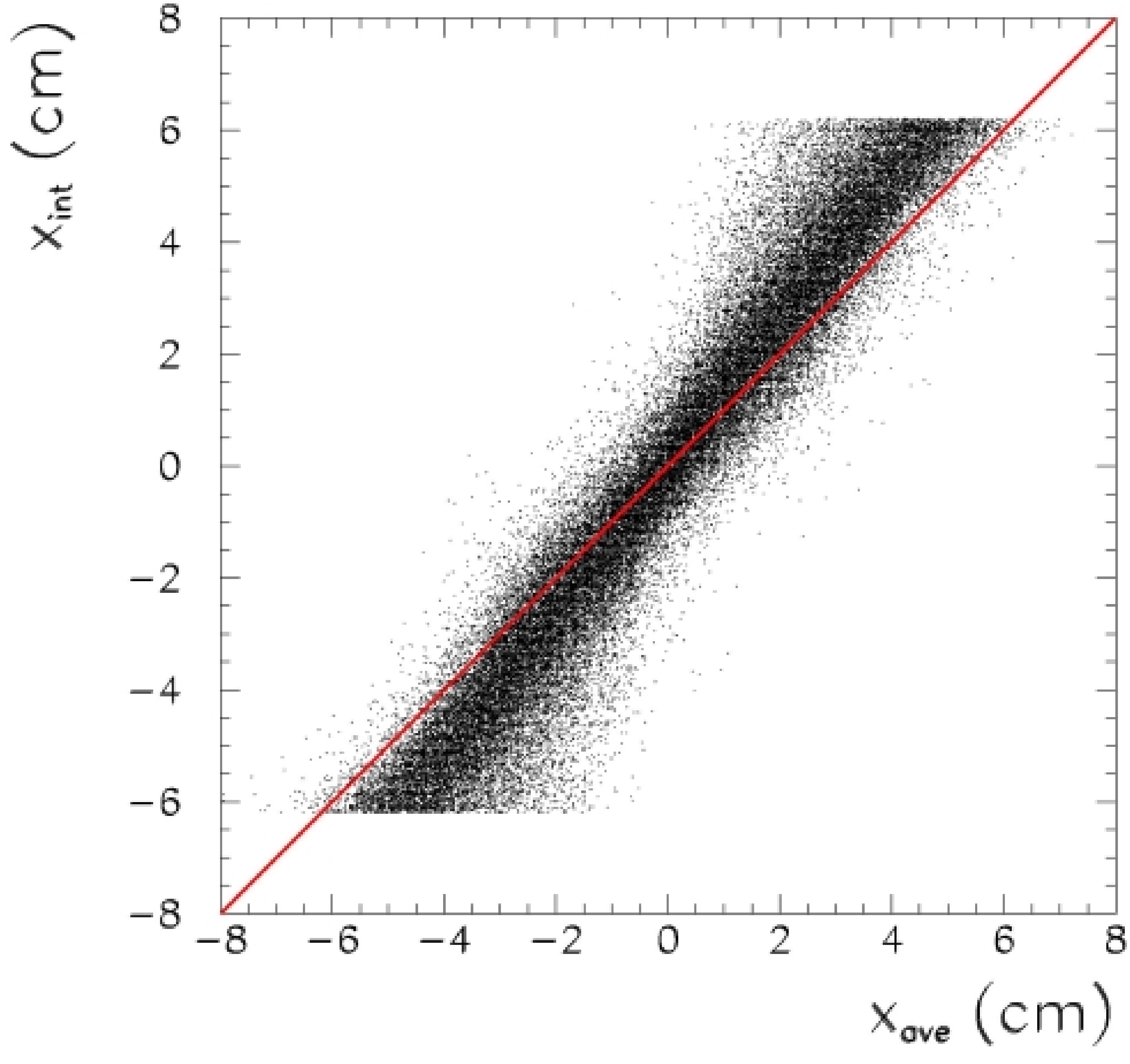
•The energy can be reconstructed on the whole detector with a resolution

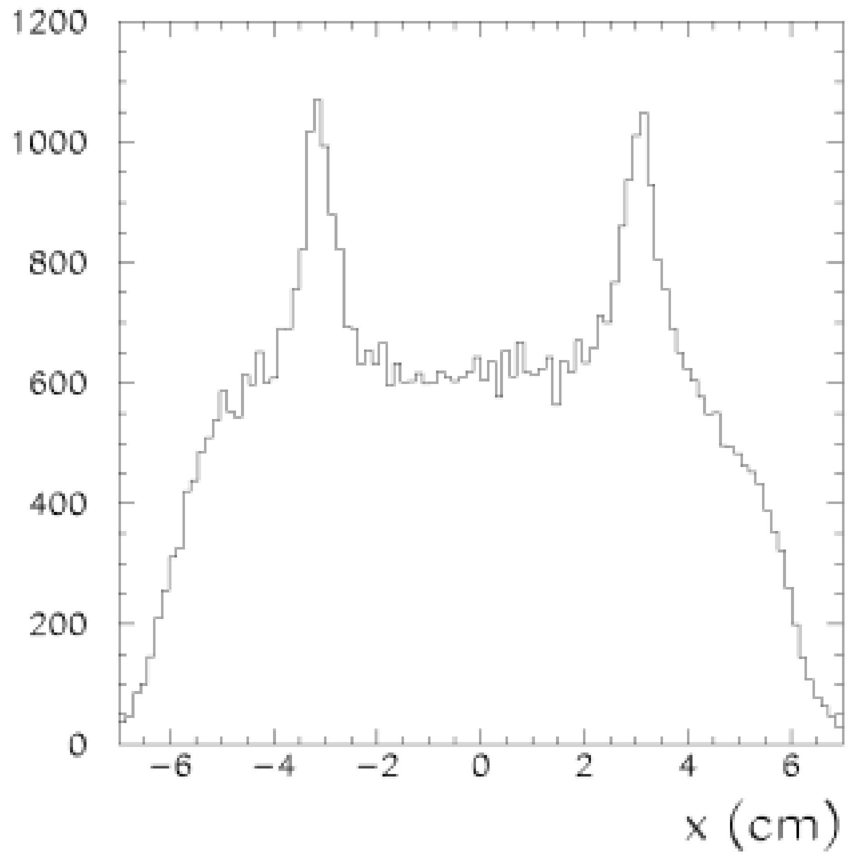
FWHM ~ 4 %

(Conservative values, λ_{abs} = 1 m, QE=5%)

End of presentation

Bias on x_{ave}




1200
1000
800
600
400
200
0
−6
−4
−2
0
2
4
6
x (cm)

MuXeC