Angular resolution study of isolated gamma with GLD detector simulation

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On behalf of the Acfa-Sim-J Group

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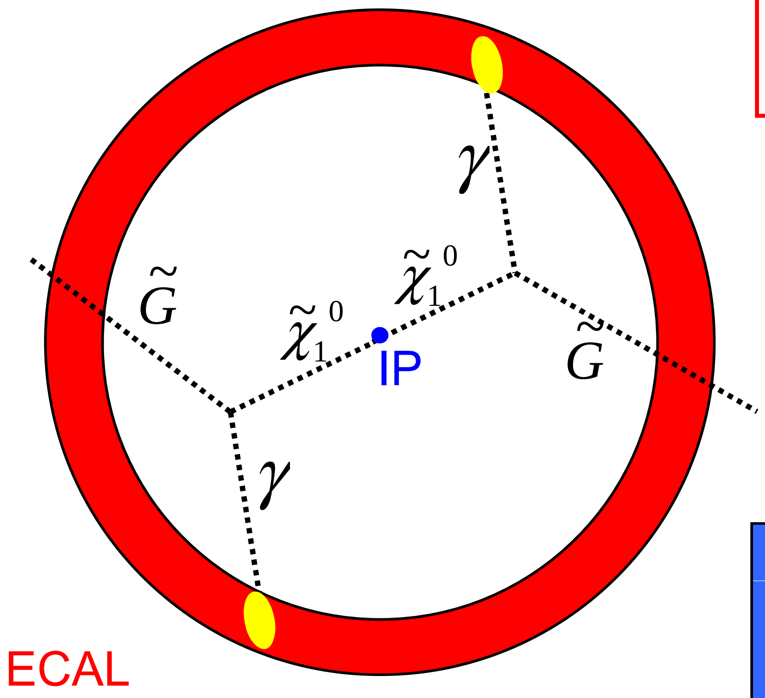
Motivation and PFA Analysis

- Measurement of the direction of non-pointing photon is important for GMSB (gauge mediated supersymmetry breaking) scenarios.

$$\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$$

decay length : $10^{-5} \sim 10^{3}$[m]



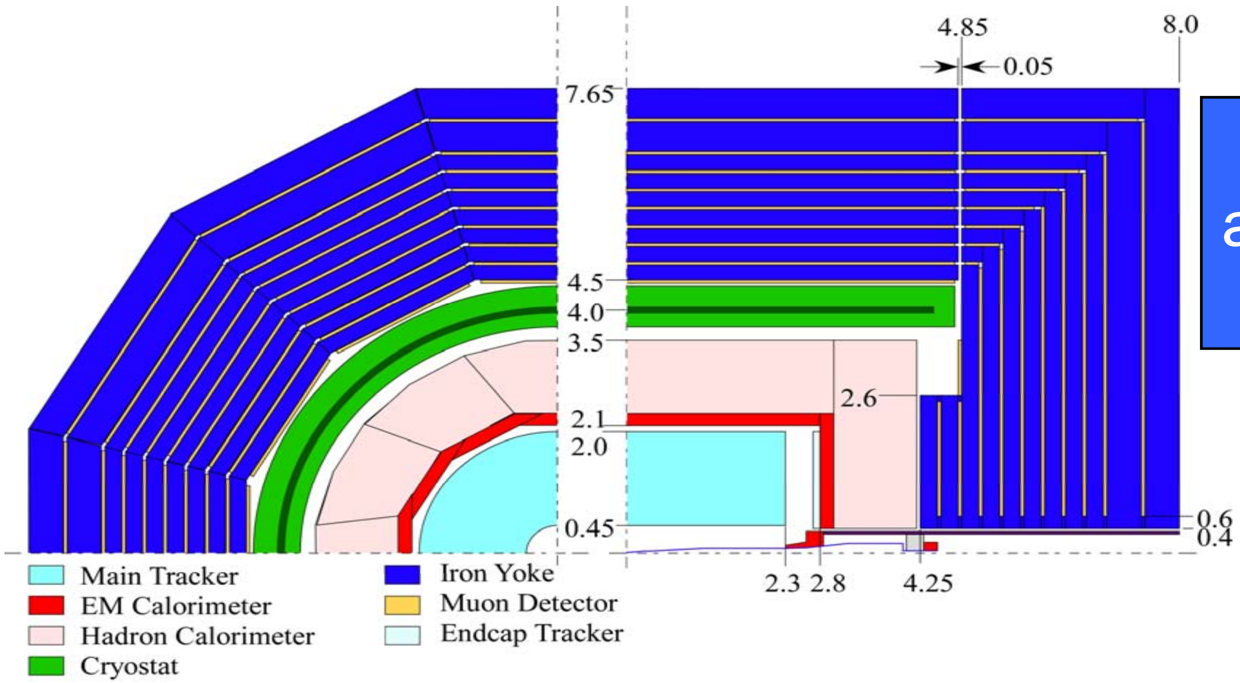
- To identify a non-pointing photon, we need to know angular resolution of the detector (EM Calorimeter).

We have studied angular resolution using full-simulator (Jupiter)

In this study, we have used single-gamma coming from IP to evaluate angular resolution.

GLD Detector Geometry in Jupiter

- GLD detector has large-radius and fine-segmented Calorimeter.



Calorimeter cell size and absorber material can be changed.

It's important to optimize

Cost

vs.

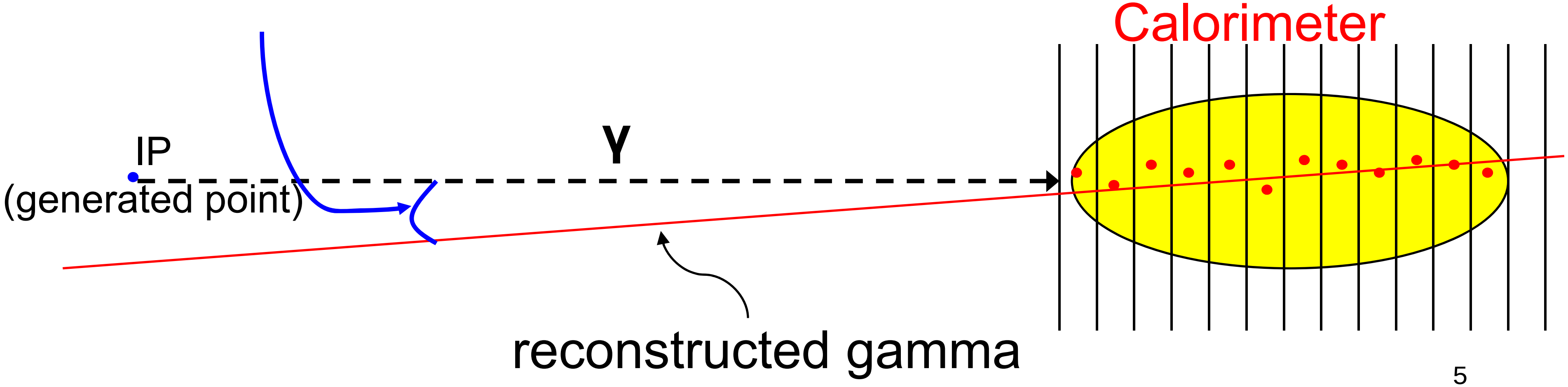
Physics Performance.

ECAL geometry in Jupiter :

		R [m]	Z [m]	Structure
ECAL	barrel	2.1-2.3	0-2.8	W/Scinti./gap 3/2/1(mm) x 33 layers cell size 1x1(cm^2)
	endcap	0.4-2.3	2.8-3.0	

Method of Gamma Reconstruction

1. Clustering
2. Find an energy-weighted central point of each layer
3. Fit each point with least-square method
4. Evaluate an angle between gamma-line and reconstructed gamma

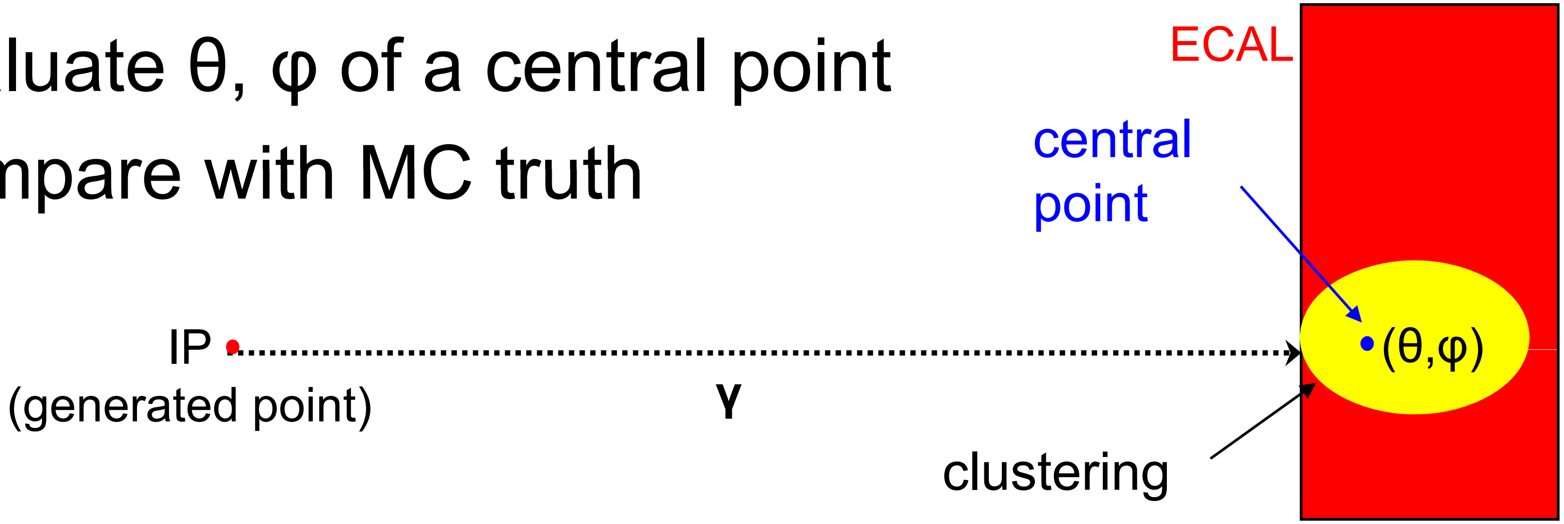


Angular Resolution Study

~ Position Resolution of Cluster ~

Method (position resolution study of isolated gamma cluster)

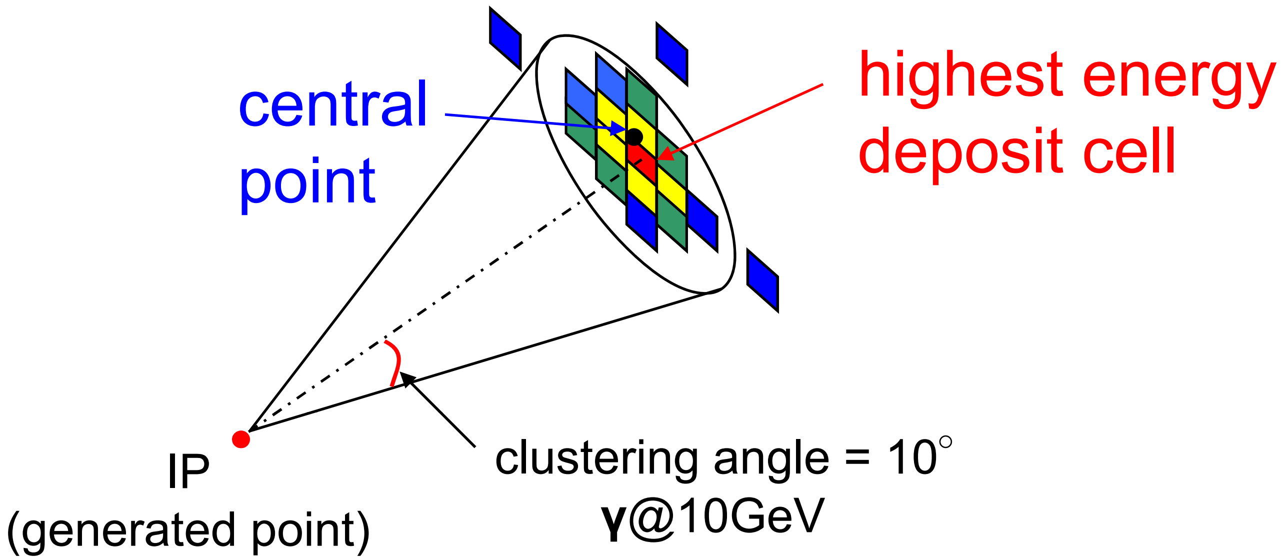
1. Generate single-gamma from IP with random direction
2. Clustering (more details in next page)
3. Search energy-weighted central point of cluster
4. Evaluate θ, φ of a central point
5. Compare with MC truth



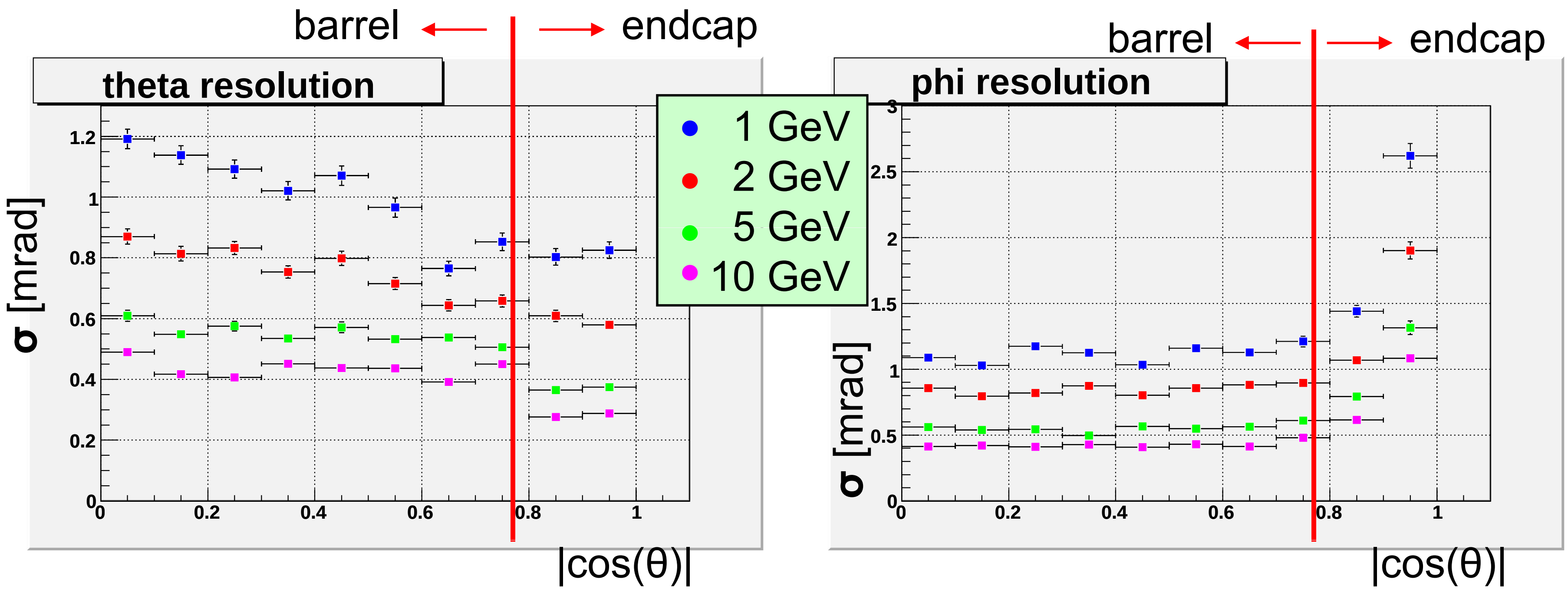
$$\theta\ (\varphi)\ \text{resolution [rad]} = \theta\ (\varphi)_{meas} - \theta\ (\varphi)_{MC}$$

Clustering Method

1. Find the highest energy deposit cell
2. Make a cone around the cell
3. Define cells which are inside of the cone as one cluster (around all layers)
4. Find energy-weighted central point



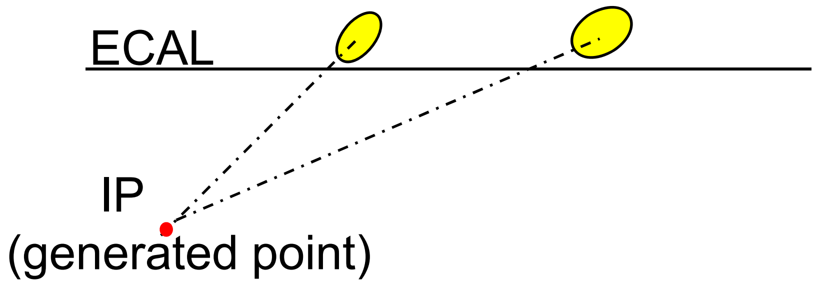
Position Resolution of Cluster (cell : 1 cm)



θ resolution is better for larger cos(θ)

φ resolution is worse for larger cos(θ)

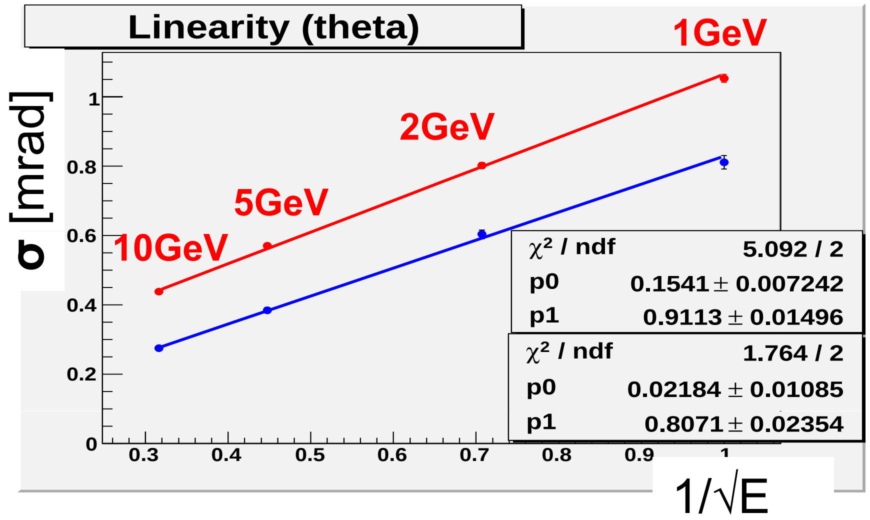
geometrical effect

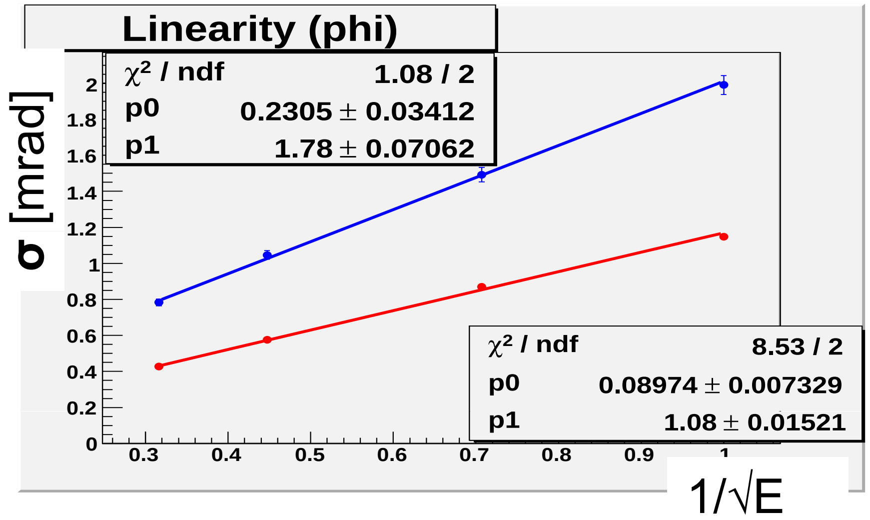


Position resolution : ~0.1 [cm]

gamma@10GeV

Energy Dependent Result of position resolution





θ barrel : $\frac{0.91}{\sqrt{E}} + 0.15$ [mrad]

θ endcap : $\frac{0.81}{\sqrt{E}} + 0.22$ [mrad]

φ barrel : $\frac{1.08}{\sqrt{E}} + 0.09$ [mrad]

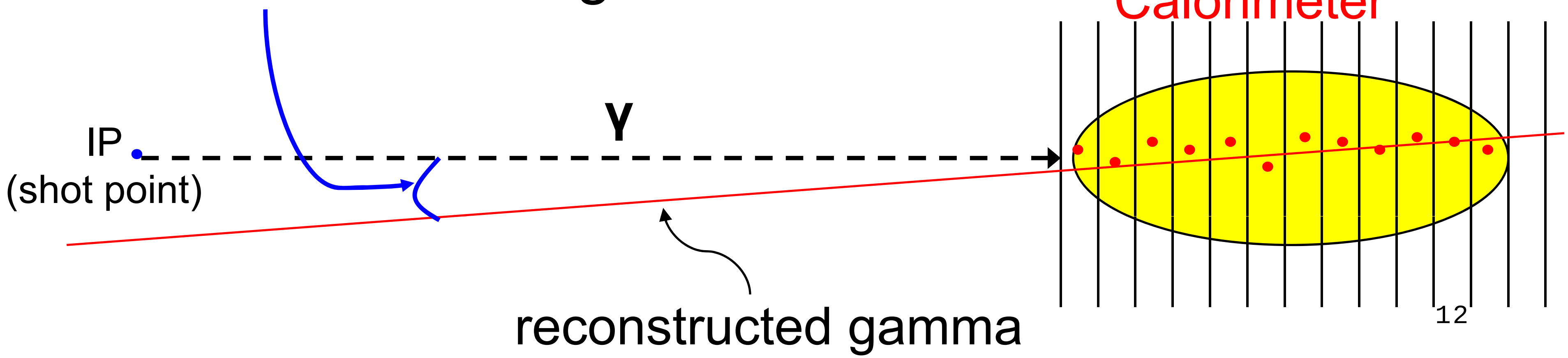
φ endcap : $\frac{1.78}{\sqrt{E}} + 0.23$ [mrad]

Angular Resolution Study

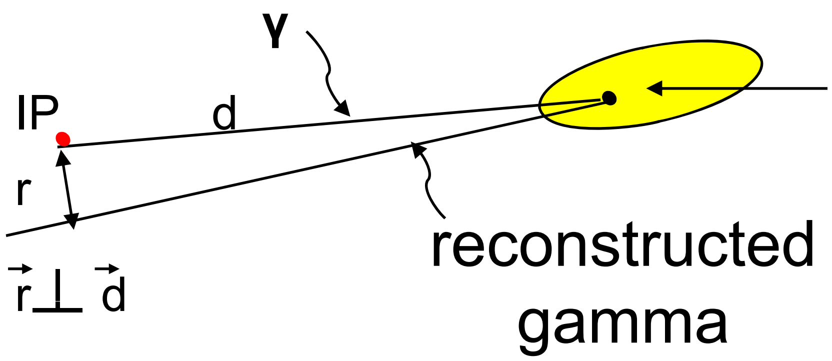
~ Direction of Reconstructed gamma ~

Method (angular resolution study of reconstructed gamma)

1. Clustering
2. Find an energy-weighted central point of each layer
3. Fit each point with least-square method
4. Evaluate an angle between gamma-line and reconstructed gamma



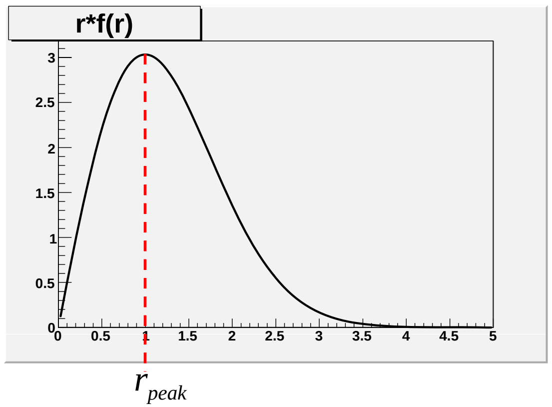
Histogram and Angular Resolution



angle [rad] = r/d

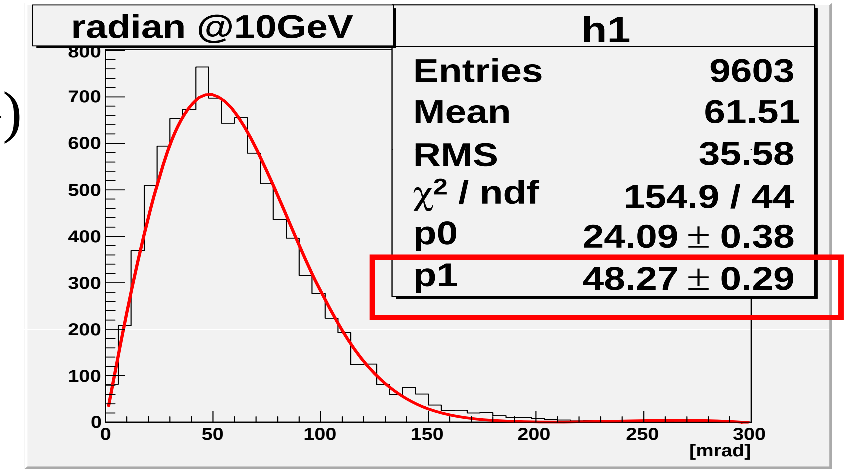
- r histogram F(r)

fitting function → $p0 * x * \exp(-\frac{x^2}{2p1^2})$



$$f(r) = A * \exp(\frac{r^2}{2\sigma^2})$$

$$F(r) = r * f(r)$$

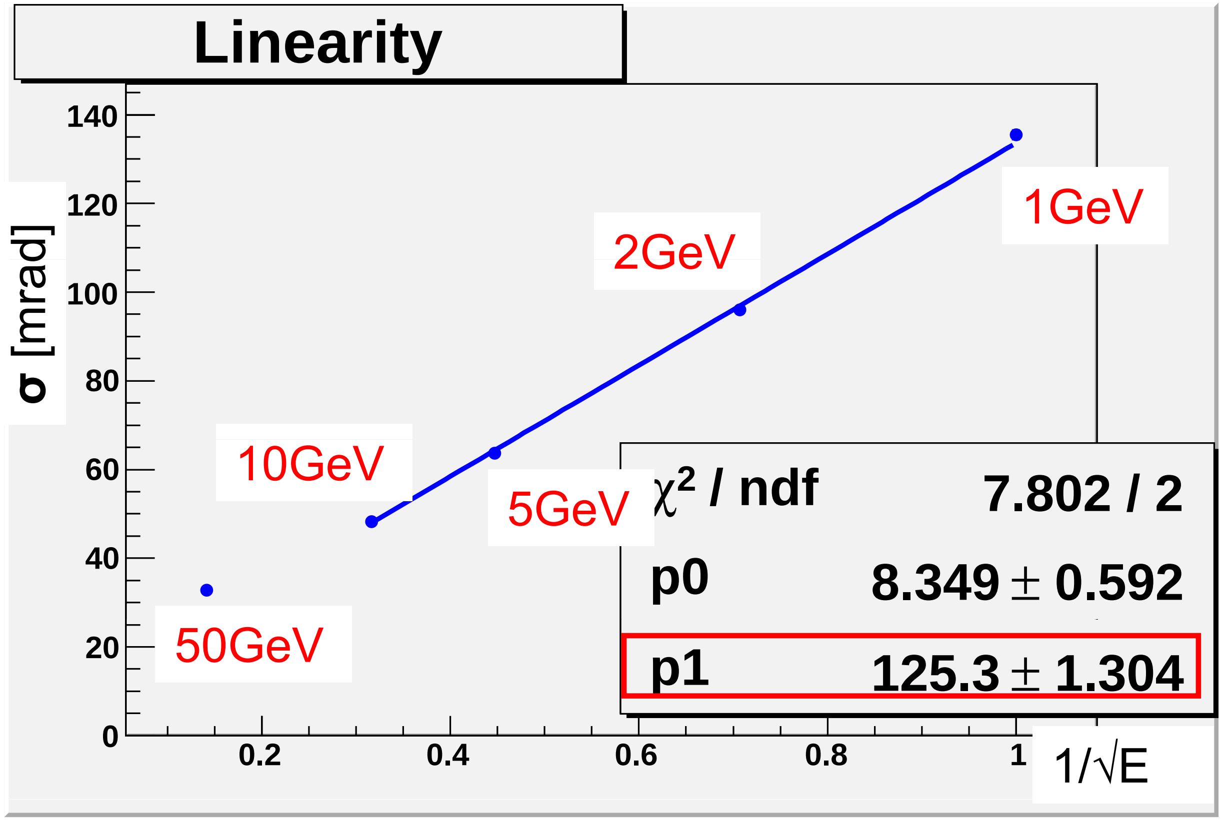


$$\therefore r_{peak} = \sigma_{angle}$$

σ = 48.3 ± 0.3 [mrad]

gamma@10GeV

Energy Dependence (1,2,5,10,50GeV)

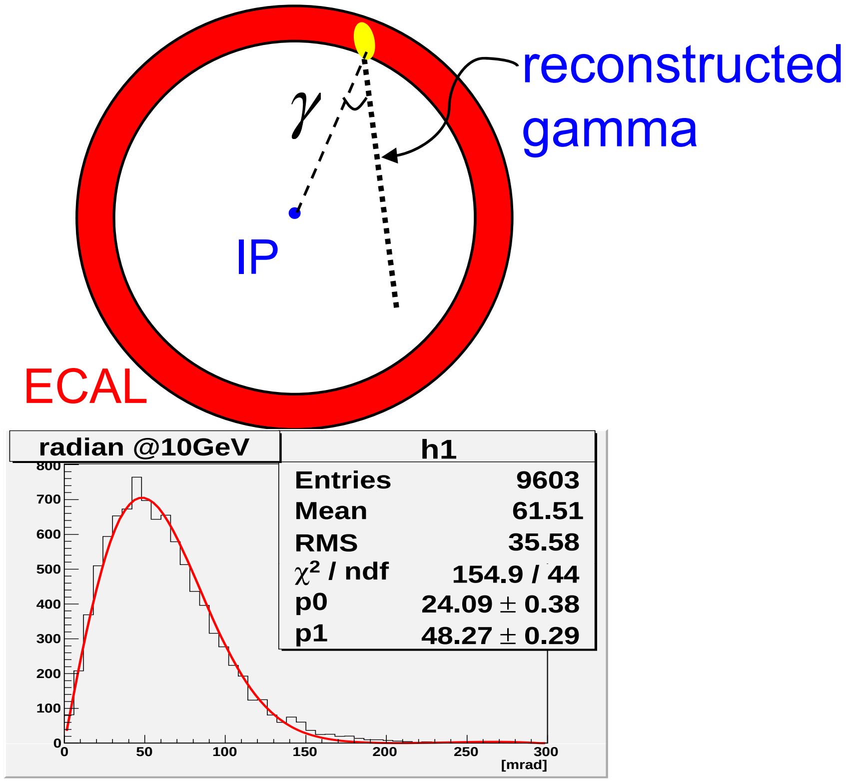


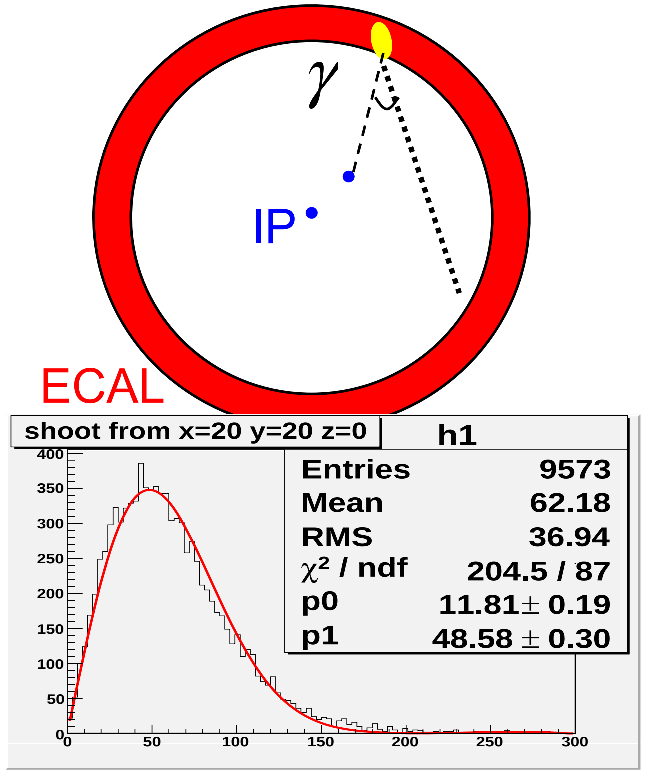
Average over full acceptance

$$\sigma_{angle} = \frac{125}{\sqrt{E}} \text{ [mrad]}$$

Shoot from another point gamma@10GeV

- Shoot from IP
- Shoot from x=y=20cm, z=0





σ= 48.3±0.3[mrad]

σ= 48.6±0.3[mrad]

If gamma has been shot from another position,
we could not observe significant difference.

Calorimeter Component Dependence

Structure (cell size dependence)

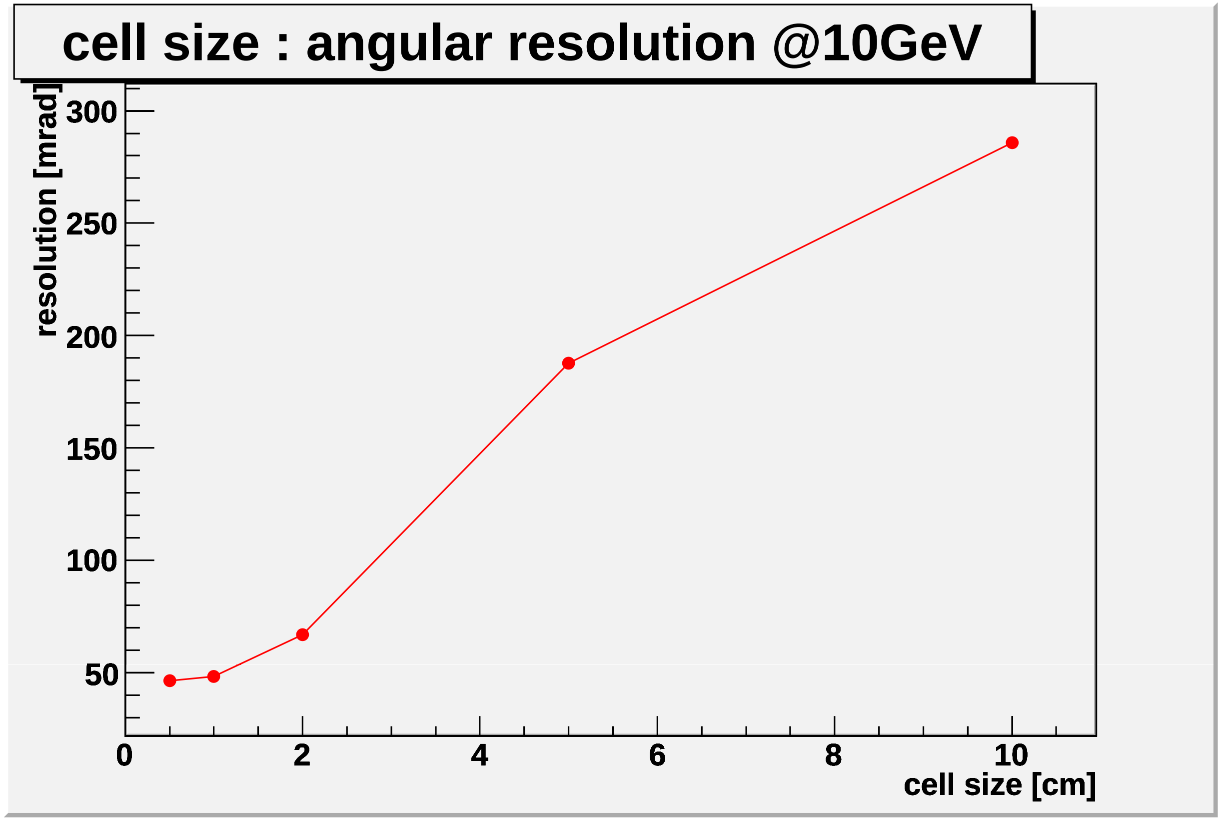
gamma : E = 10GeV

33 layers

Absorber	cell size [cm]	X_0	Energy Resolution
W[3mm]	0.5~10	28	14.8%

How about cell size dependence?

Cell size dependence



gamma @10GeV

1 [cm] : 48.3 ± 0.3 [mrad] 0.5 [cm] : 46.4 ± 0.3 [mrad]

<5%

We could not observe significant improvement from 1cm to 0.5cm

Structure (energy dependence)

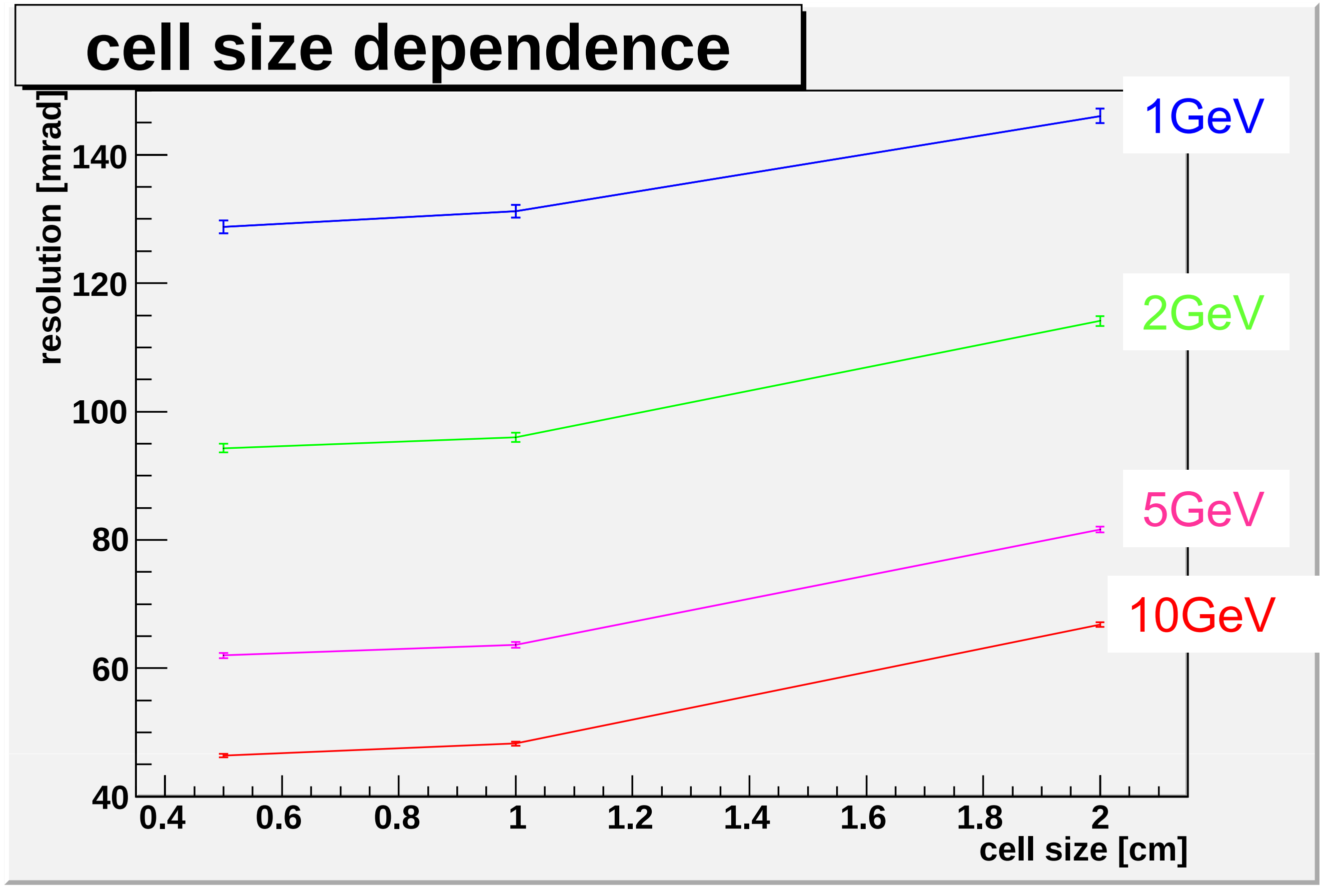
gamma : E = 1~10GeV

33 layers

Absorber	cell size [cm]	X_0	Energy Resolution
W[3mm]	0.5~2	28	14.8%

How about energy dependence between 1cm and 0.5cm?

Energy Dependence (1,2,5,10GeV)



No significant difference has been observed between 1cm and 0.5cm around all of energy.

Structure (Absorber dependence)

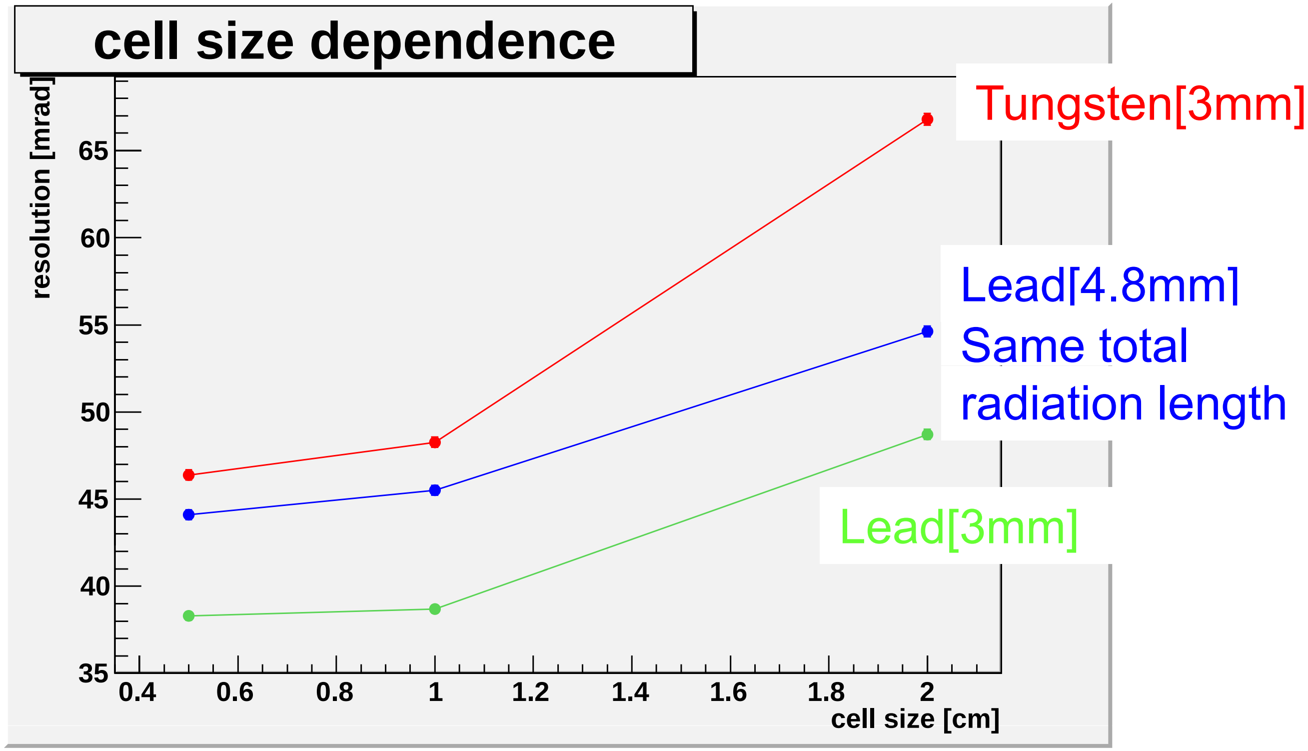
gamma : E = 10GeV

33 layers

Absorber	cell size [cm]	X_0	Energy Resolution
W [3mm]	0.5~2	28	14.8%
Pb [4.8mm]	0.5~2	28	15.0%
Pb [3mm]	0.5~2	22	10.5%

How about absorber dependence?

Absorber Dependence (Tungsten, Lead)

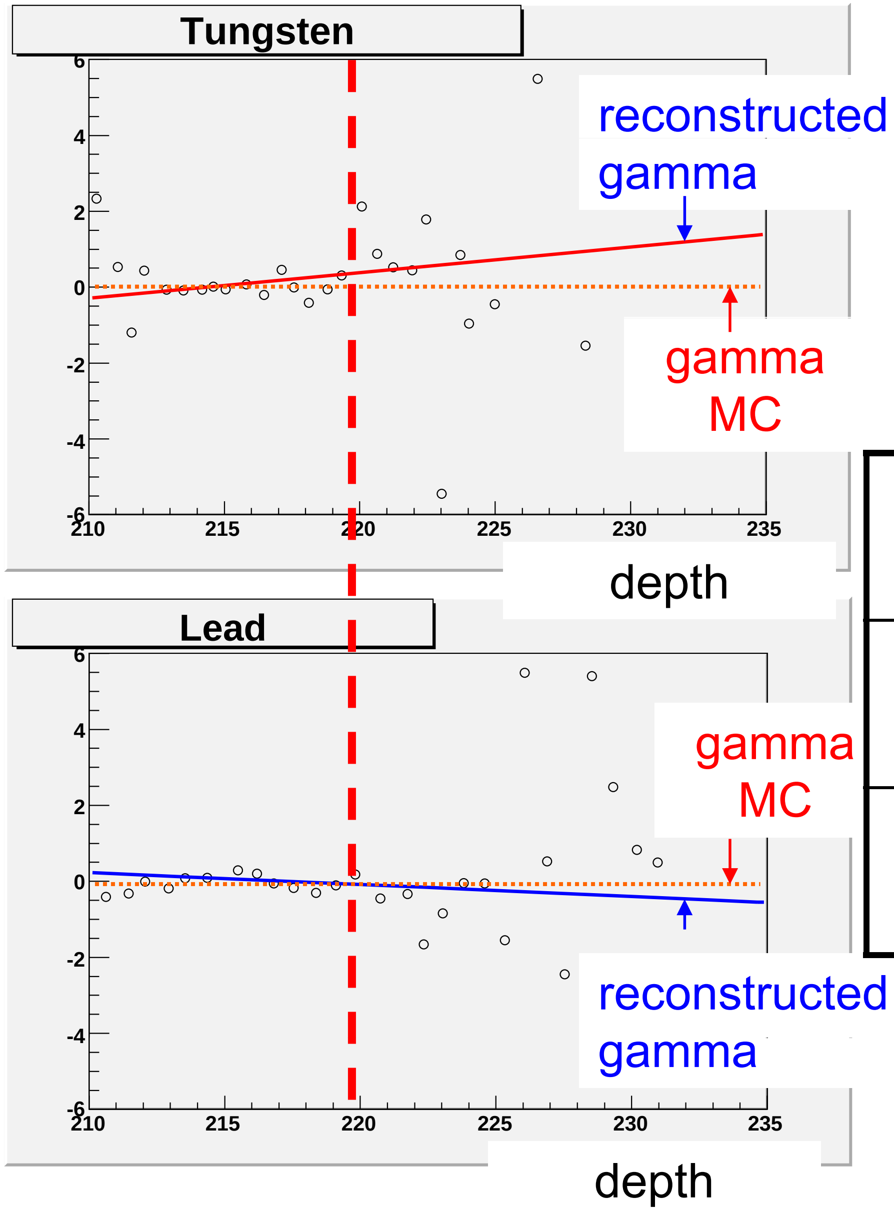


Tungsten [3mm]	:	48.3 ± 0.3 [mrad]
Lead [4.8mm]	:	45.5 ± 0.3 [mrad]

@1x1 [cm]

Angular resolution with Lead is better than Tungsten

Hit Distribution



Angular resolution is better than Tungsten, since shower length is longer in Lead

gamma @10GeV	Tungsten [3mm]	Lead [4.8mm]
Angular resolution	48.3 $\pm$ 0.3 [mrad]	45.5 $\pm$ 0.3 [mrad]
Energy Resolution	14.8%	15.0%

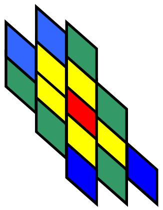
Summary

- Angular resolution of default-GLD Calorimeter (W:1cm)
  - The angular resolution is estimated to be 125mrad/√(E/GeV)
- Dependence on cell size granularity and material dependence (W, Pb) has been studied
  - No significant difference has been observed between 1cm and 0.5cm
  - Lead is better than Tungsten for isolated gamma
  - Energy resolution is same
  - How about energy resolution for jet ? → Next speaker T.Yoshioka

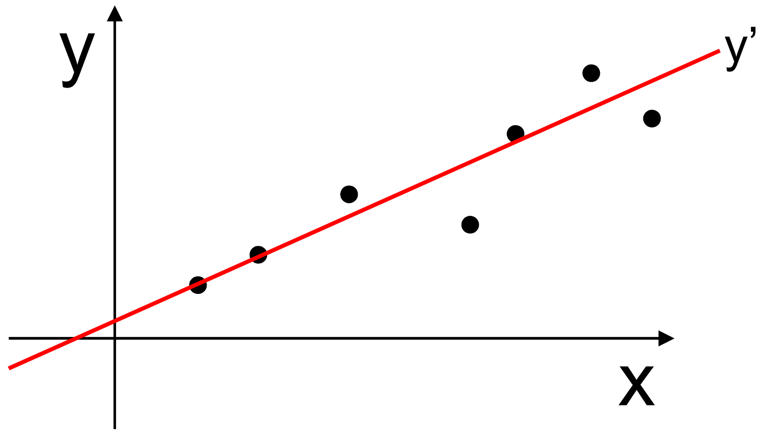
Backup

Fitting method

Find a central point of each layer by energy weighted mean

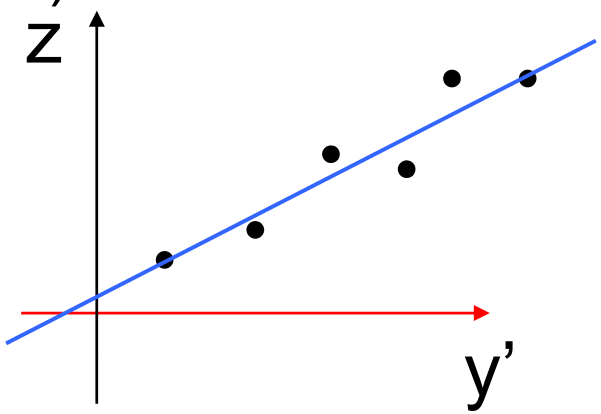


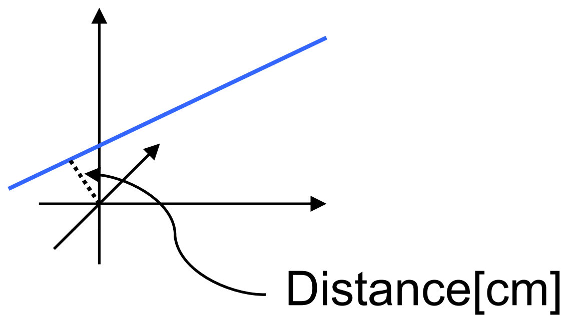
Fitting 2-dimentions (x-y)



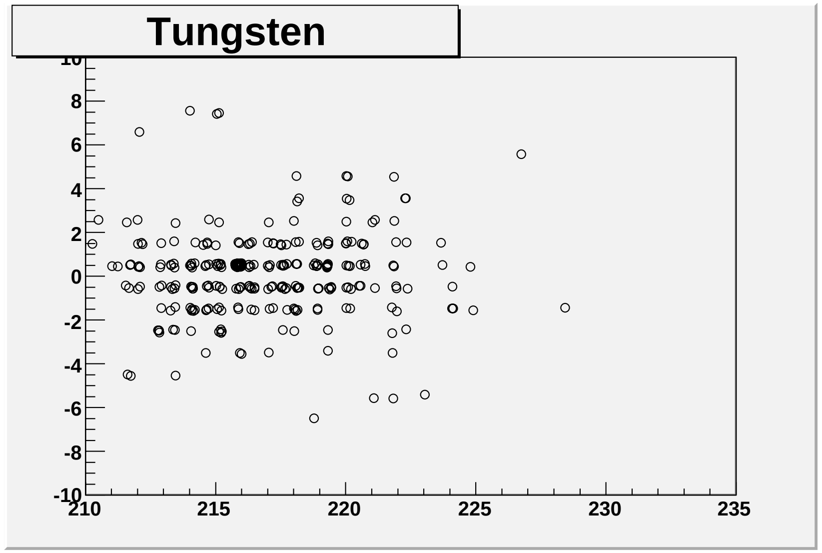
weighted by energy deposit

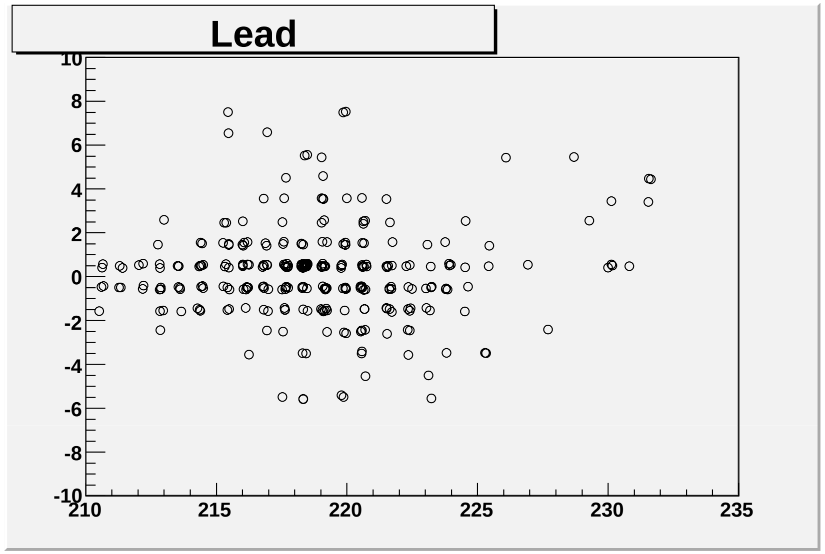
Fitting new 2-dimentions (y’-z)





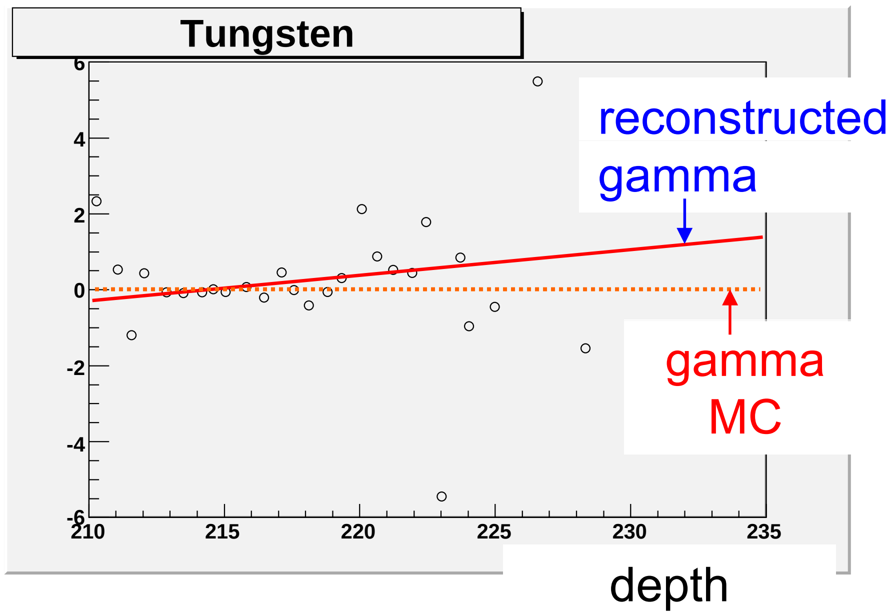
Hitting distribution and Average

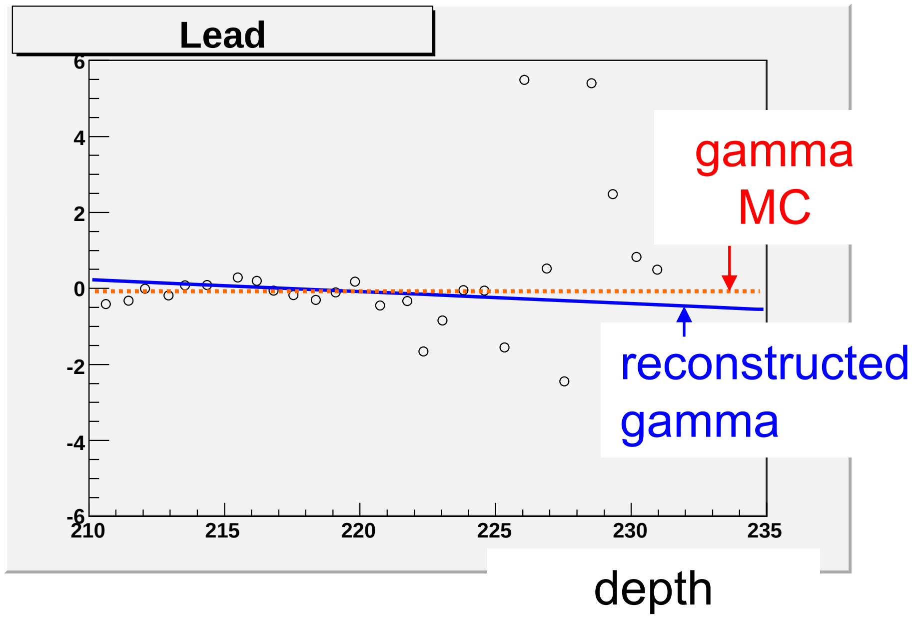




gamma@10GeV	Hit cell number	Layer number of central point	Energy Resolution
Tungsten	252	5.7	14.8%
Lead	284	5.6	15.0%

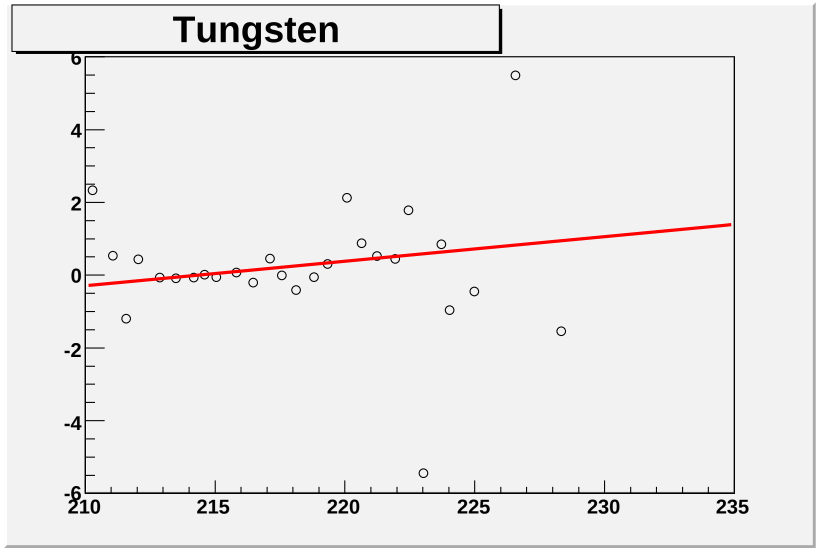
Hit Distribution

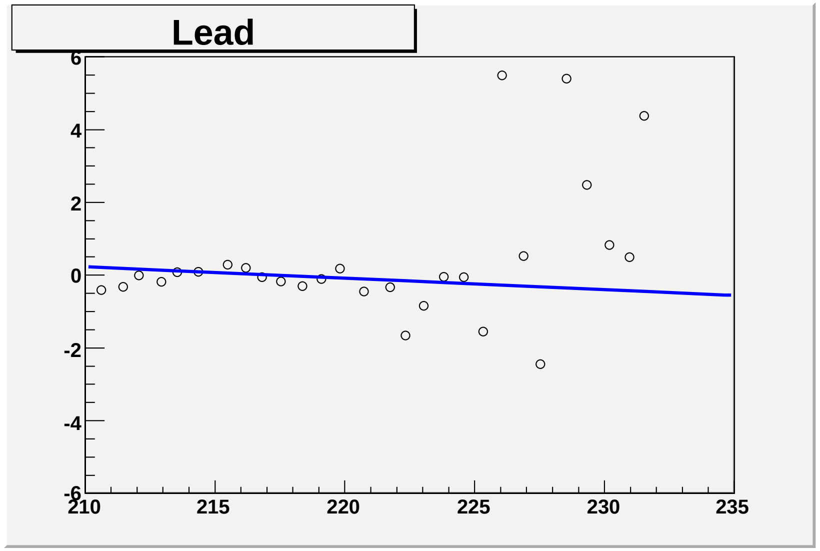


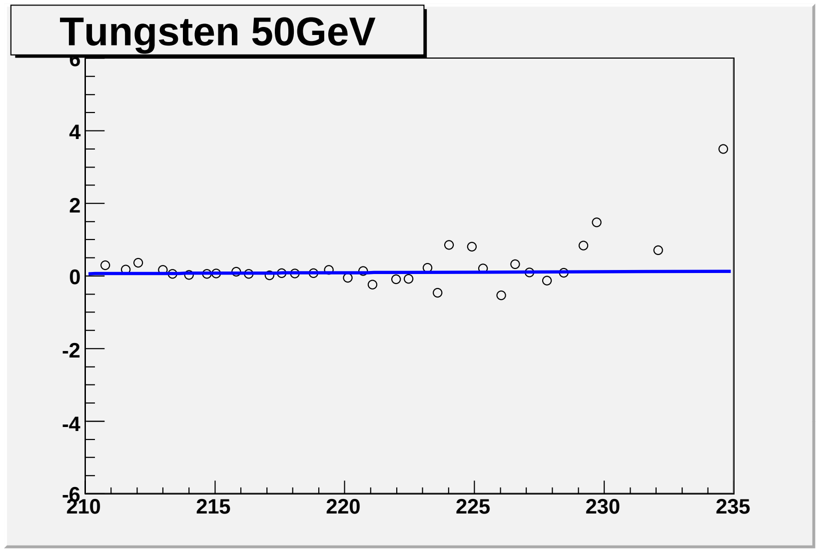


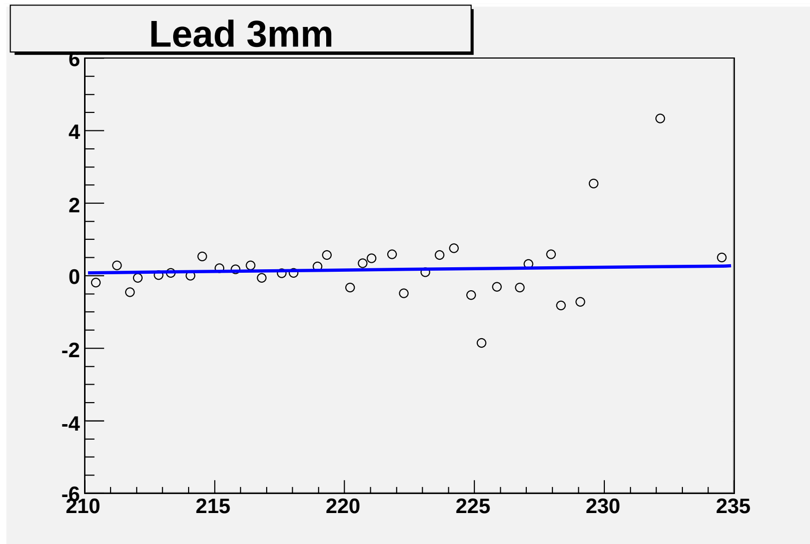
Angular resolution is better than Tungsten, since Lead has geometrical deeper distribution.

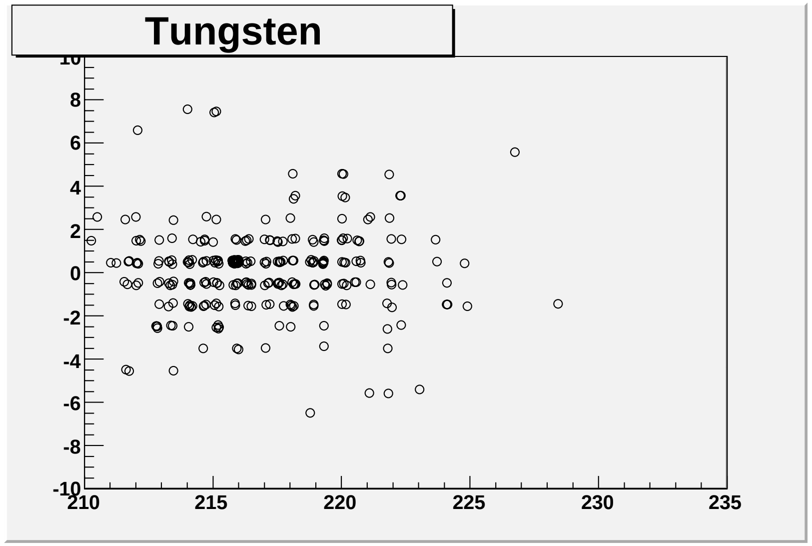
gamma@10GeV	Angular Resolution	Energy Resolution
Tungsten [3mm]	48.3 ± 0.3 [mrad]	14.8%
Lead [4.8mm]	45.5 ± 0.3 [mrad]	15.0%

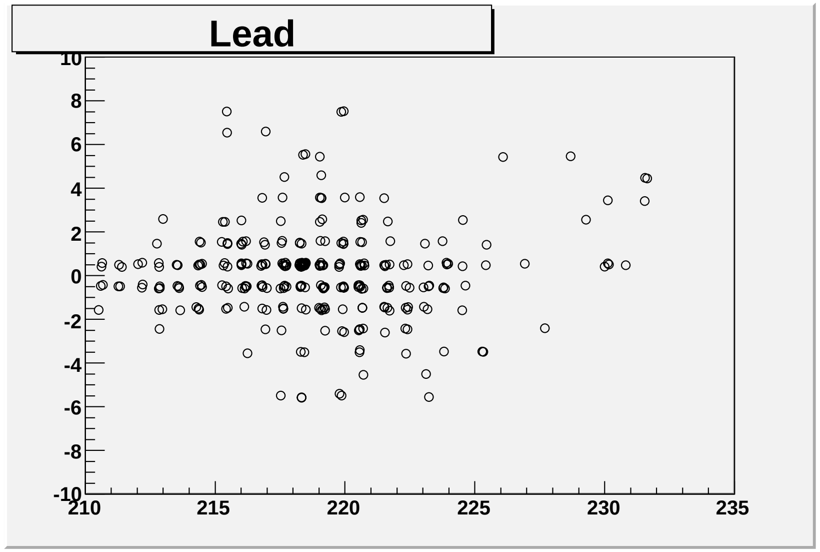

Tungsten
6
4
2
0
-2
-4
-6
210
215
220
225
230
235


Lead
6
4
2
0
-2
-4
-6
210
215
220
225
230
235


Tungsten 50GeV
4
2
0
-2
-4
-6
210
215
220
225
230
235


Lead 3mm
6
4
2
0
-2
-4
-6
210
215
220
225
230
235


Tungsten
10
8
6
4
2
0
-2
-4
-6
-8
-10
210
215
220
225
230
235


Lead
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-4
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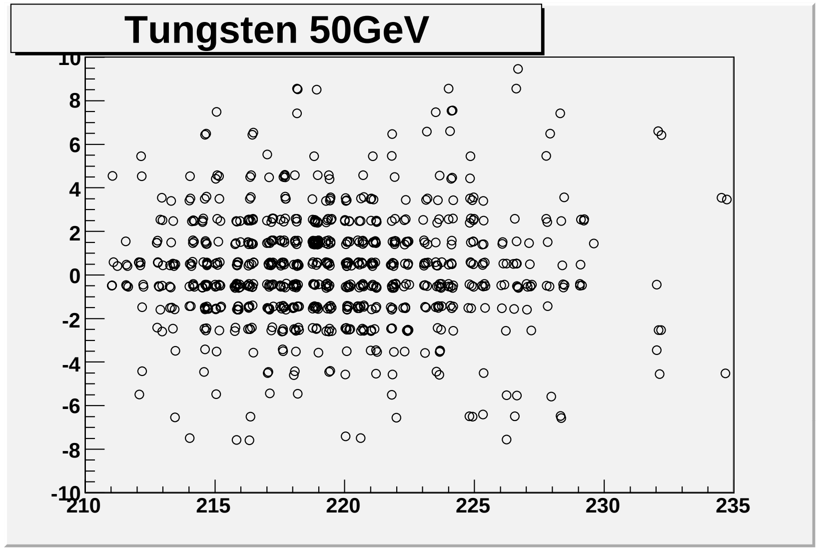
Tungsten 50GeV
10
8
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-8
-10
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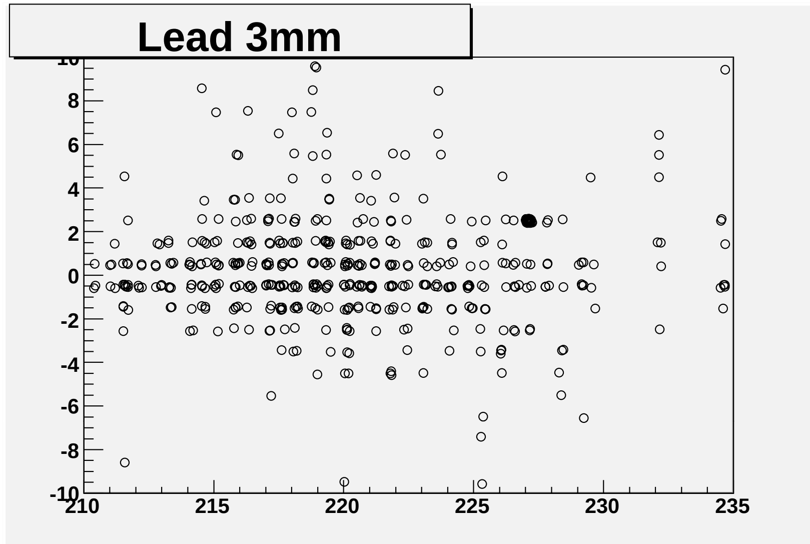
Lead 3mm
10
8
6
4
2
0
-2
-4
-6
-8
-10
210
215
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235