Photons in SPD detector

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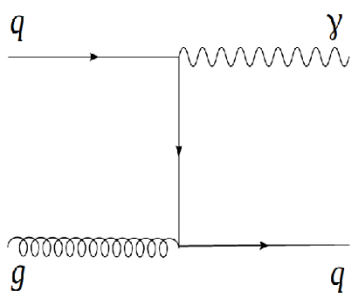
Direct photons program on SPD detector

Photons produced in the hard scattering, named the direct photons, provide information about gluon component of the proton.

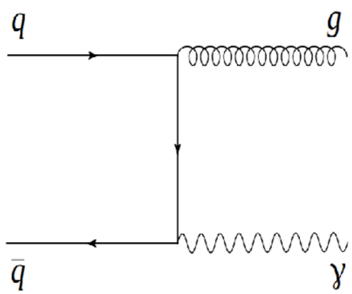
two main sources of direct photons:

quark gluon Compton scattering



$$\sigma_{pp\to\gamma X} = 1.22 \times 10^{-3} mb$$

q-qbar annihilation



$$\sigma_{pp\to\gamma X} = 0.24 \times 10^{-3} mb$$

$$\sqrt{S} = 26\ \mathrm{GeV}$$

Signal/background estimation

Total pp cross section $\sigma_{pp} = 40$ mb

Planned luminosity $L = 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-2}$

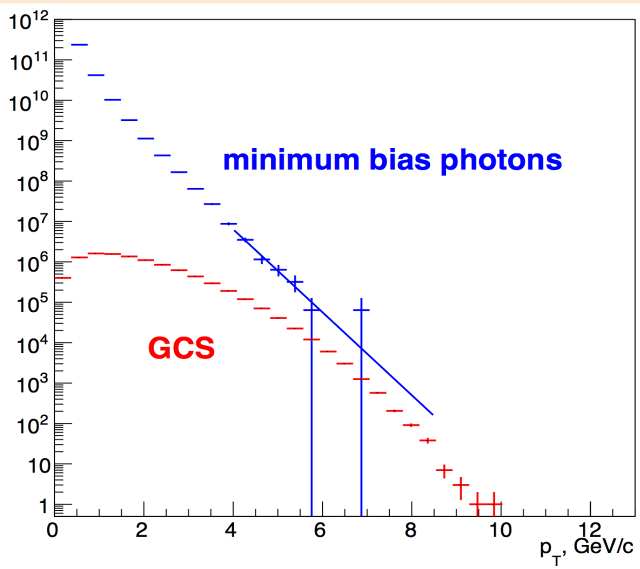
An average multiplicity of decays photons ≈ 9 (per 1 event)

we should expect **Per 1 second**
34 800 000 - background photons and
122 - direct photons

$$\frac{\textbf{signal}}{\textbf{background}} = \frac{\mathbf{1}}{\mathbf{285\ 000}}$$

The main source of photons (almost 99%) in proton-proton collision is the production and decay of π^0 and η mesons

photons in 10^6-pp collisions	
π^0	$8.7 * 10^6$
η	400000
ω	59500
η'	46200
Σ^0	34500
Δ^+	1610
Δ^0	1130
ρ^0	743
K^{*0}	600
ρ^{+0}	570
ϕ	540
Λ	470
K^{*+}	370
γ_{direct}	30



For $p_T \geq 3$ GeV/c

$$\frac{\textbf{signal}}{\textbf{background}} = \frac{\mathbf{1}}{\mathbf{454}}$$

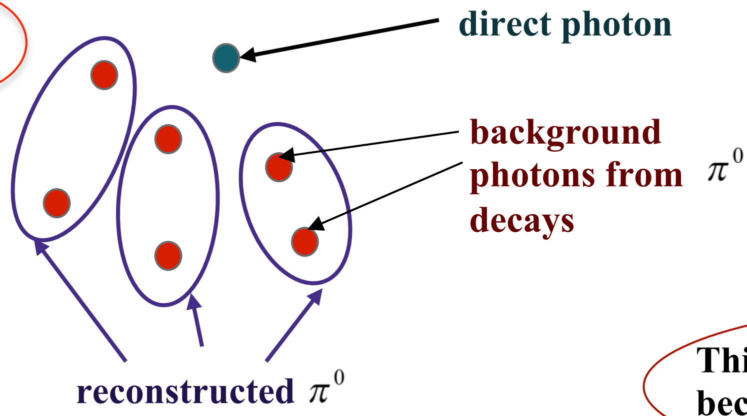
630 times better

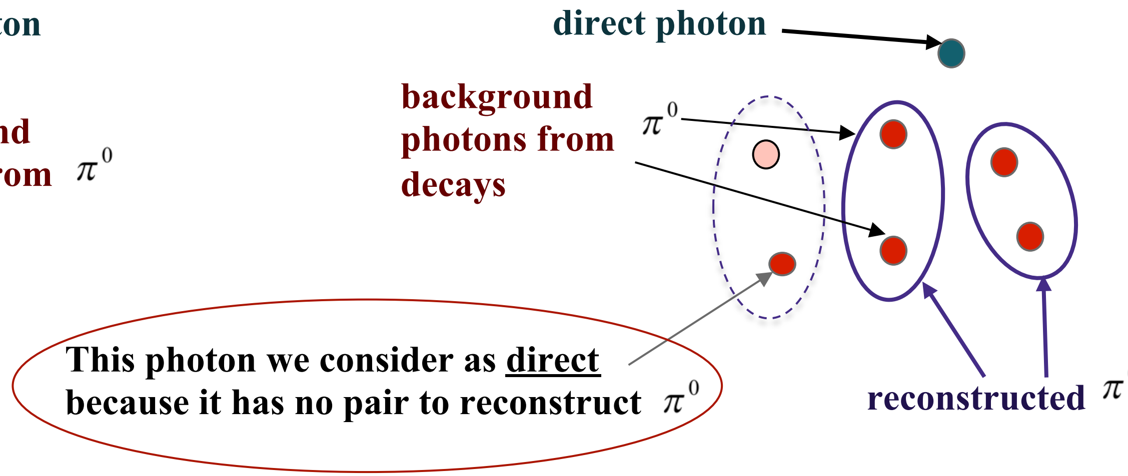
Background subtraction

in an ideal calorimeter

in an real calorimeter

1





2

from Monte Carlo information we know there must be photons from π^0

we can find out what part of the π^0 we could not reconstruct

$$\sigma \sim N_{\text{direct}} = N_{\text{single }\gamma} - 2 \times N_{\pi^0} \times k$$

k - from MC data

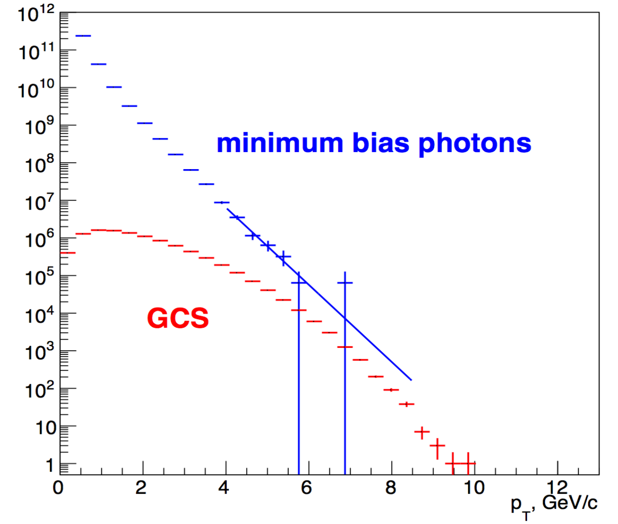
$$k = \frac{1}{reconstruction\ efficiency} - 1$$

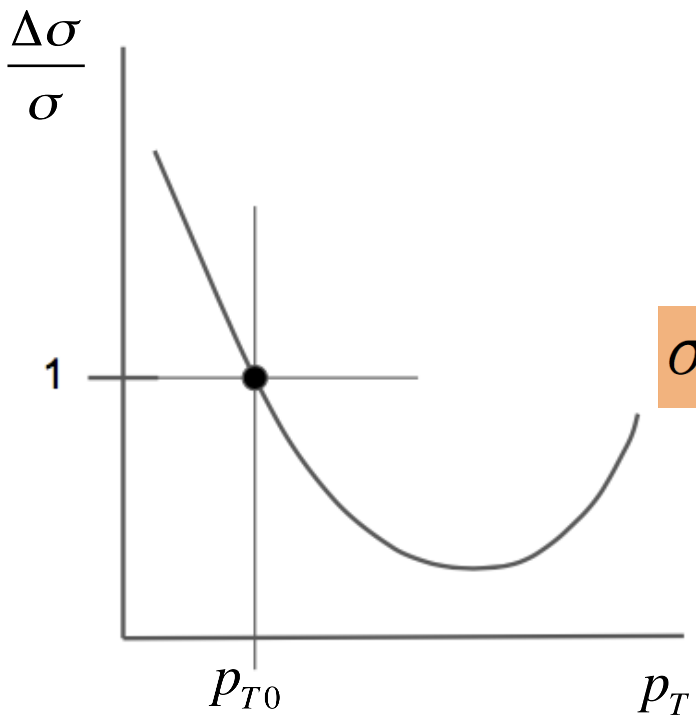
Effective reconstruction of π^0 decays is the main way to suppress the background.

for 100% efficiency of the π^0 reconstruction <u>k=0</u>

Transverse momentum threshold

With p_T increasing the ratio signal to background increases





$$\sigma \sim N_{\text{direct}} = N_{\text{single }\gamma} - 2 \times N_{\pi^0} \times k$$

$$\frac{\Delta k}{k} = 0.01$$ from MC data

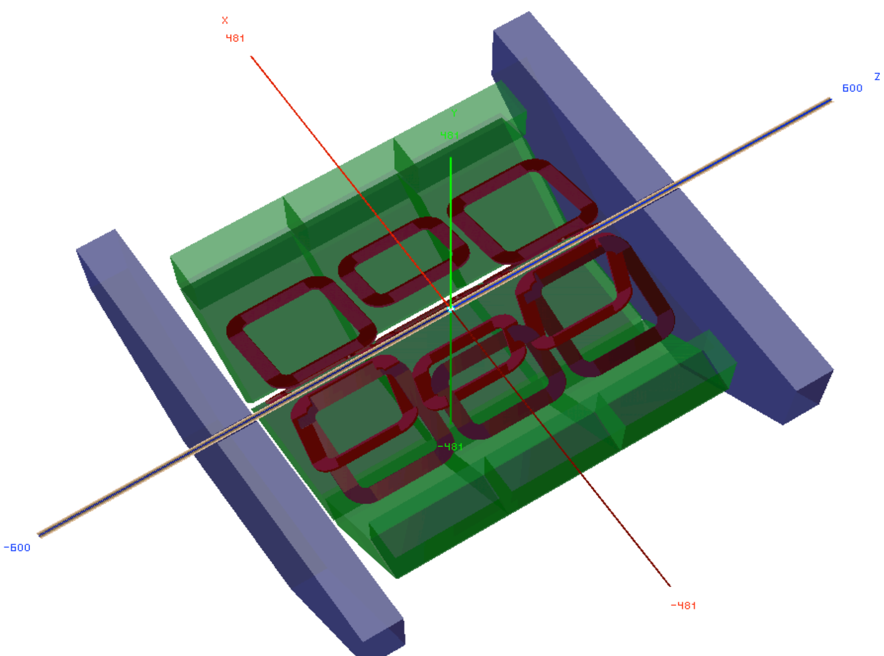
p_{T0} From previous experiments is in the range [2-4] GeV/c

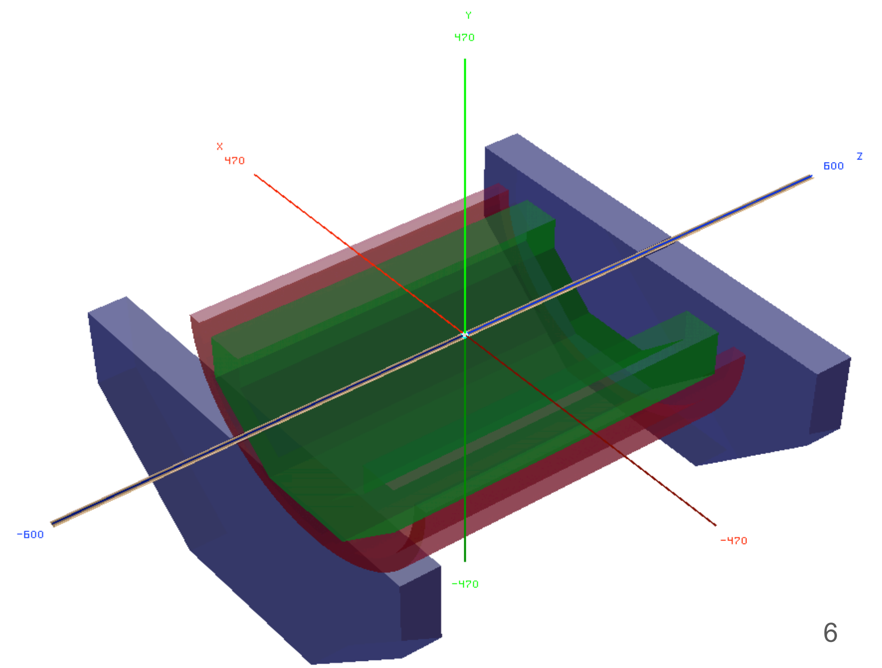
Threshold on transverse momentum to get an error less than 100 %

Two types of magnet system will be discuss in this contest

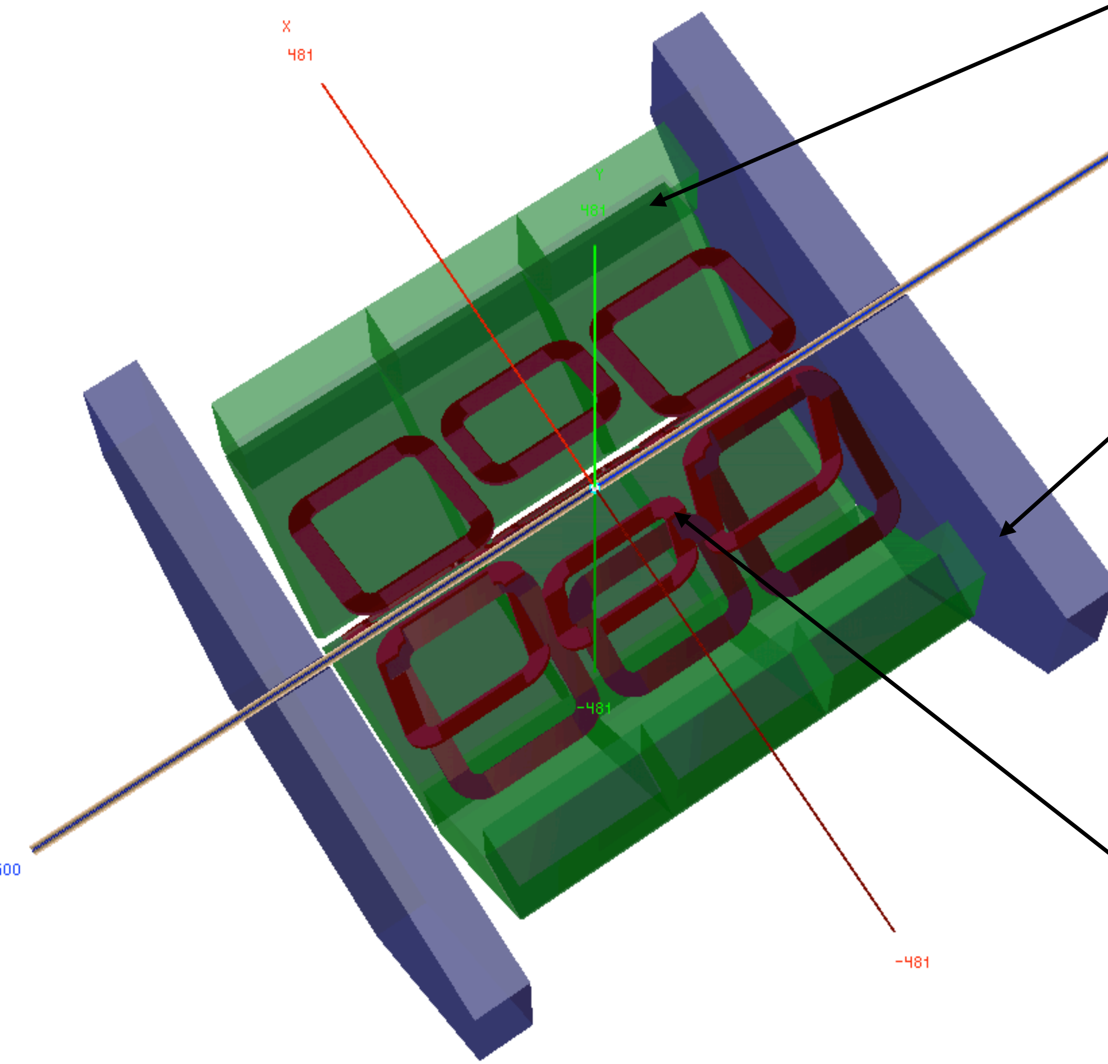
- Toroidal magnet system
- Solenoidal magnet system

Pythia 6 Monte Carlo generator, SPDROOT
Geometry: Beryllium pipe, magnet coils, electromagnetic calorimeter (ECAL). The calorimeter response is not simulated





Geometry with toroidal magnet



TOROIDAL ELECTROMAGNETIC CALORIMETER BARREL

Barrel length = 510 cm

Barrel internal R = 205 cm

Barrel width = 60 cm

TOROIDAL ELECTROMAGNETIC CALORIMETER ENDCAPS

Caps R = 340 cm

Caps width = 58 cm

Internal R = 6 cm

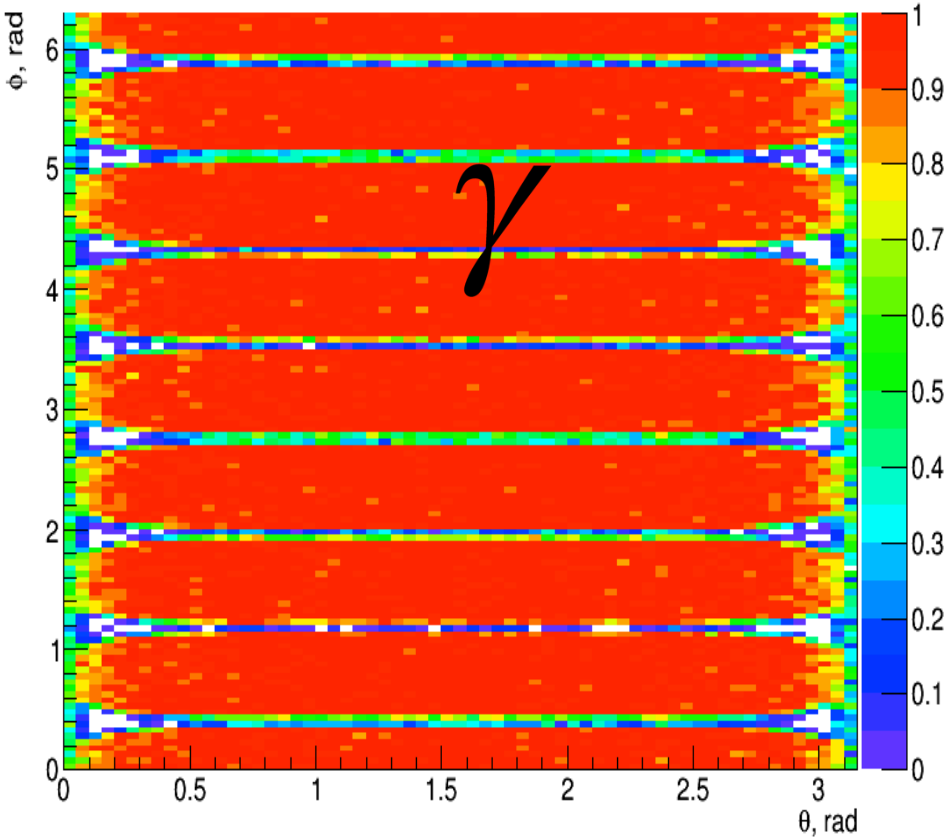
TOROIDAL MAGNET SYSTEM

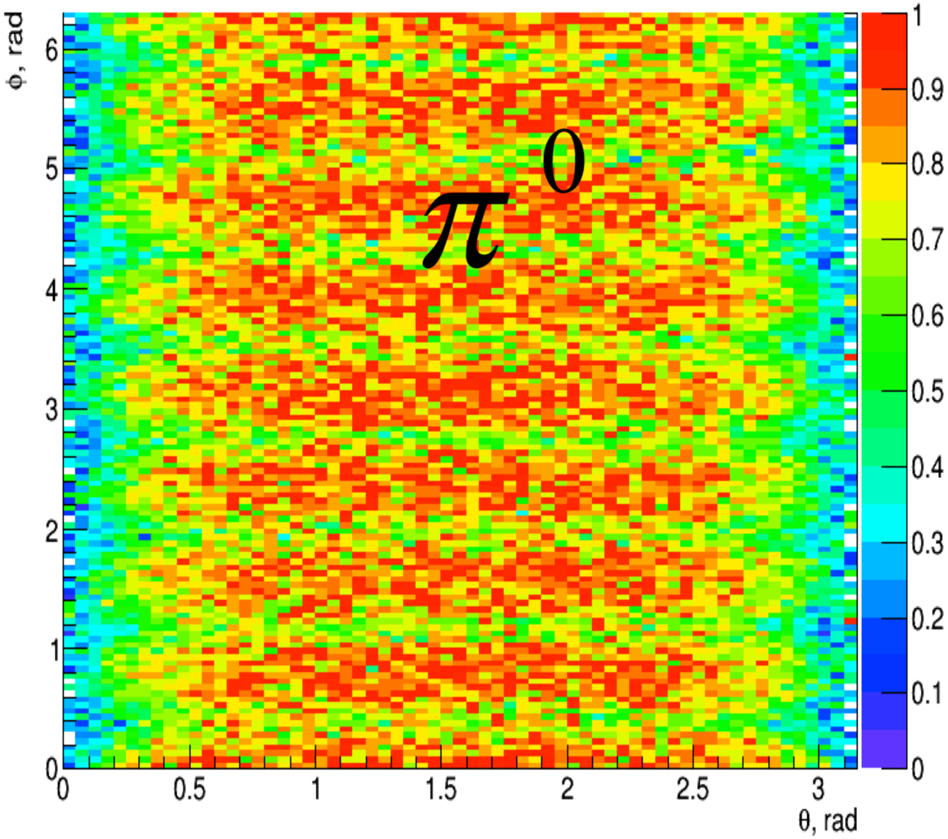
Mag field ≈ 1 T

BEAM PIPE (Be)

Thickness = 2.8 % of radiational lenght

Reconstruction efficiency

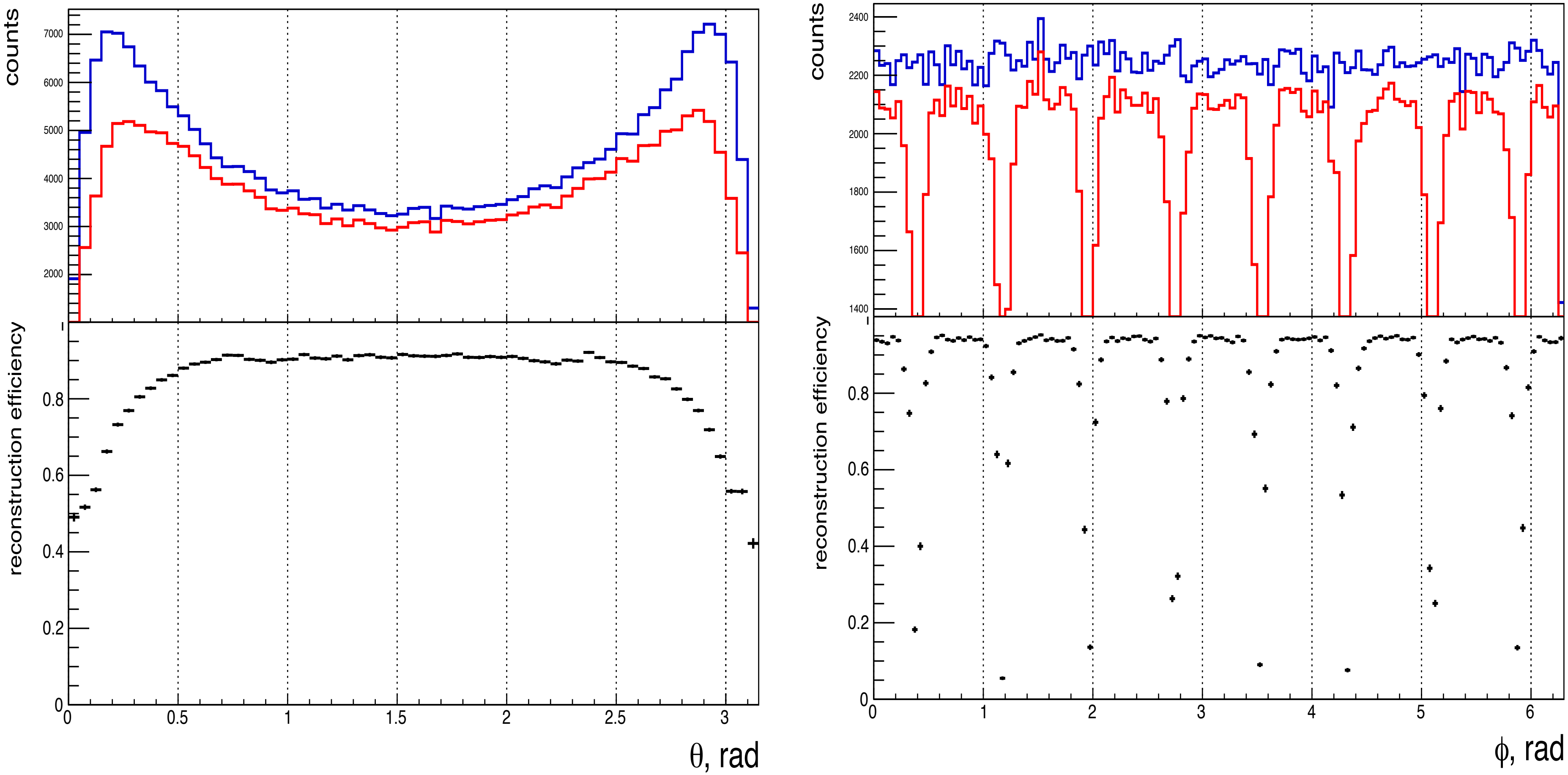




Reconstuction efficiency as function of angles for single γ from π^0 decays (left) and when both photons from π^0 decay reached ECAL (right)

Single photon	π^0
83.1 %	68.9 %

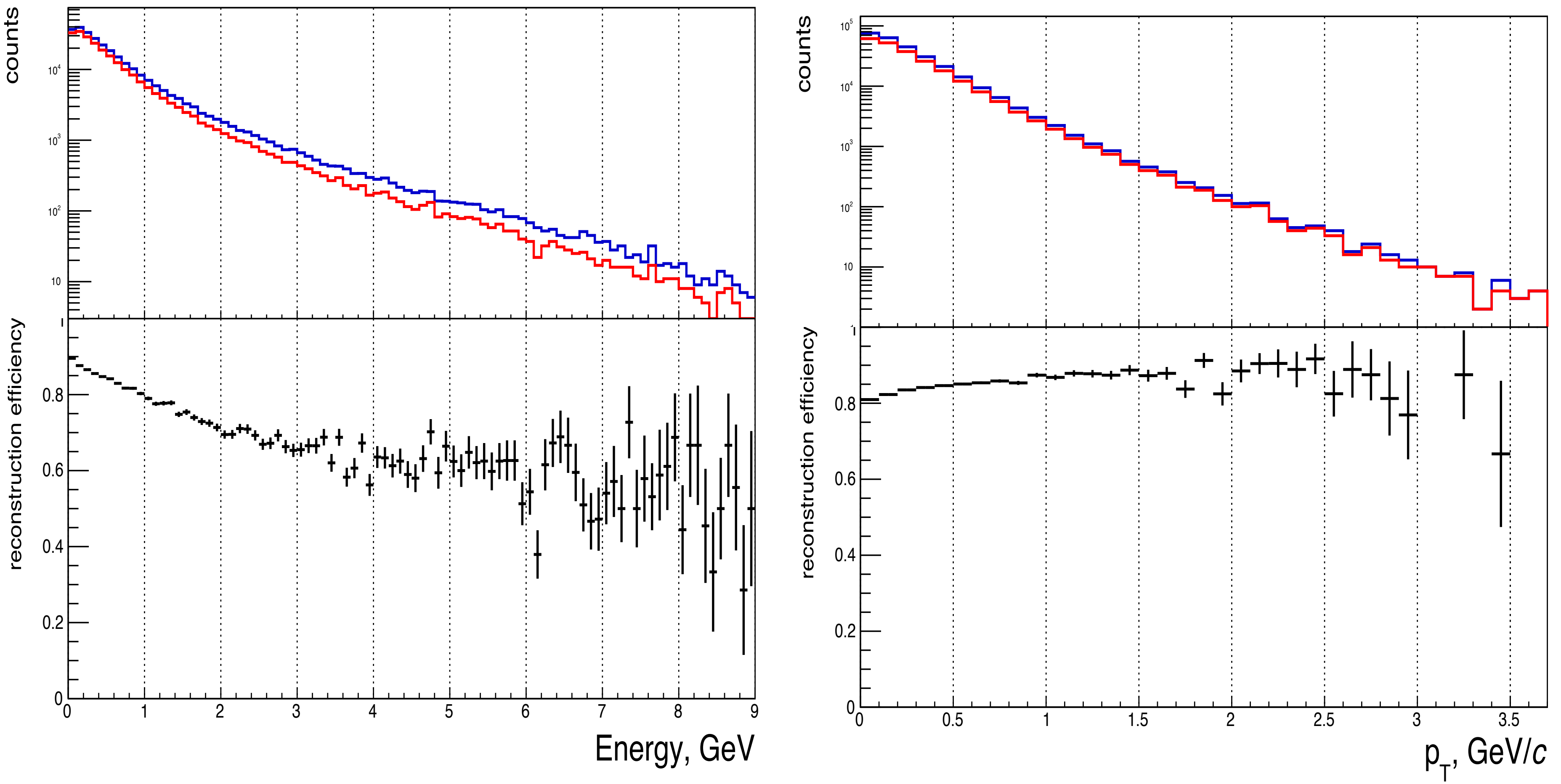
Orbital and asimutal angle distributions



Bottom - the ratio of produced photons to photons in ECAL for γ from π^0 decays

The efficiency on azimutal angle falls because of interaction of photons with magnets coils

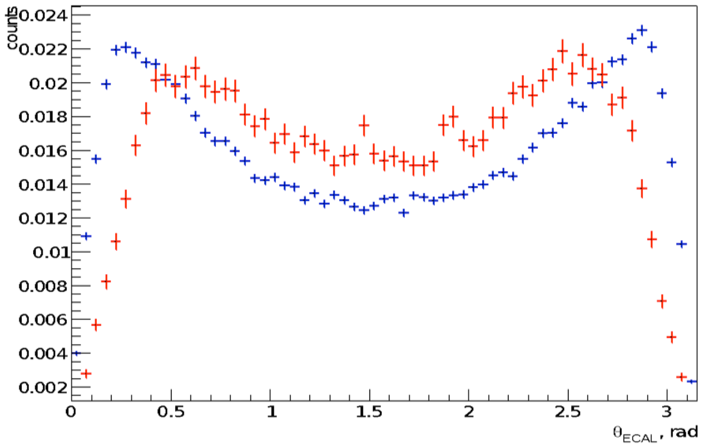
Energy and transerve momentum distributions

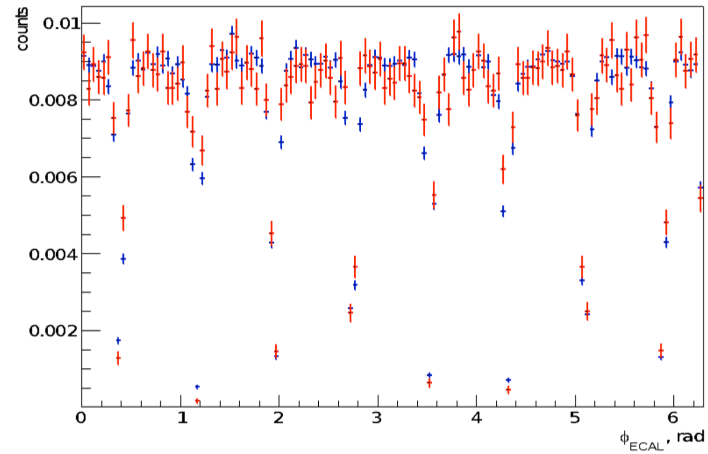


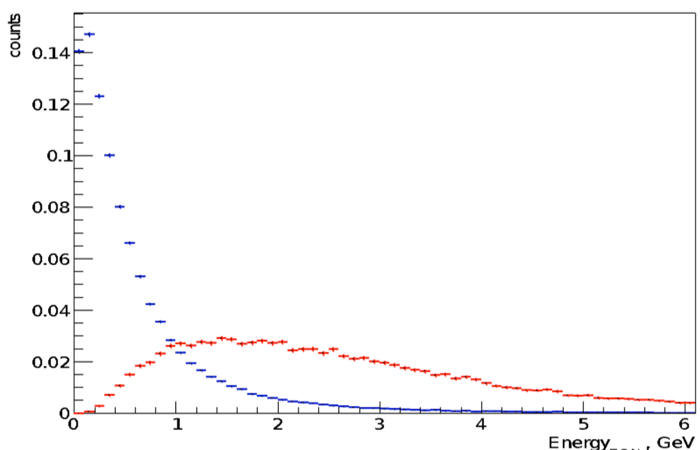
Bottom - the ratio of vertex photons to photons in ECAL for γ from π^0 decays

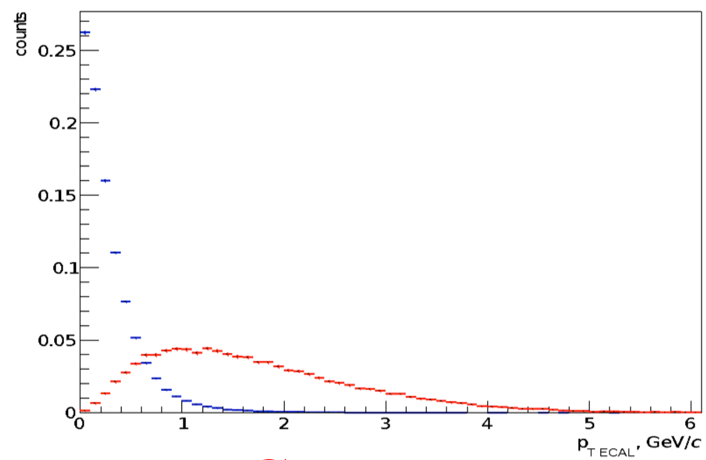
Direct photons distributions

Scaled to Integral





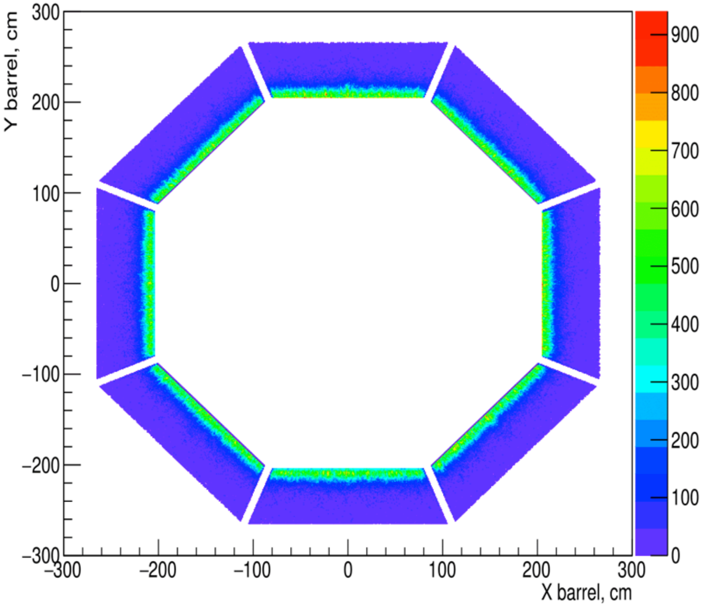




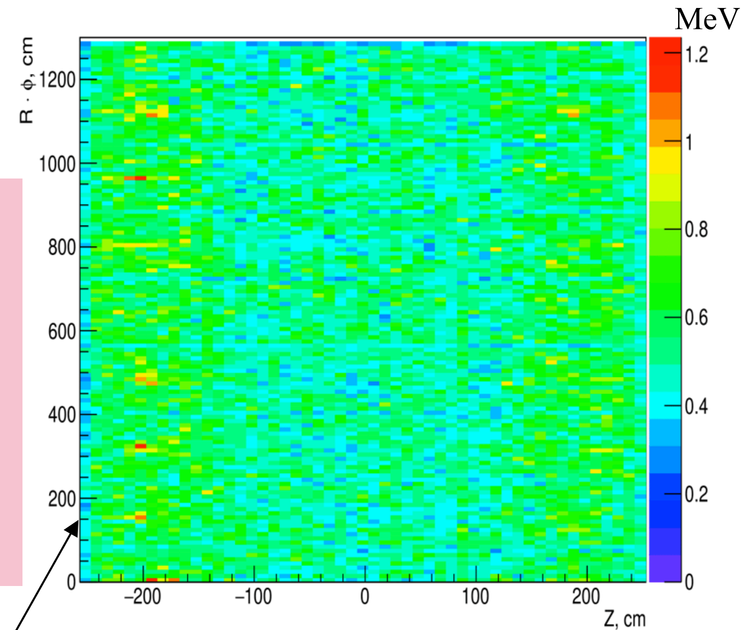
Red line – direct photons from quark gluon Compton scattering

Blue line – photons from π^0 minimus bias

XY distribution in barrel



Particles energy loss in barrel

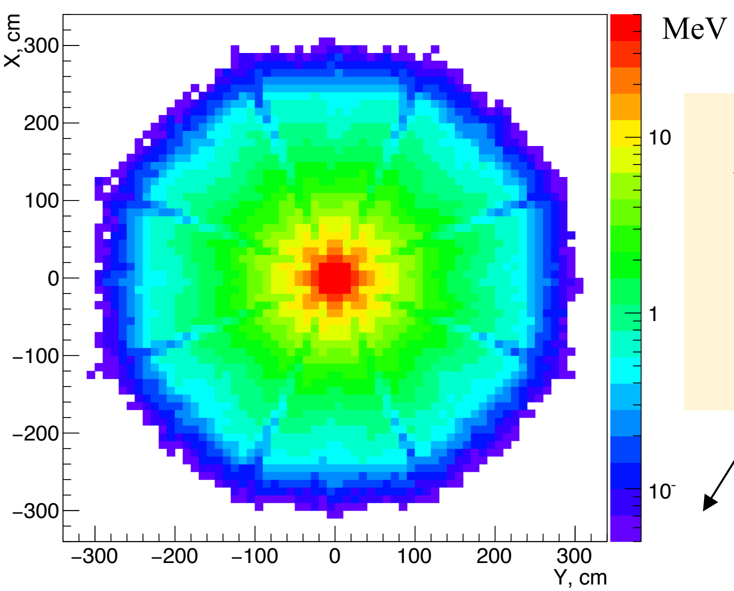


An average energy loss on

$$\frac{MeV}{(dm)^2}$$

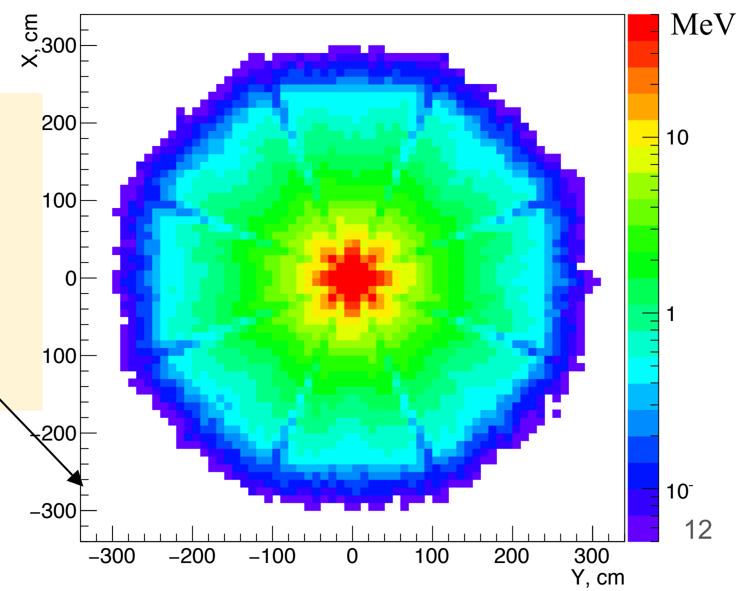
per one event

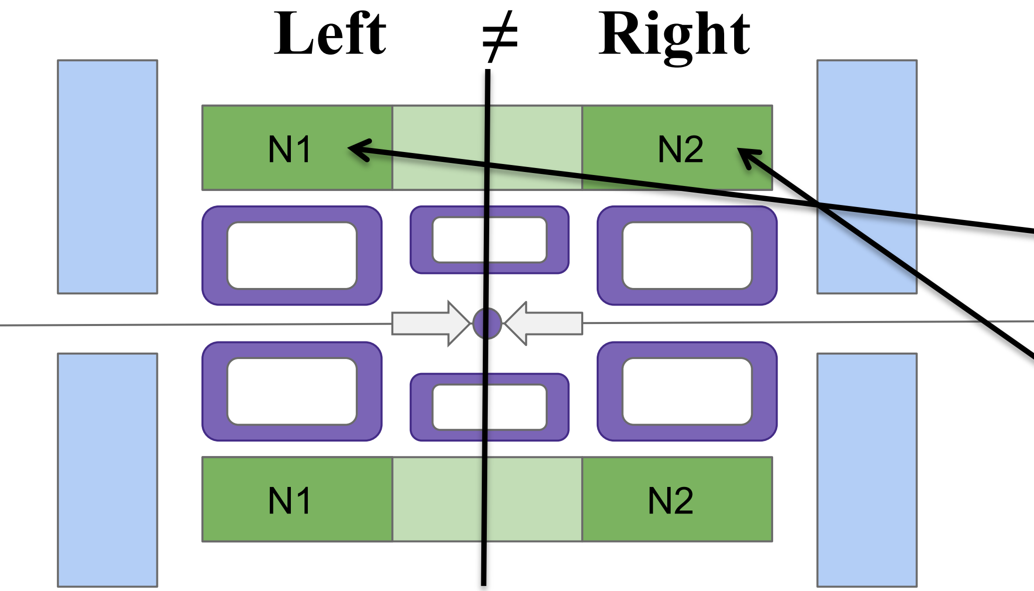
Particles energy loss in endcap 1



2D distributions weighted with energy

Particles energy loss in endcap 2

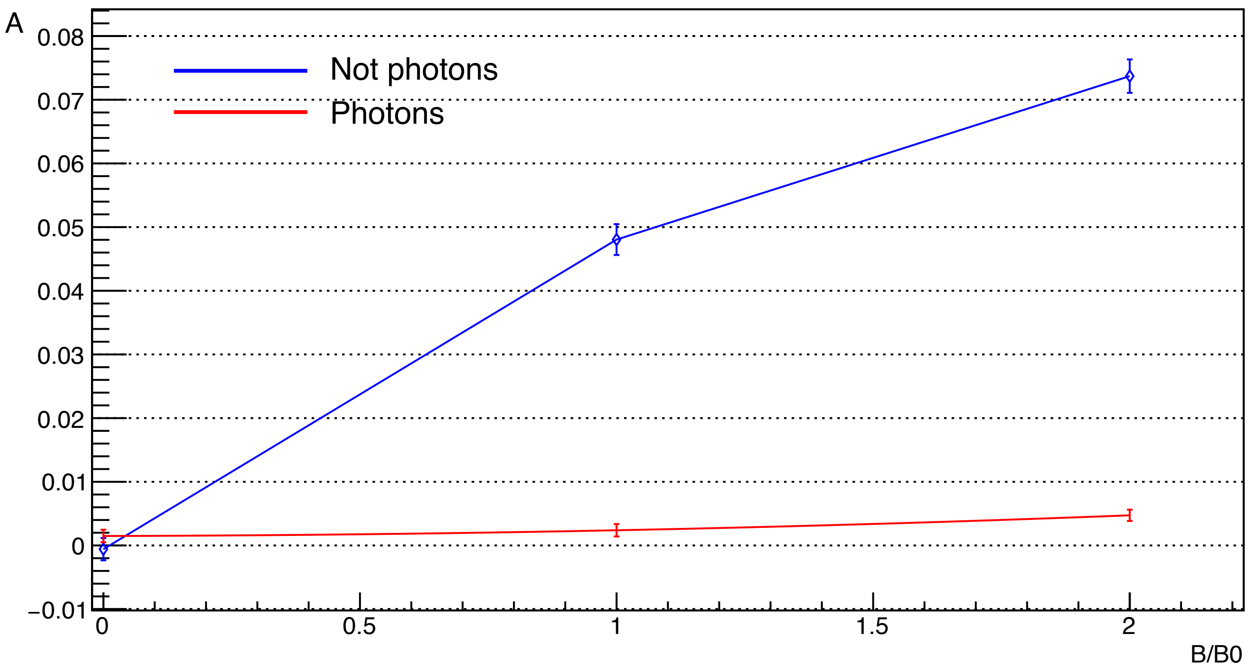




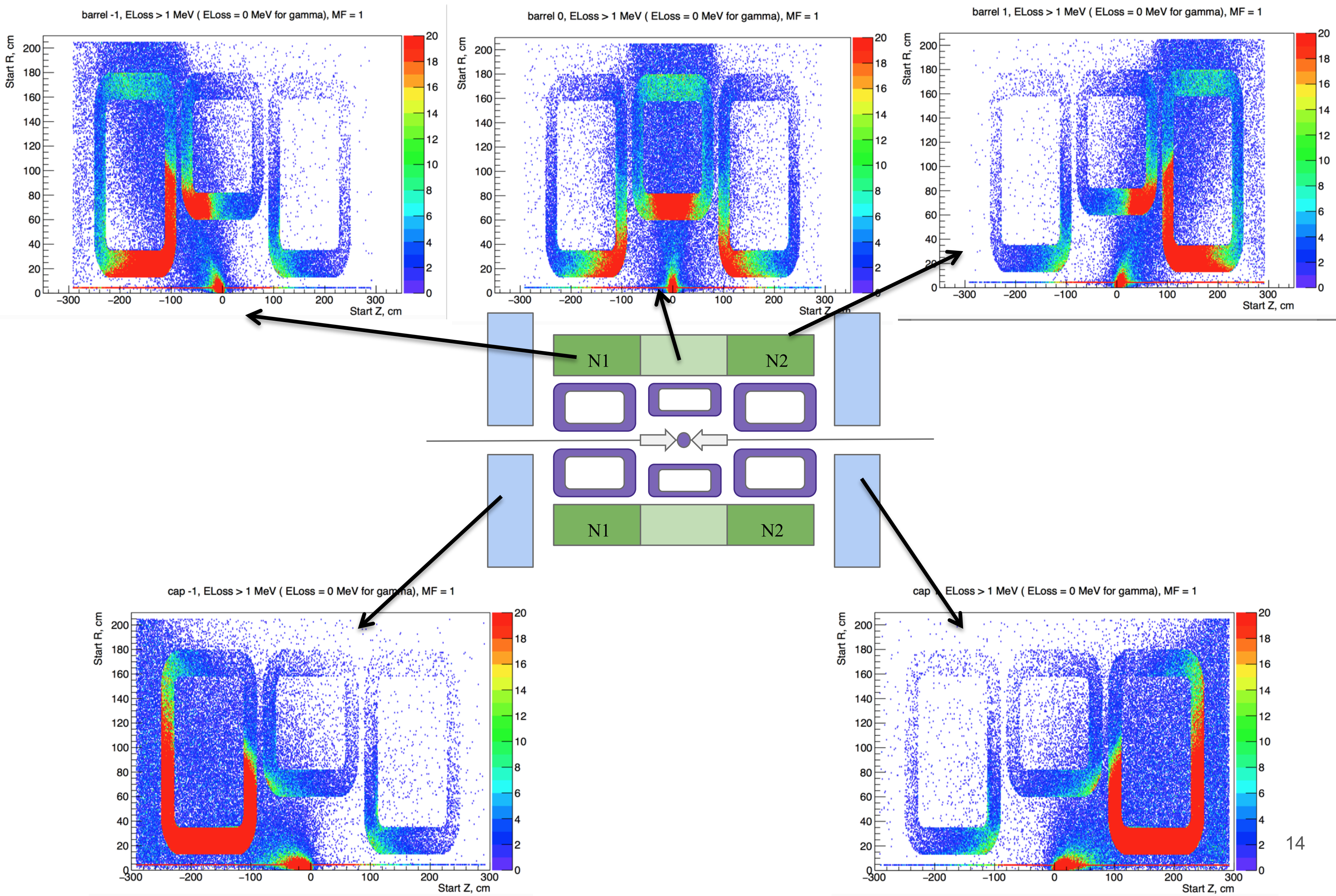
$$A = \frac{N_1 - N_2}{N_1 + N_2}(B)$$

N_1 - Rate of particles in the left part of barrel

N_2 - Rate of particles in the right part of barrel



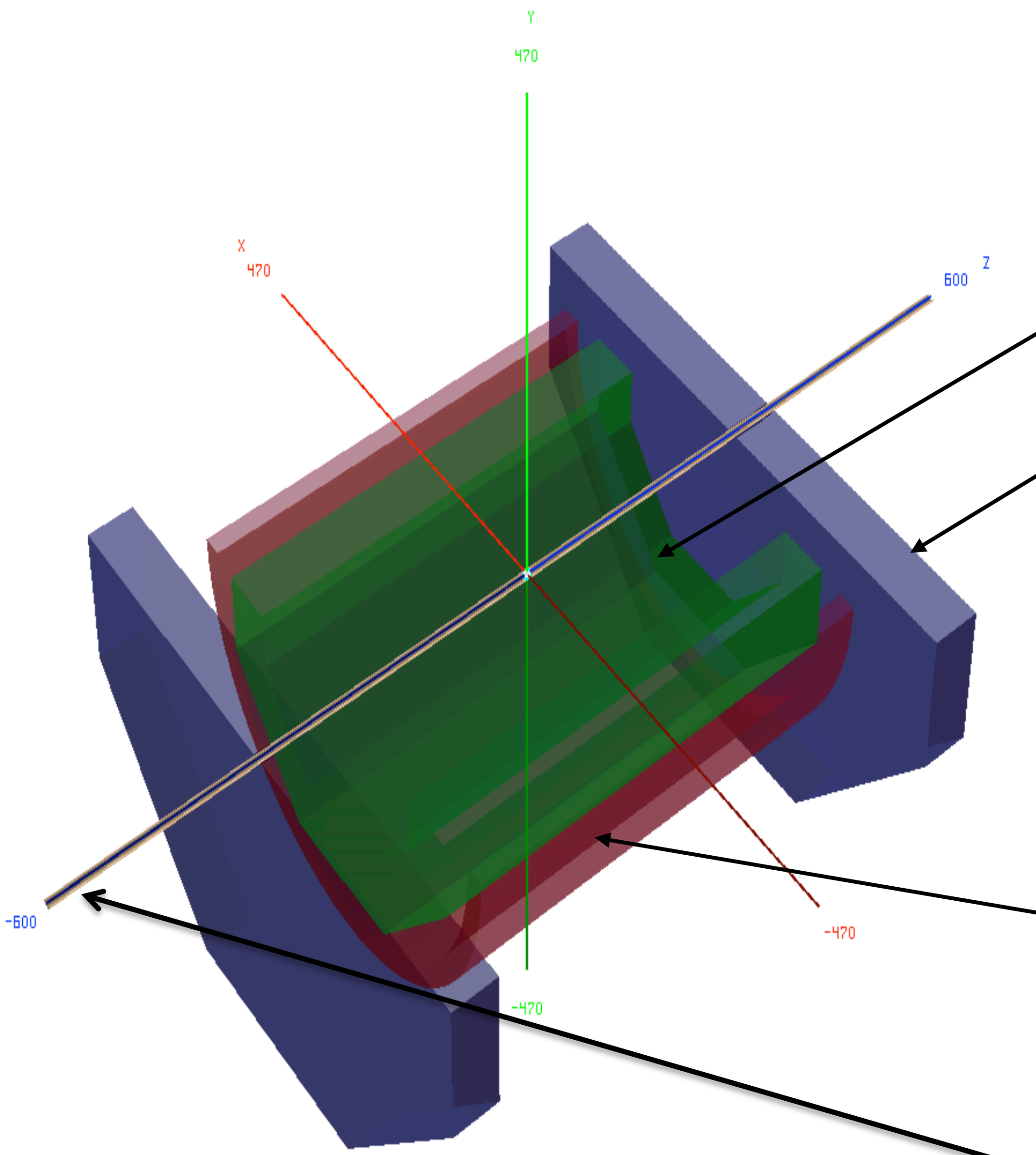
Sources for all particles in different parts of calorimeter



Reconstruction efficiency

	Solenoid		Toroid	
	all	pT>2 GeV/c	all	pT>2 GeV/c
Single photon			83.1	88.7
π^0			68.9	78.8
Direct photon			86.6	88.9

Geometry with solenoidal magnet



SOLENOIDAL ELECTROMAGNETIC CALORIMETER BARREL

Barrel length = 510 cm

Barrel internal R = 132 cm

Barrel width = 60 cm

SOLENOIDAL ELECTROMAGNETIC CALORIMETER ENDCAPS

Caps R = 332 cm

Caps width = 58 cm

Internal R = 6 cm

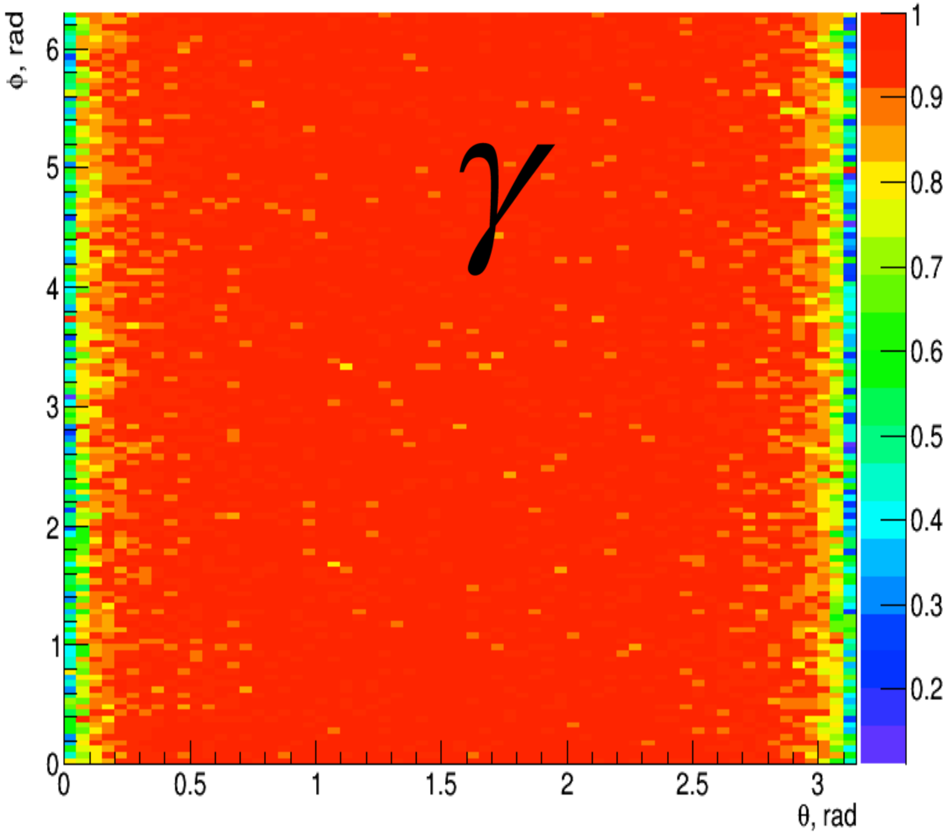
SOLENOIDAL MAGNET SYSTEM

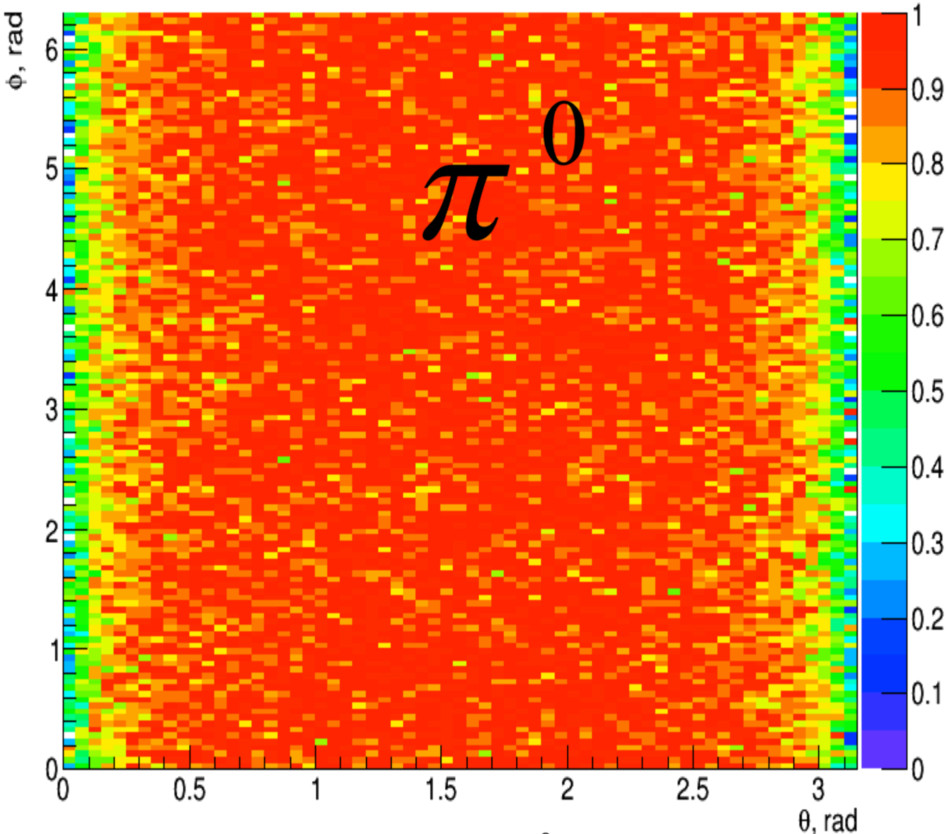
Mag field = 1 T

BEAM PIPE (Be)

Thickness = 2.8 % of radiation lenght

Reconstruction efficiency

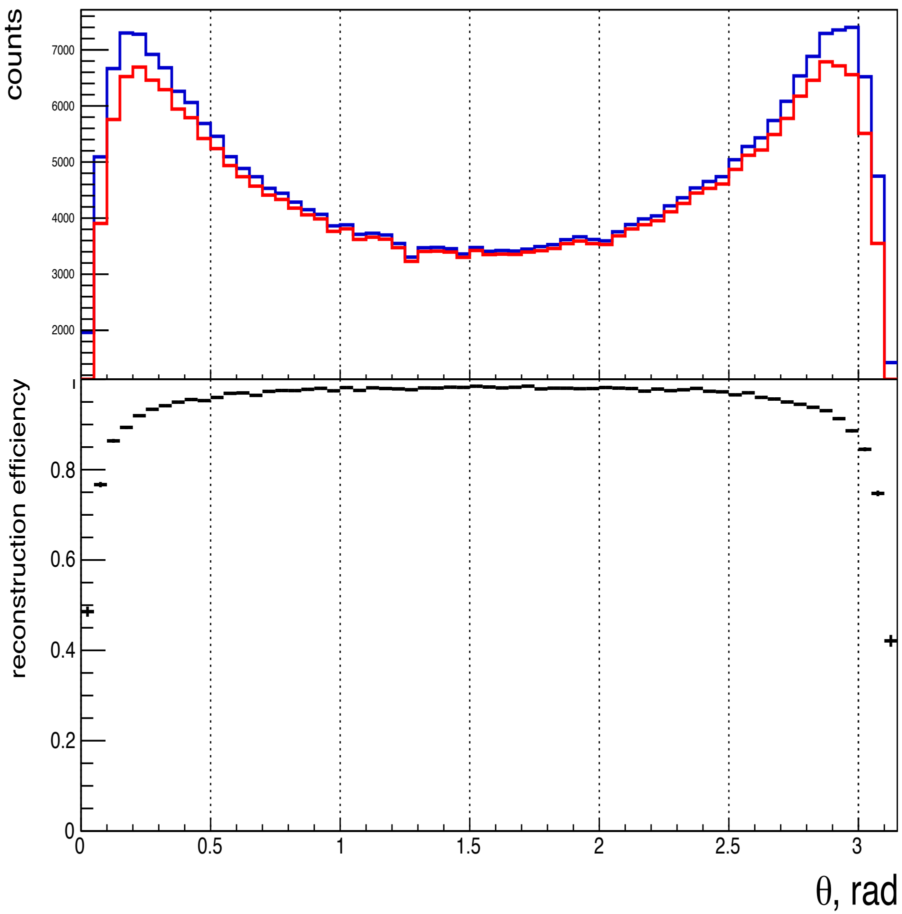


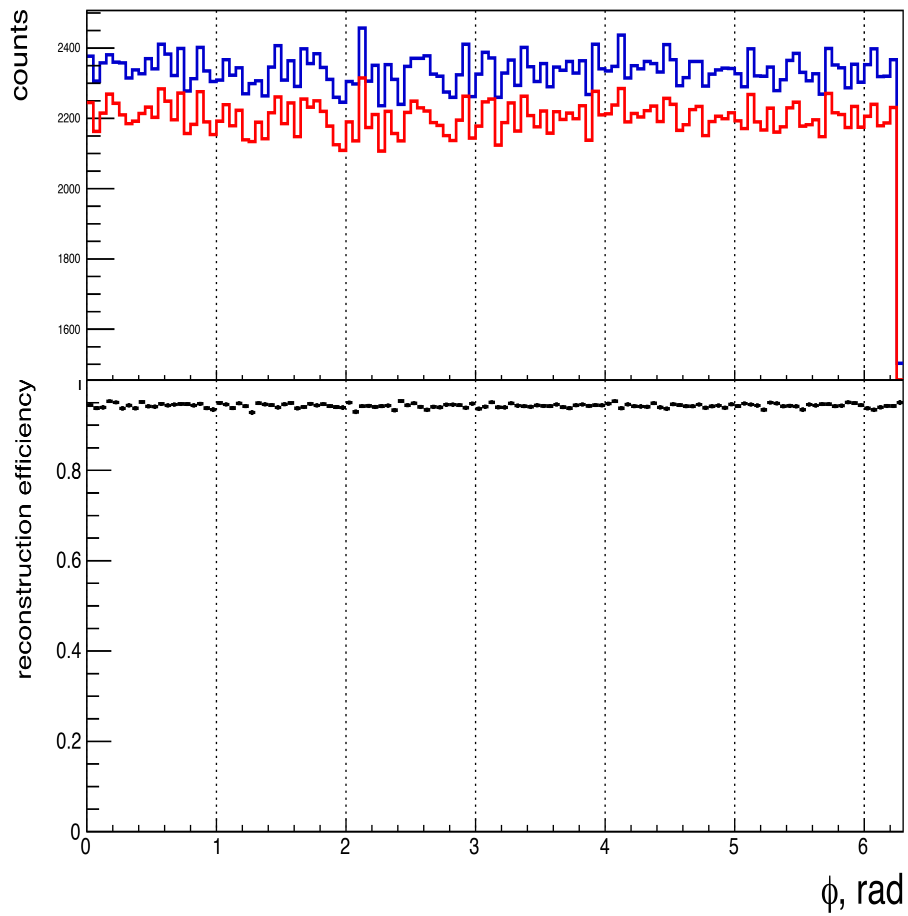


Reconstuction efficiency as function of angles for single γ from π^0decays (left) and when two photons from π^0 decay goes to ECAL (right)

Single photon	π^0
94.3 %	88.2 %

Angle distributions

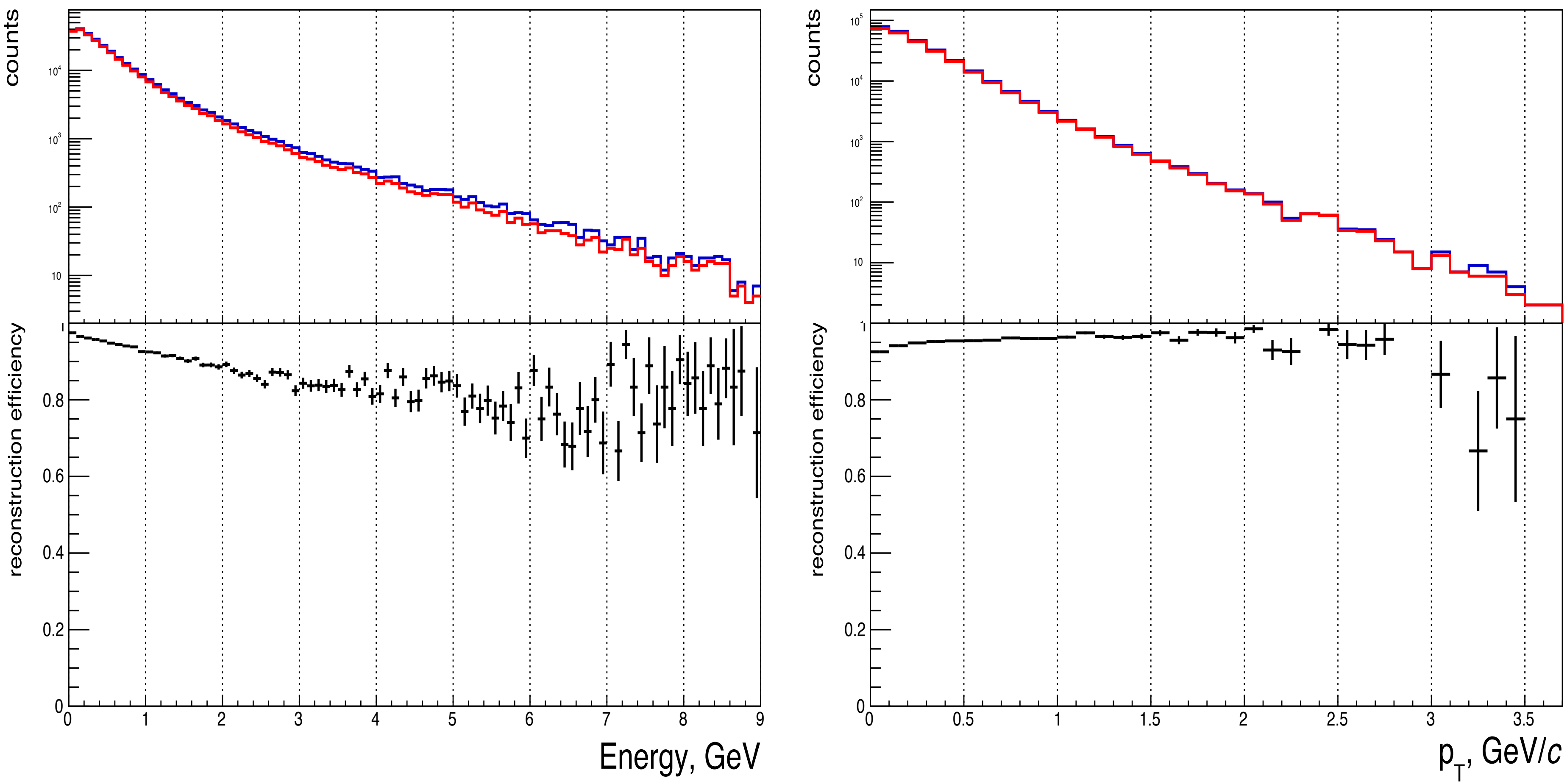




Bottom - the ratio of vertex photons to photons in ECAL for γ from π^0 decays

The efficiency on azimutal is uniform due to symmetrical setup

Energy and transerve momentum distributions



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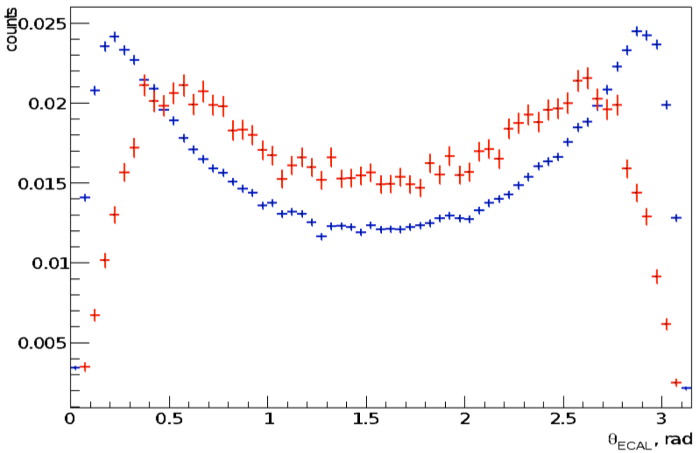
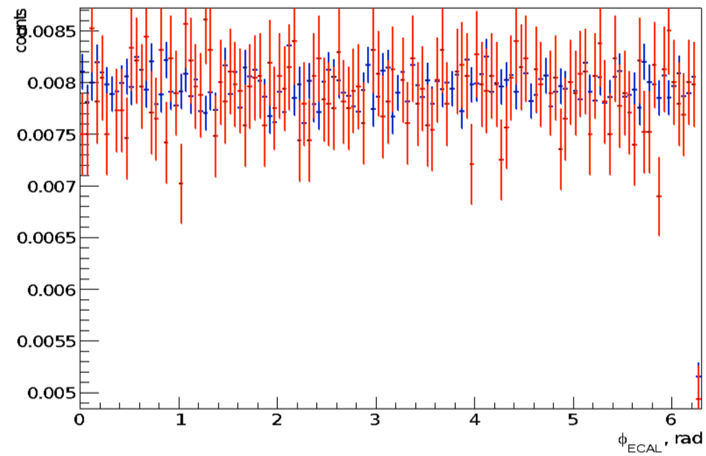
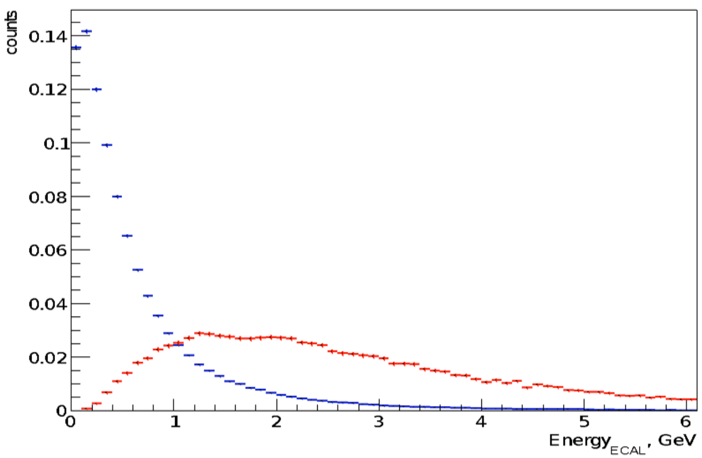
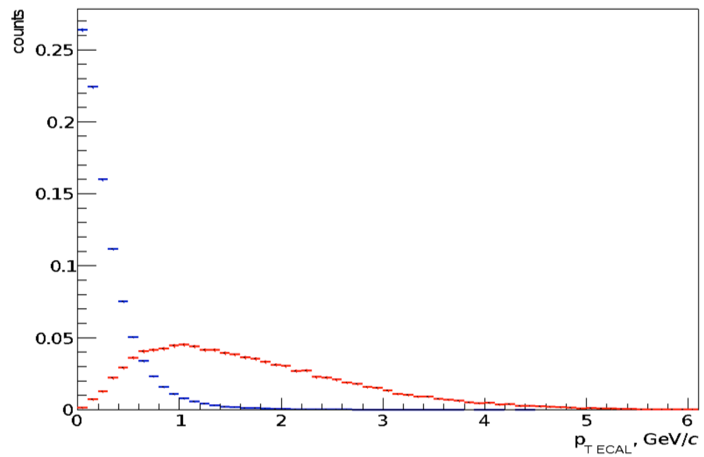
Direct photons distributions

Scaled to Integral









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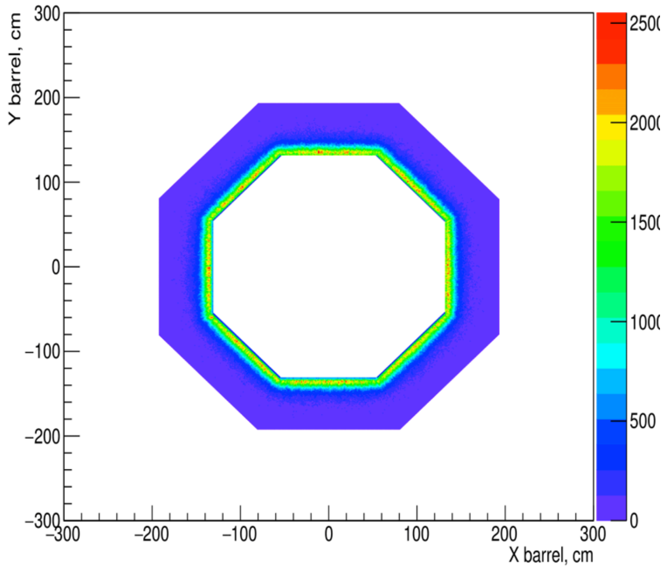
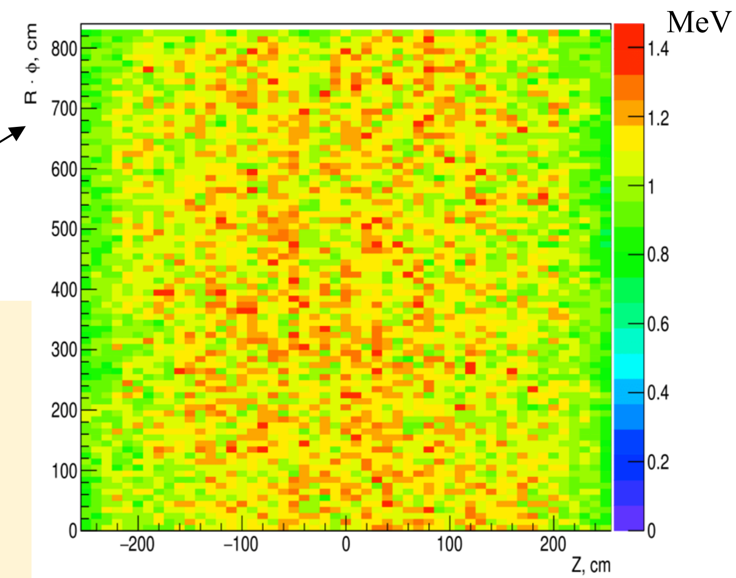
XY distribution in barrel

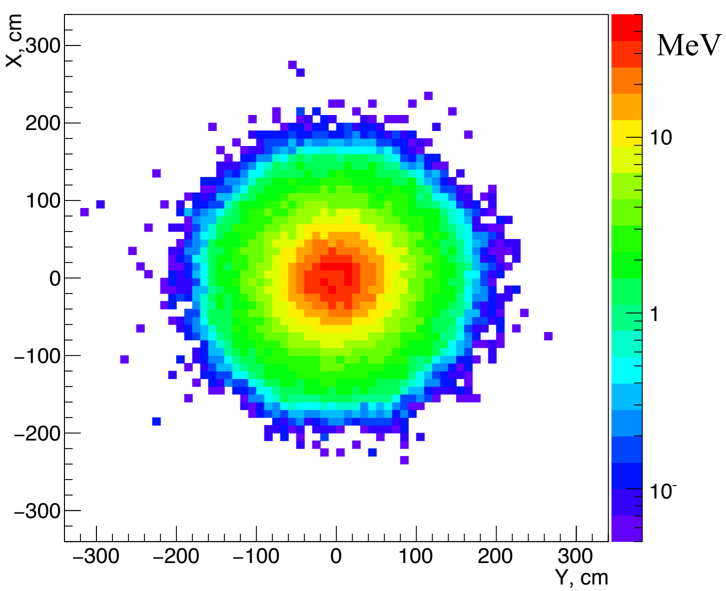


Particles energy loss in barrel



2D distributions weighted with energy

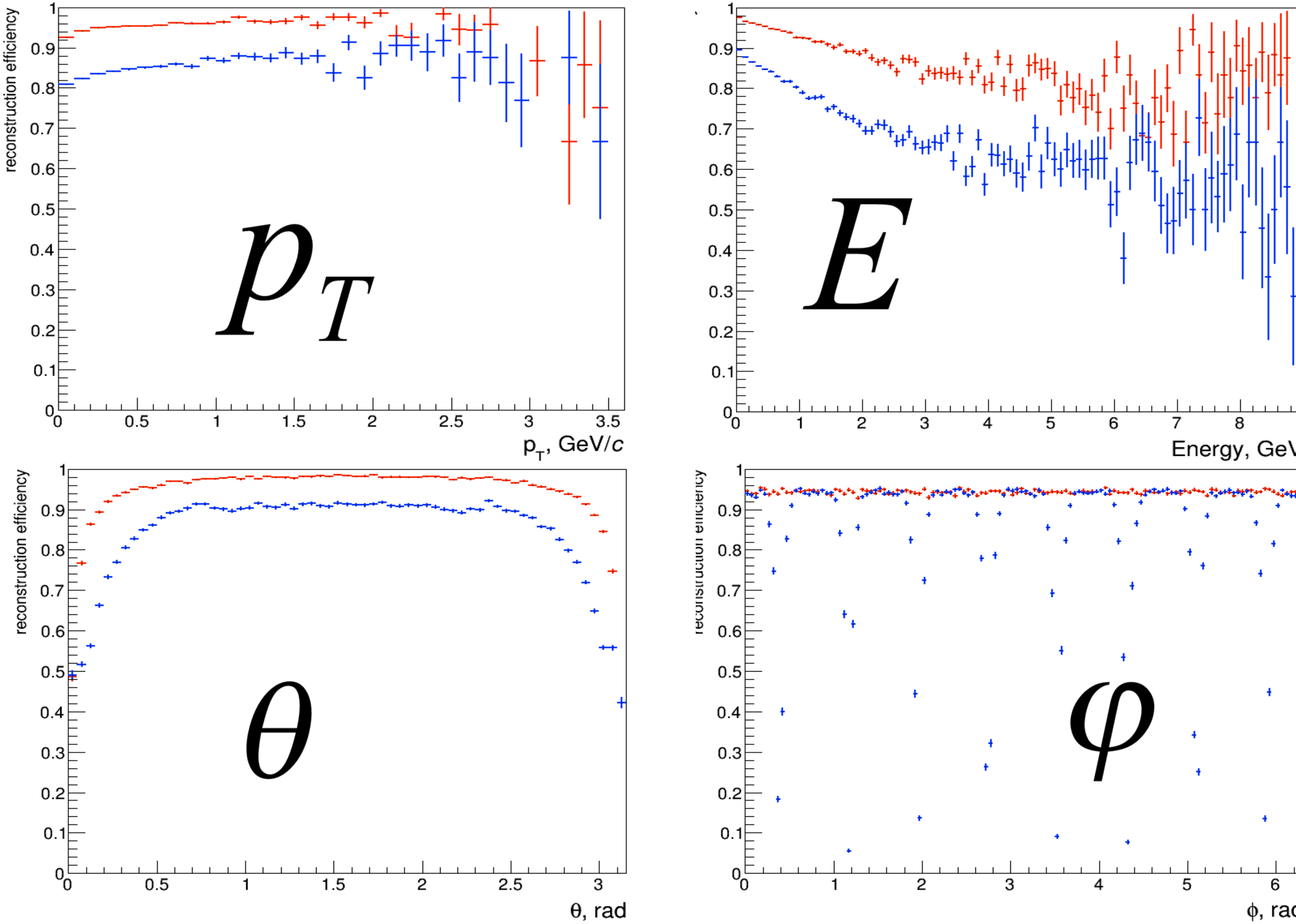
Particles energy loss in endcaps



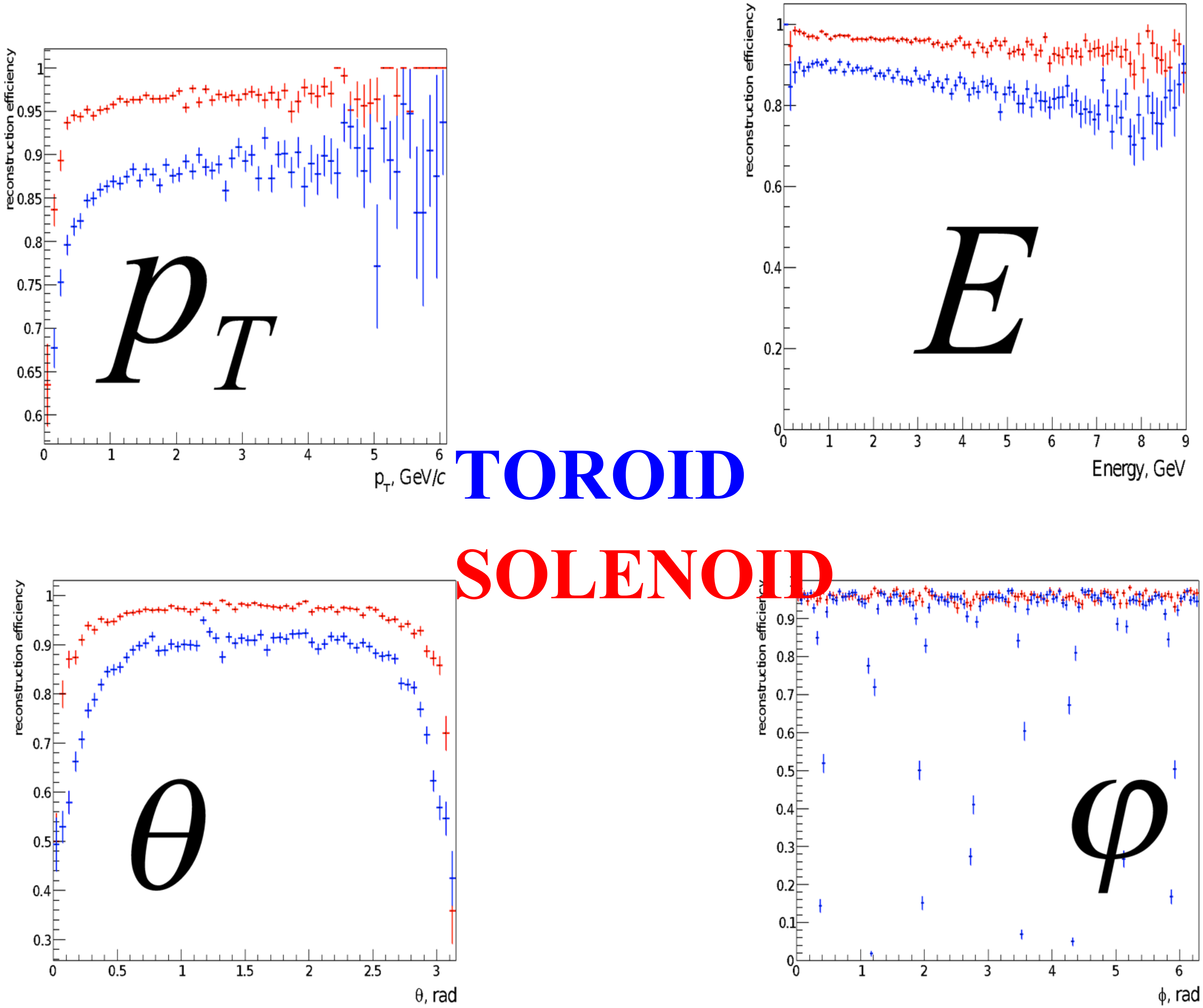
An average energy loss on $\frac{MeV}{dm^2}$ per one event

Comparison of reconstruction efficiency for toroid and solenoid

TOROID **SOLENOID**



Comparison of reconstruction efficiency of direct photons for toroid and solenoid



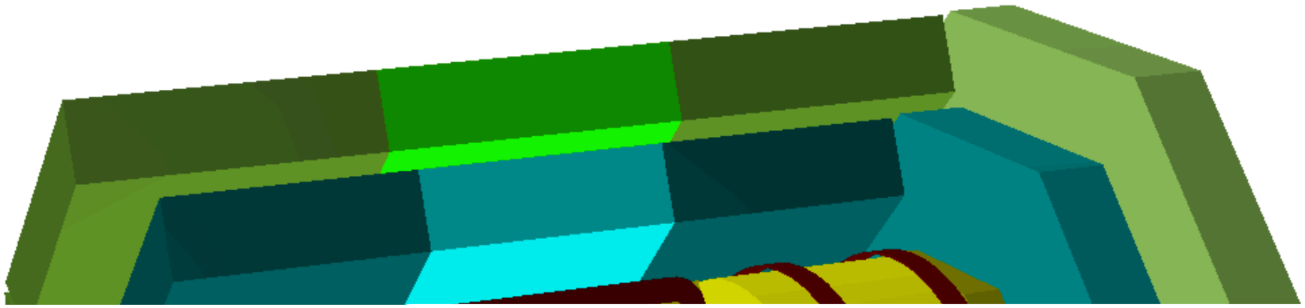
Reconstruction efficiency

	Solenoid		Toroid	
	all	pT>2 GeV/c	all	pT>2 GeV/c
Single photon	94.3	97.1	83.1	88.7
π^0	88.2	92.9	68.9	78.8
Direct photon	95.5	96.9	86.4	88.9
k	0.1338	0.0764	0.4514	0.2690

$$\sigma \sim N_{\text{direct}} = N_{\text{single }\gamma} - 2 \times N_{\pi^0} \times k$$

$$k = \frac{1}{reconstruction\ efficiency} - 1$$

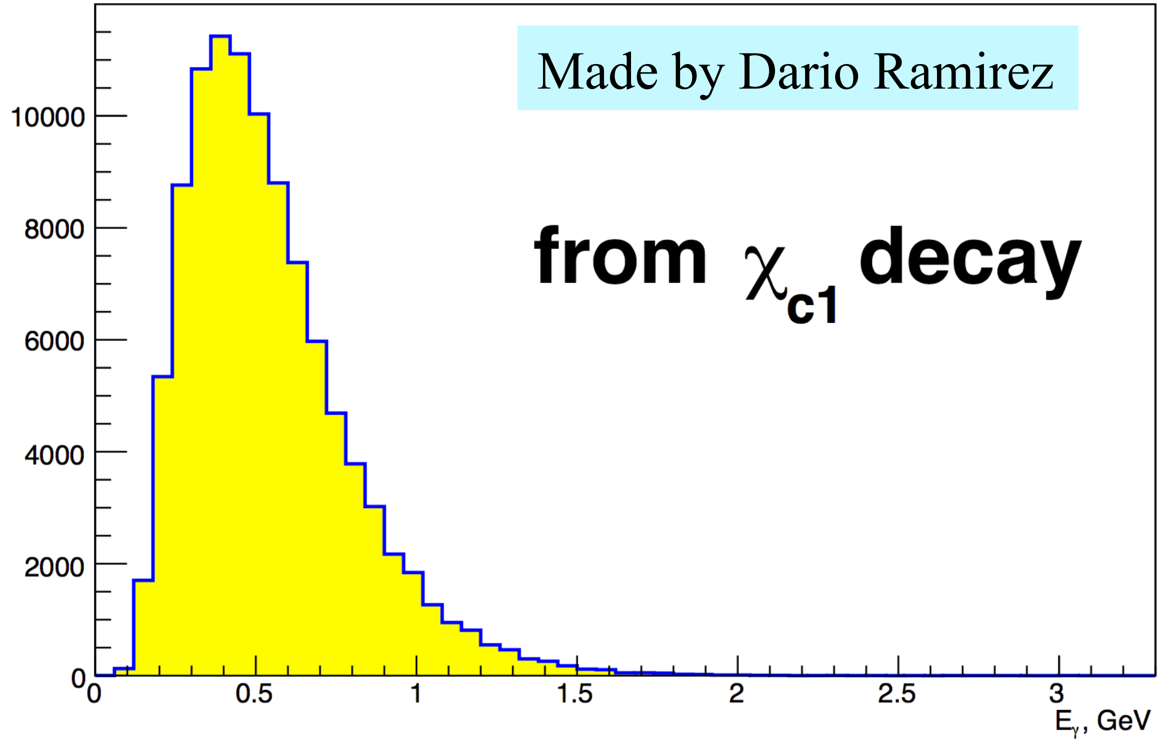
Hybrid magnetic system



Photons from charmonium

See the talk by I. Dinesenko

Name	Mass, MeV	Decay modes	Probability, %
$\chi_{c0}(1P)$	3414.75 ± 0.31	$\gamma J/\psi(1S)$	1.27 ± 0.06
$\chi_{c1}(1P)$	3510.66 ± 0.07	$\gamma J/\psi(1S)$	33.9 ± 1.2
$\chi_{c2}(1P)$	3556.20 ± 0.09	$\gamma J/\psi(1S)$	19.2 ± 0.7



Summary

1. Direct photons provide information about gluon component of the proton

2. The main source of background photons (almost 99%) in proton-proton collision is the production and decay of π^0 and η mesons

3. The main way to suppress the background is effective reconstruction of π^0 decays and an accurate simulation of setup behaviour.

4. For the direct photon studies the solenoidal system is much better (inefficiency is 3 times smaller, k = 0.0764 for solenoid and k = 0.2690 for toroid)

5. The possibility of using a hybrid system is considering