PANDA L. Collaboration Meeting
& Hadron Physics Workshop

JÜLICH
FORSCHUNGSZENTRUM

Simulation of the Ds Semileptonic Decay and Neutral Candidate Construction

Lu Cao

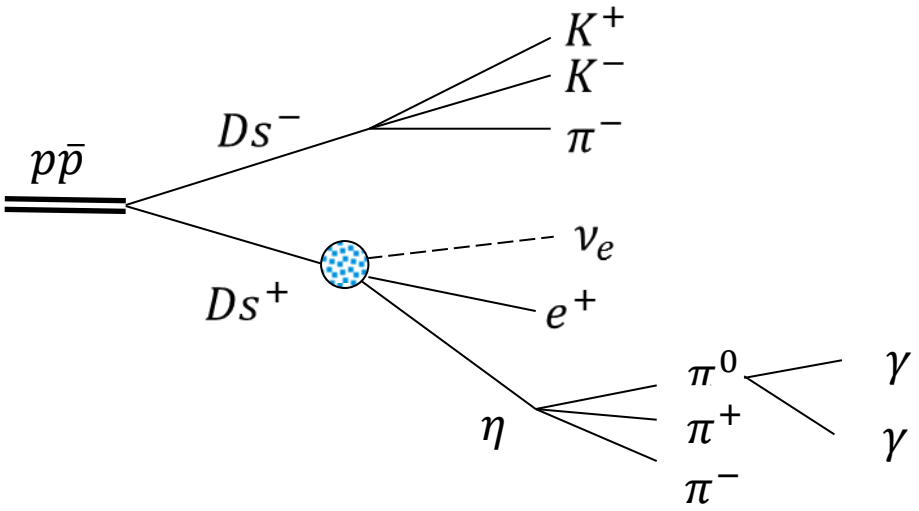
8th September， 2014

Outline

- Decay chain and reconstruction strategy
- EMC correlator in PID
- Neutral candidate multiplicity in Geant 3/4
- Reconstruction results with Geant 3/4
- Summary & outlook

Decay Chain and Reconstruction Strategy

$P_{beam} = 8.0\ GeV/c$



$$M^2(\nu_e) = \left(E_{p\bar{p}} - E_{Ds^-} - E_{\eta} - E_{e^+}\right)^2 - \left|\vec{P}_{p\bar{p}} - \vec{P}_{Ds^-} - \vec{P}_{\eta} - \vec{P}_{e^+}\right|^2$$

Decay Chain and Reconstruction Strategy

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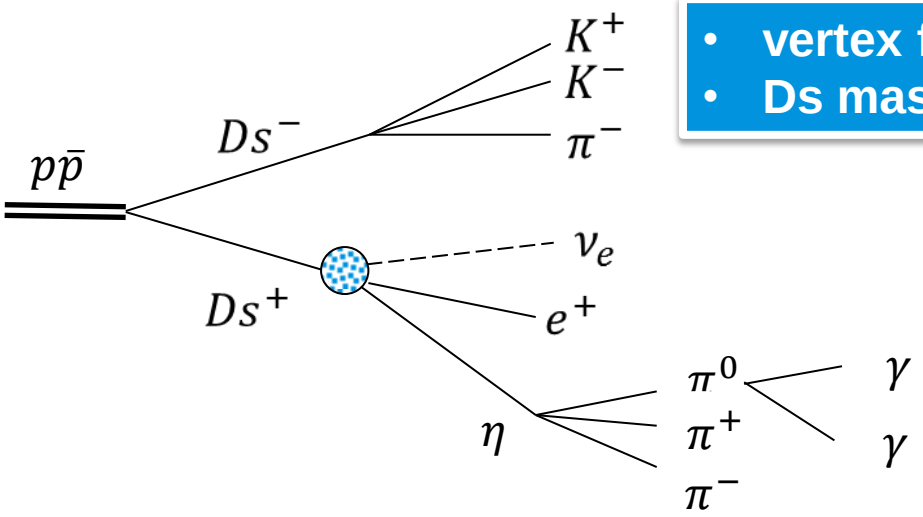

- vertex fit for $(K^+K^-\pi^-)$
- Ds mass constraint fit

$$M^2(\upsilon_e) = \left(E_{p\bar{p}} - E_{Ds^-} - E_\eta - E_{e^+}\right)^2 - \left|\vec{P}_{p\bar{p}} - \vec{P}_{Ds^-} - \vec{P}_\eta - \vec{P}_{e^+}\right|^2$$

Decay Chain and Reconstruction Strategy

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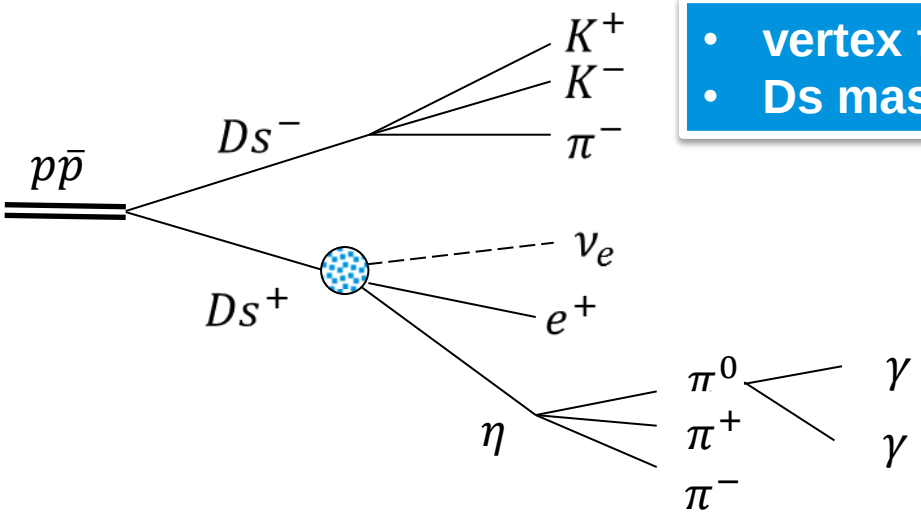

- vertex fit for $(K^+K^-\pi^-)$
- Ds mass constraint fit

- photon pre-selection
- pi0 mass constraint fit

$$M^2(\upsilon_e) = \left(E_{p\bar{p}} - E_{Ds^-} - E_{\eta} - E_{e^+}\right)^2 - \left|\vec{P}_{p\bar{p}} - \vec{P}_{Ds^-} - \vec{P}_{\eta} - \vec{P}_{e^+}\right|^2$$

Decay Chain and Reconstruction Strategy

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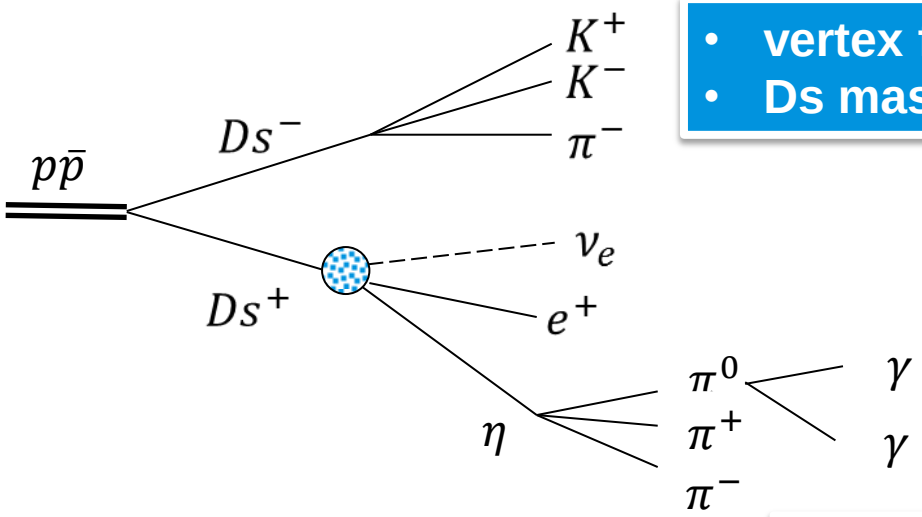


- vertex fit for $(K^+K^-\pi^-)$
- Ds mass constraint fit

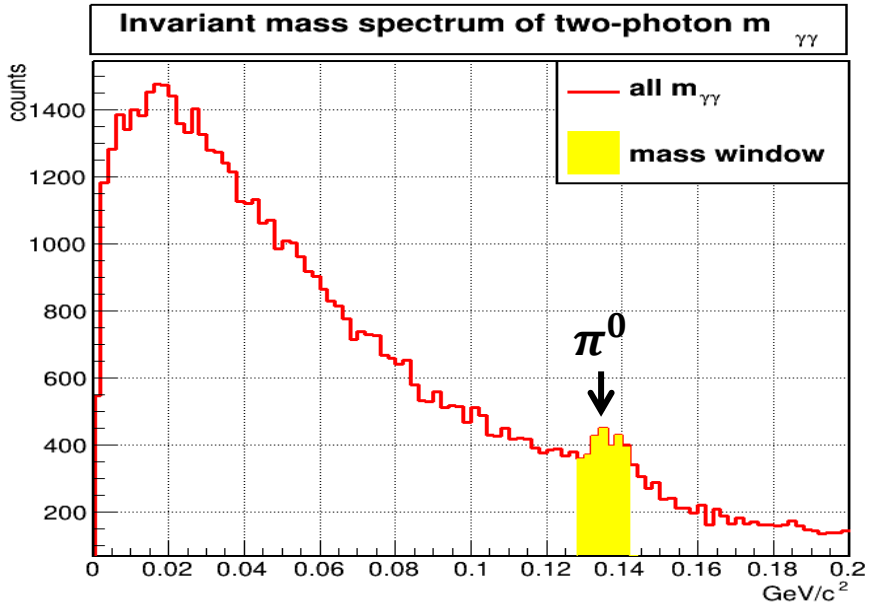
- photon pre-selection
- pi0 mass constraint fit

- vertex fit for $(\pi^+\pi^-)$
- eta mass constraint fit

$$M^2(\upsilon_e) = \left(E_{p\bar{p}} - E_{Ds^-} - E_{\eta} - E_{e^+}\right)^2 - \left|\vec{P}_{p\bar{p}} - \vec{P}_{Ds^-} - \vec{P}_{\eta} - \vec{P}_{e^+}\right|^2$$

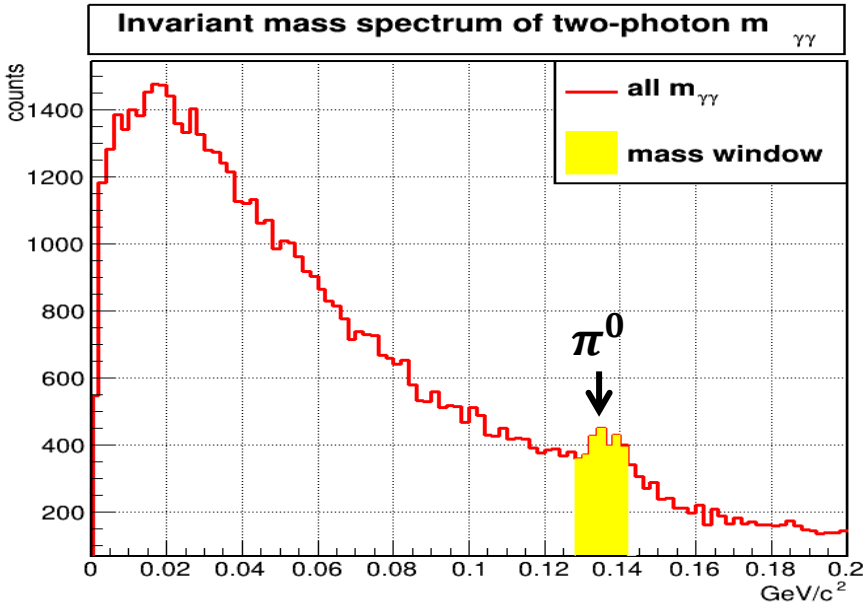
Neutral Candidate Multiplicity

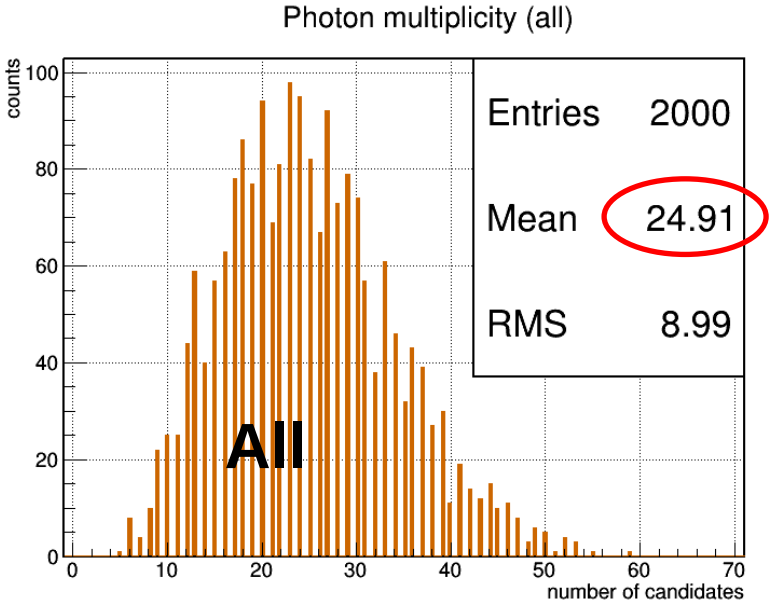
FullSim 2k evt #25800

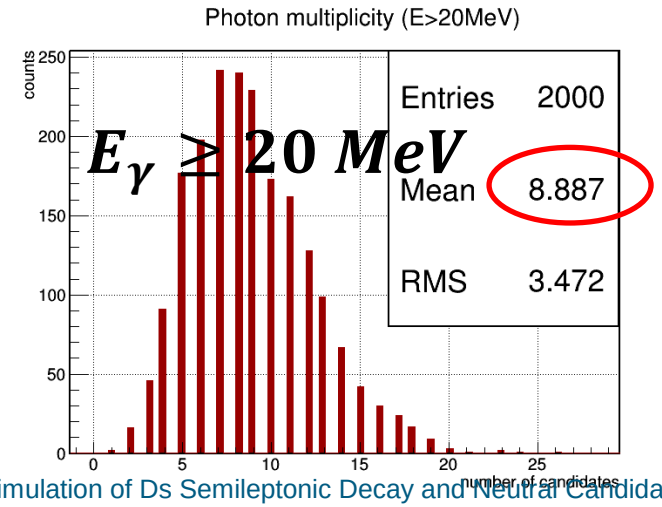


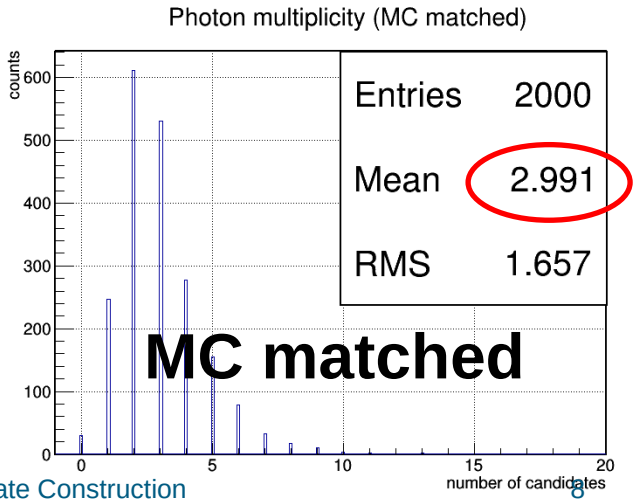
Neutral Candidate Multiplicity

FullSim 2k evt #25800









Neutral Candidate Multiplicity

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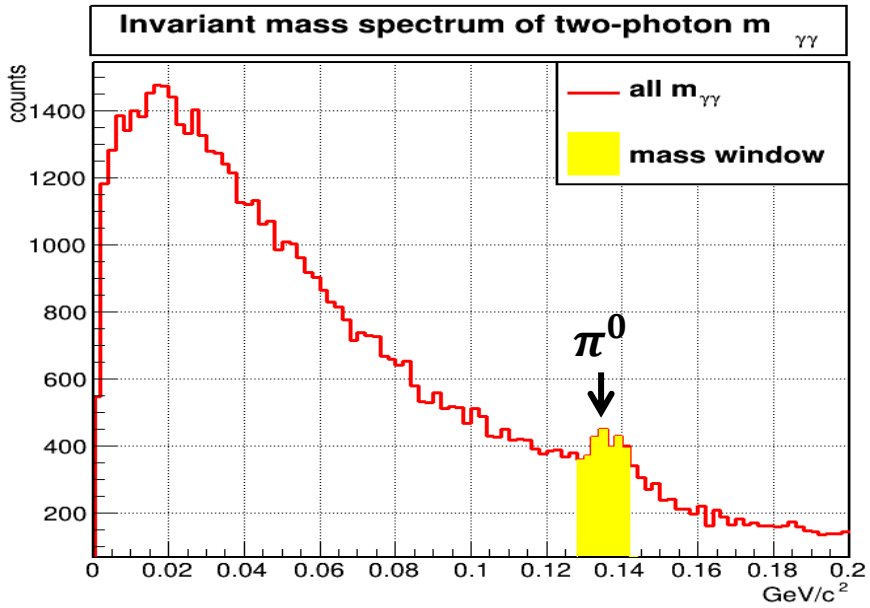
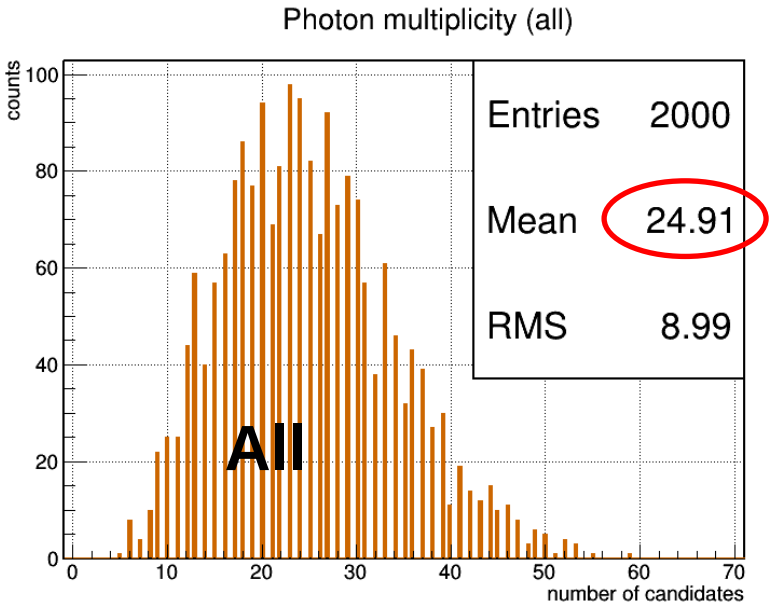
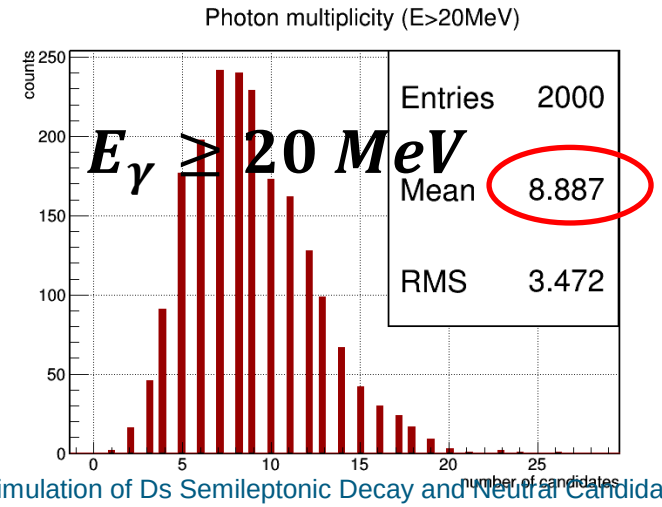
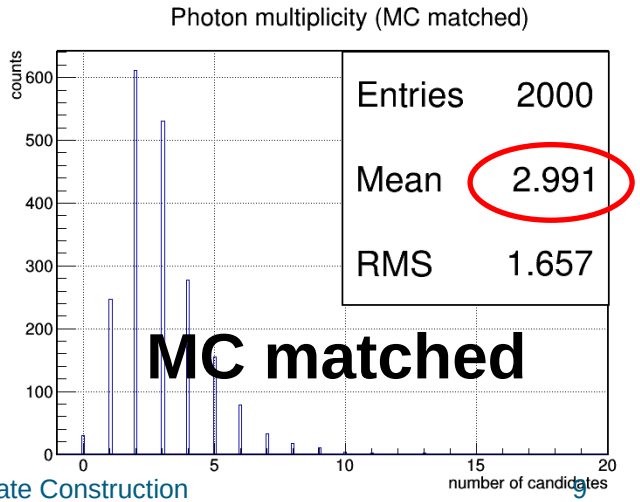


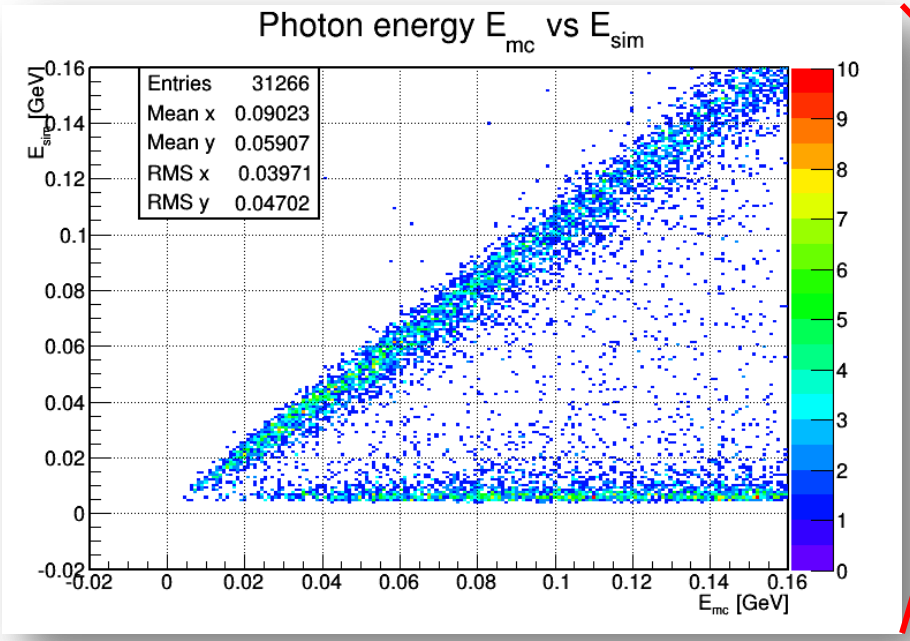


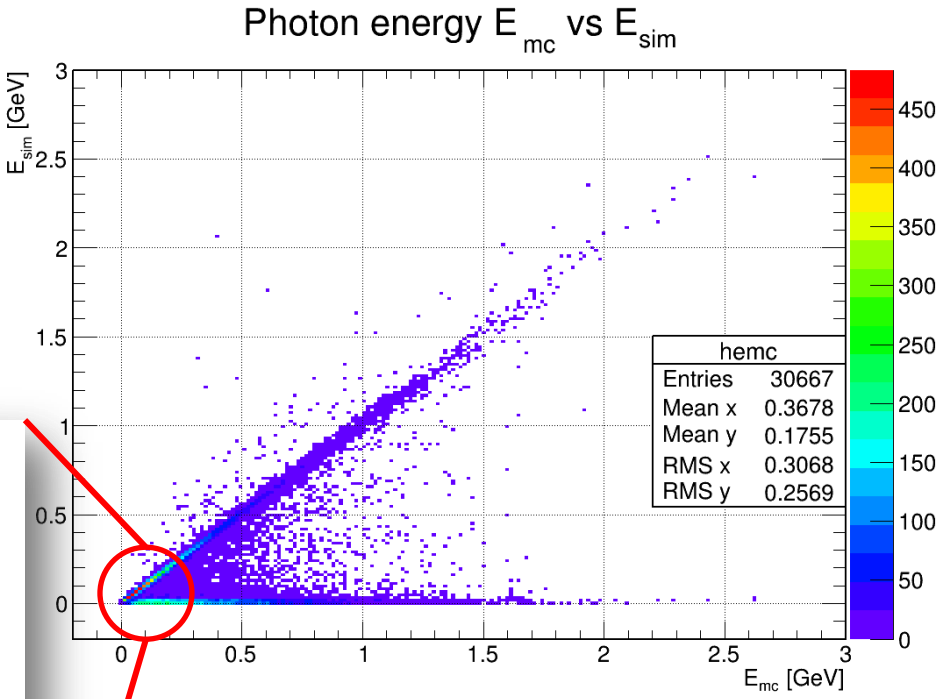
- Bremsstrahlung?
- Bump split off?
- MisPID?
- … ???





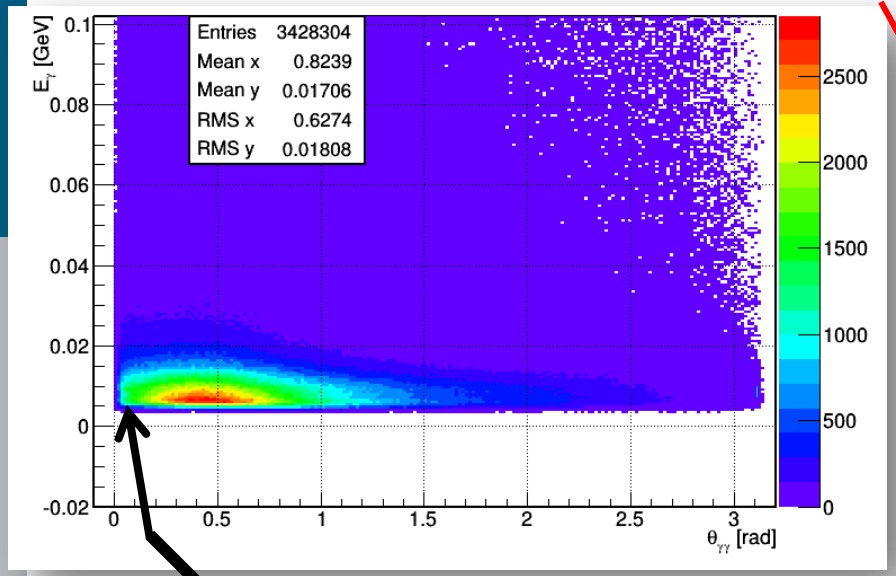
MC Truth Matched Photon

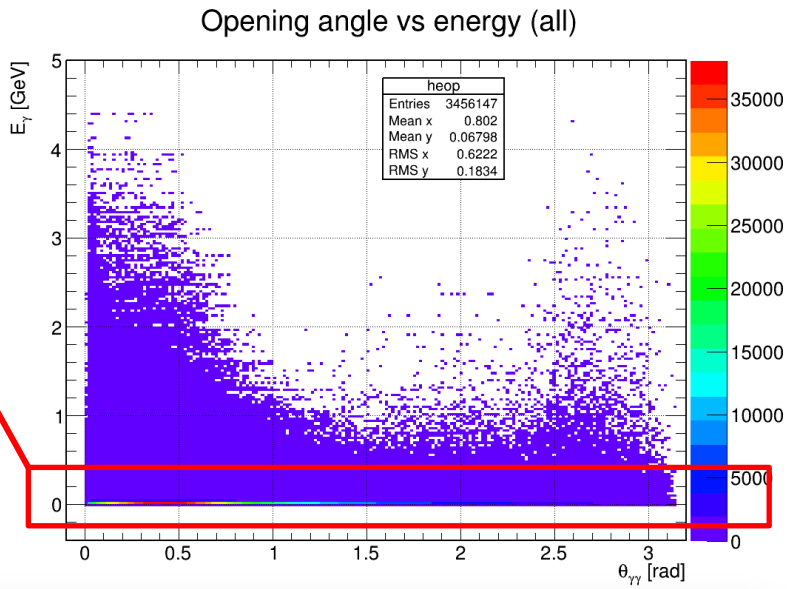




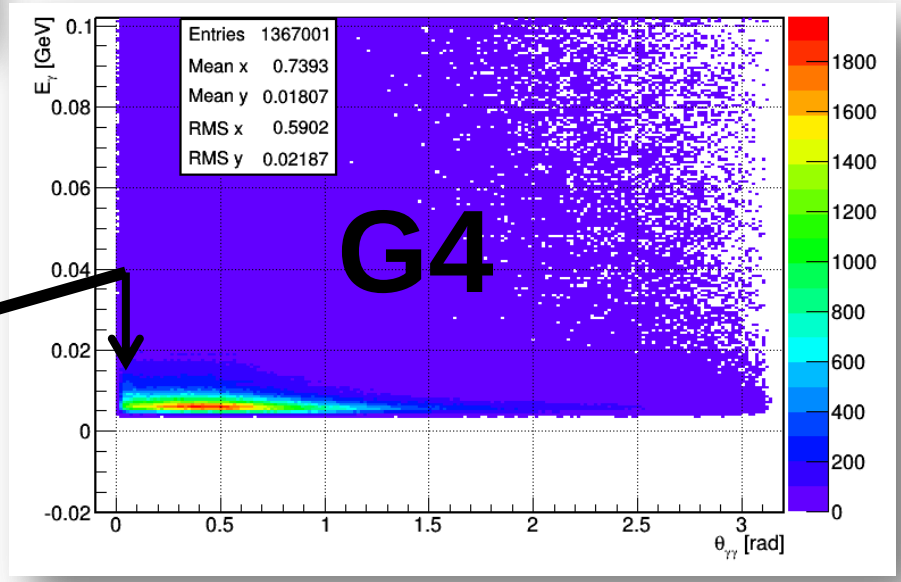
FullSim 10k evt #25800

G3


Entries 3428304
Mean x 0.8239
Mean y 0.01706
RMS x 0.6274
RMS y 0.01808
E_γ [GeV]
$\theta_{\gamma\gamma}$ [rad]


Opening angle vs energy (all)
heop
Entries 3456147
Mean x 0.802
Mean y 0.06798
RMS x 0.6222
RMS y 0.1834
E_γ [GeV]
$\theta_{\gamma\gamma}$ [rad]

Split off

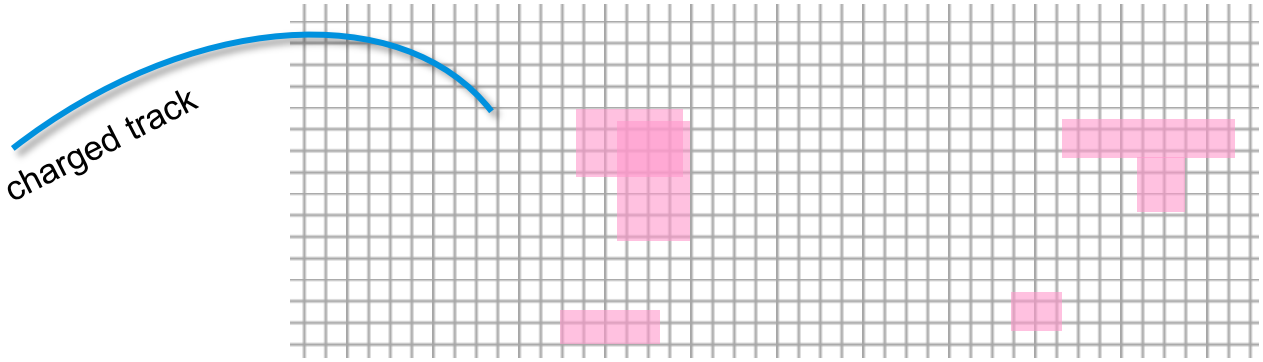

Entries 1367001
Mean x 0.7393
Mean y 0.01807
RMS x 0.5902
RMS y 0.02187
G4
E_γ [GeV]
$\theta_{\gamma\gamma}$ [rad]

EMC Correlator in PID: EMC Quality

PndPidCorrelator.cxx

- Distance squared of the cluster position from the closest track (in cm^2)

- fEmcQuality > 2500
  → consider neutral candidates only when the closest track is 50 cm away



Forum

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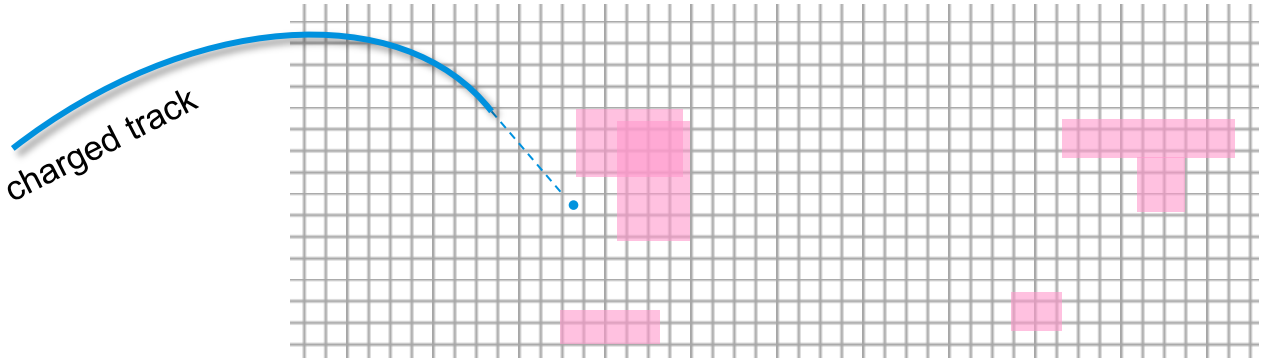

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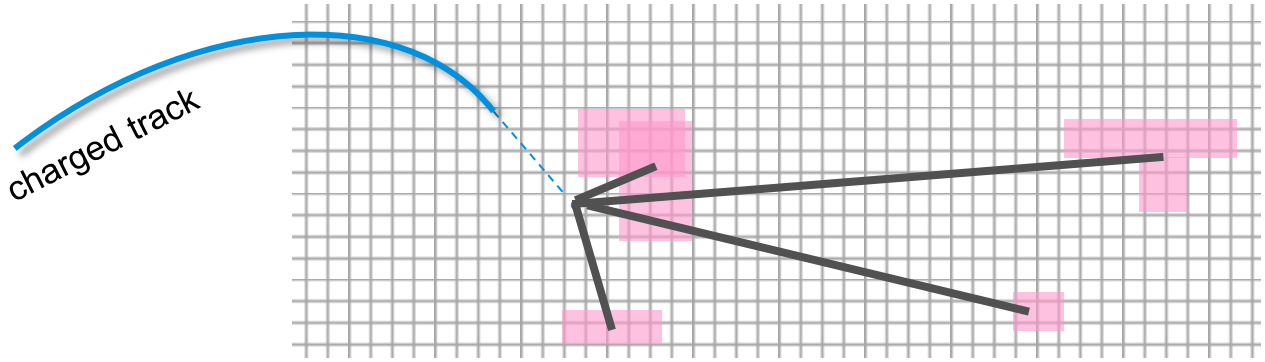

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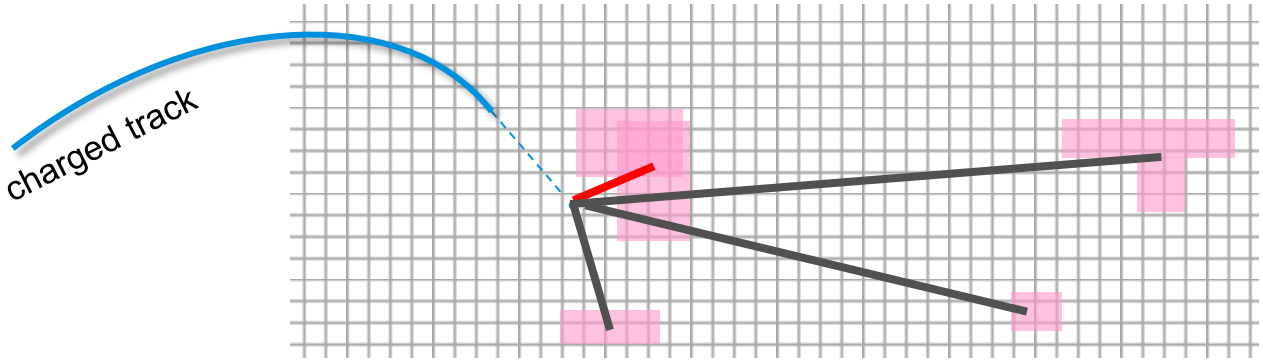

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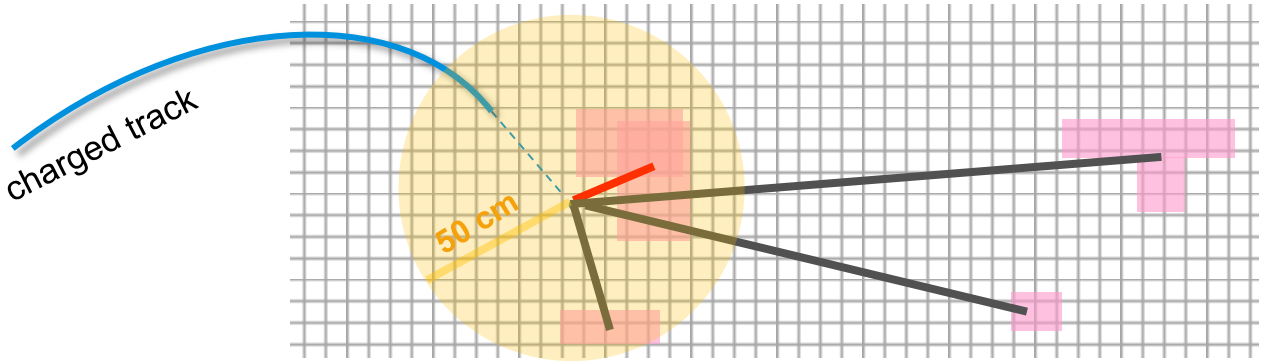

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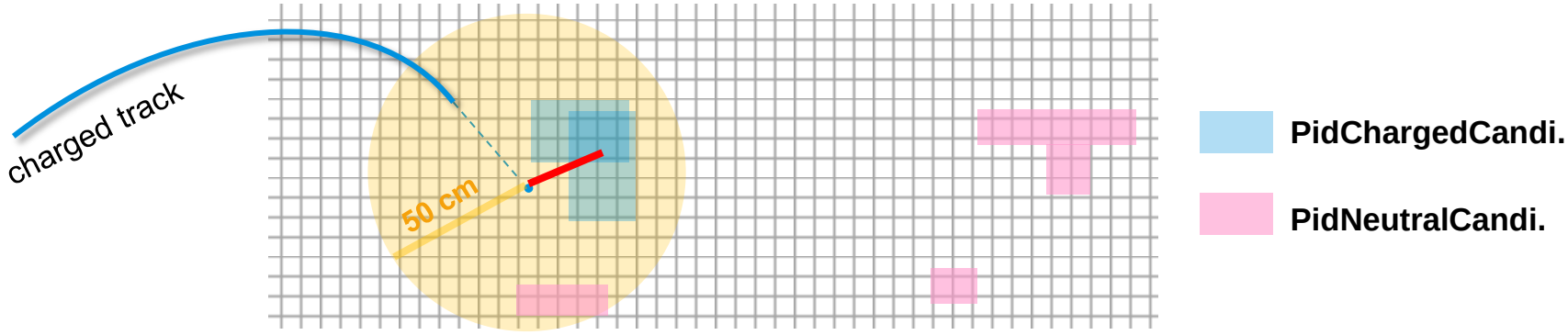

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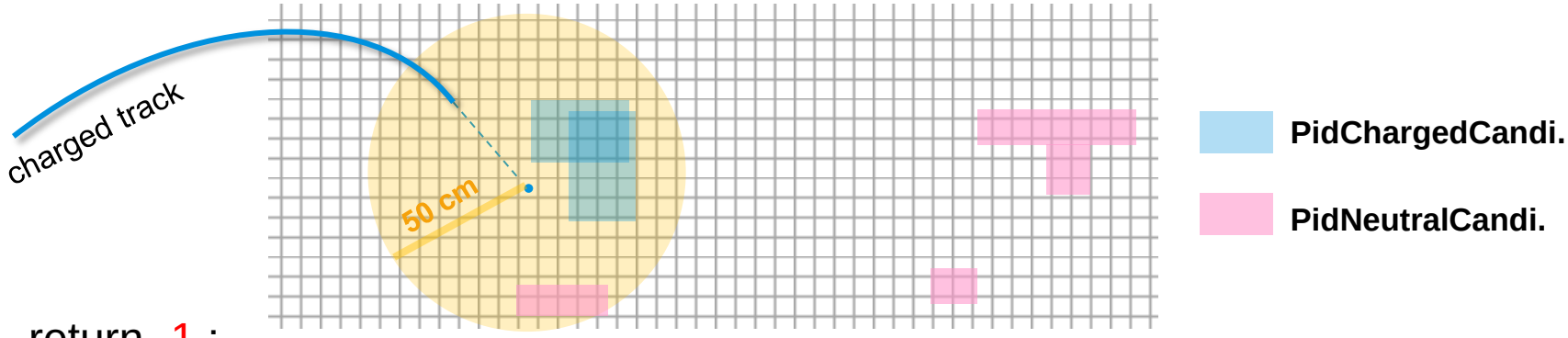


- return -1 :

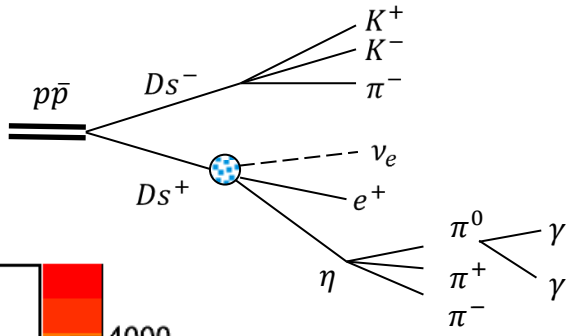
  - no MC or no MCindex found when ideal PID is used
  - cluster energy below EMC barrel threshold 20 MeV
  - hit not come from EMC or FSC
  - no propagation at module when Geane is used

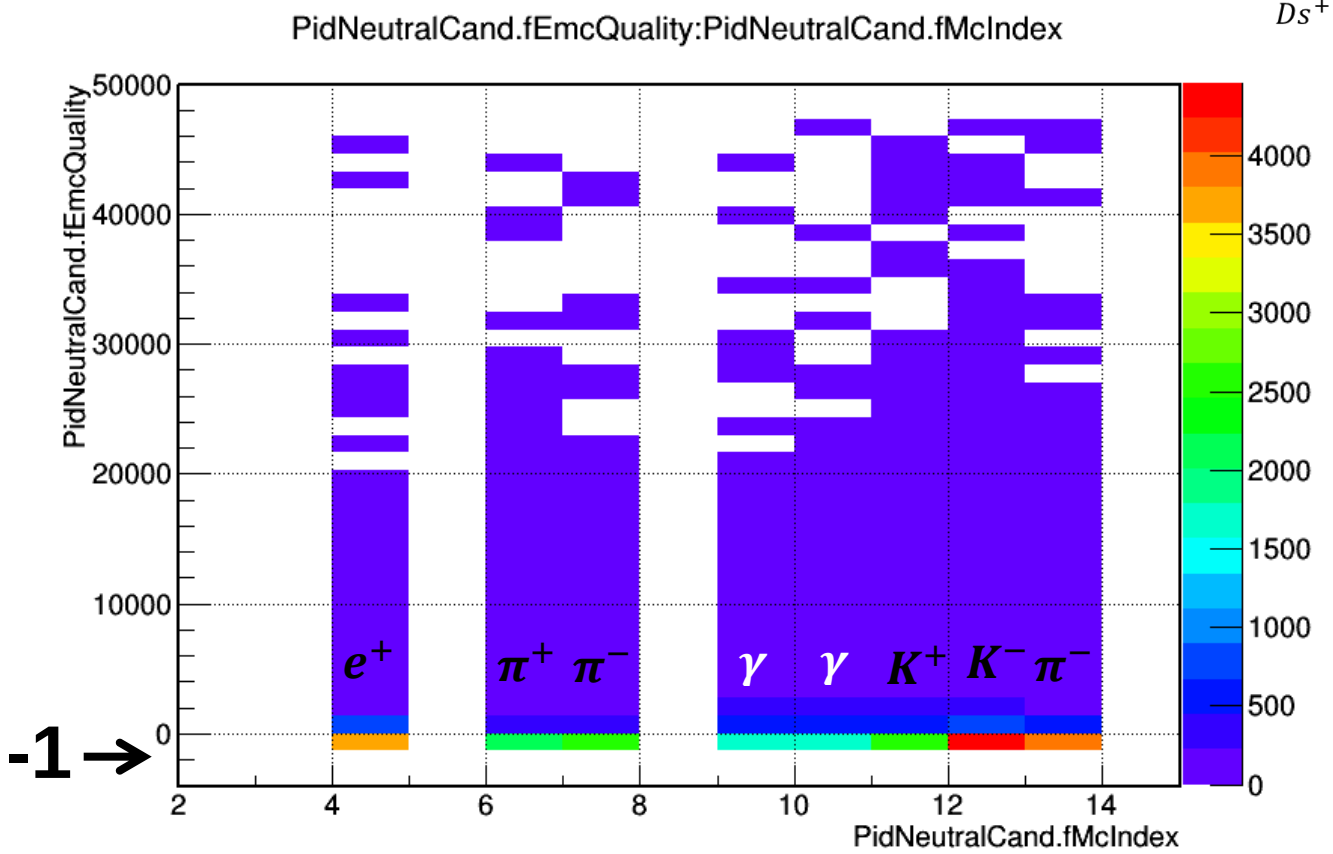
  - momenta too low (<0.1) or too high (> 15)
  - poor tracking quality
  - no track info

Forum

EMC Quality vs MC Index

MC Id	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Cand.	$P\bar{P}$	D_s^+	D_s^-	η	e^+	ν_e	π^+	π^-	π^0	γ	γ	K^+	K^-	π^-

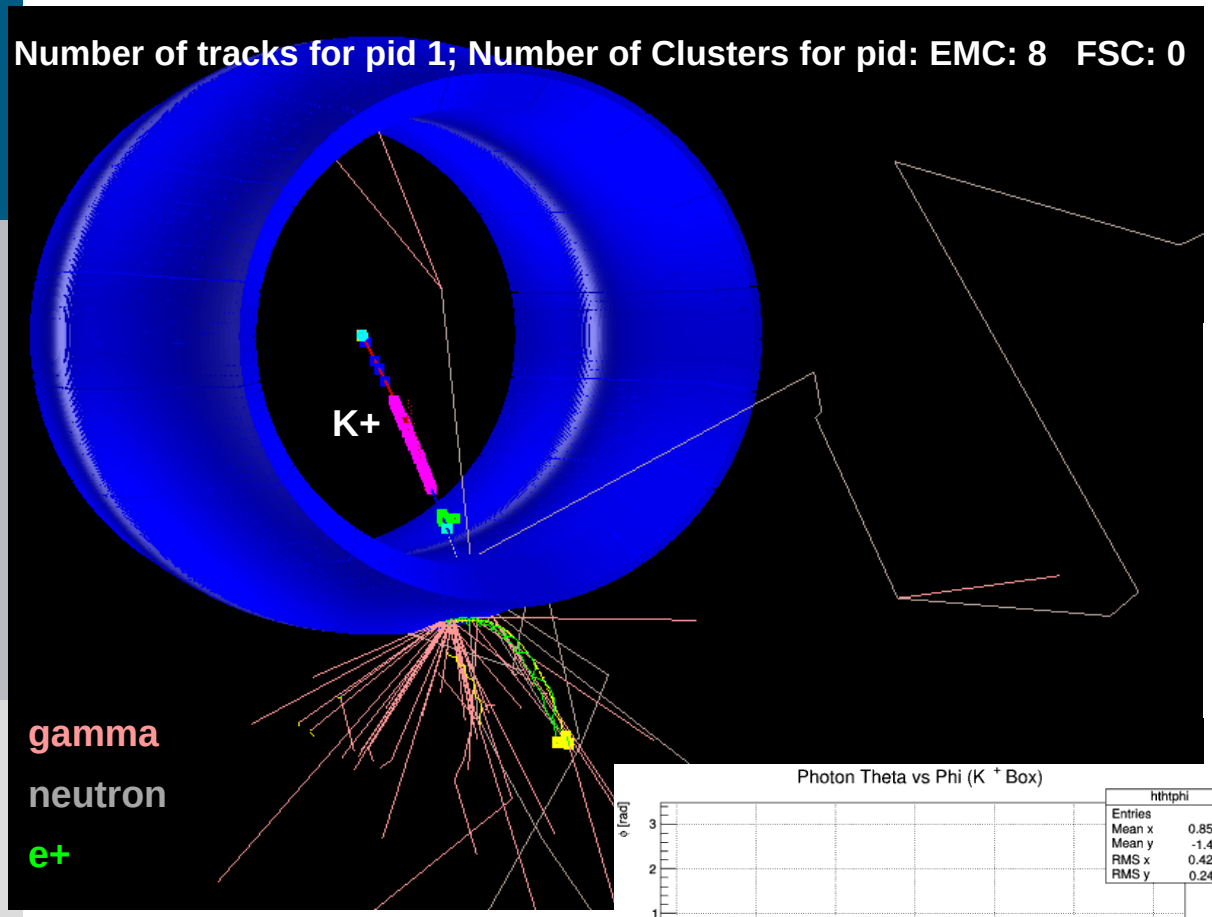


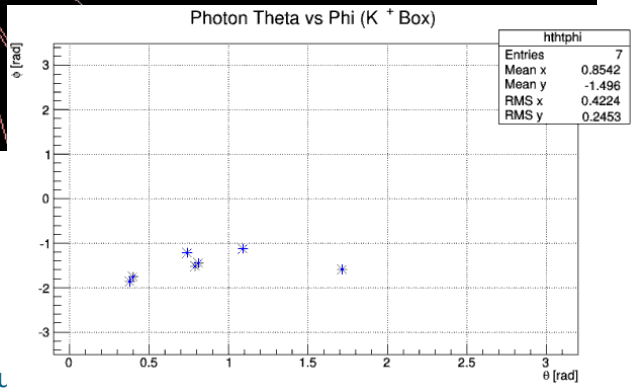


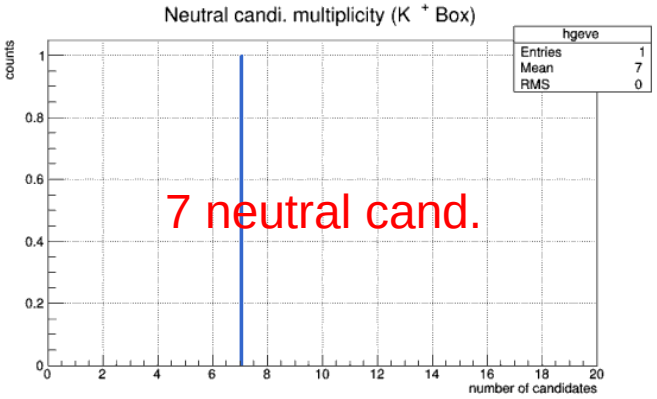
FullSim 2k evt #25800

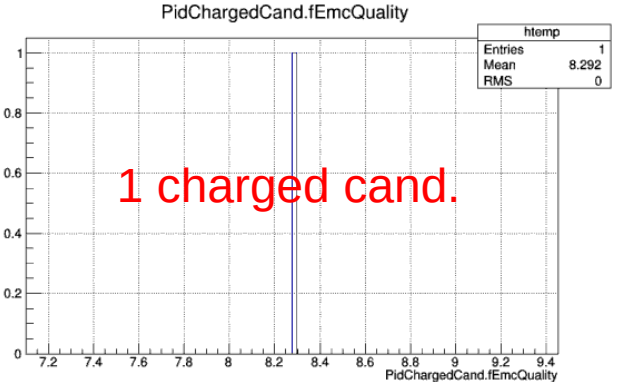
Single Event of K+

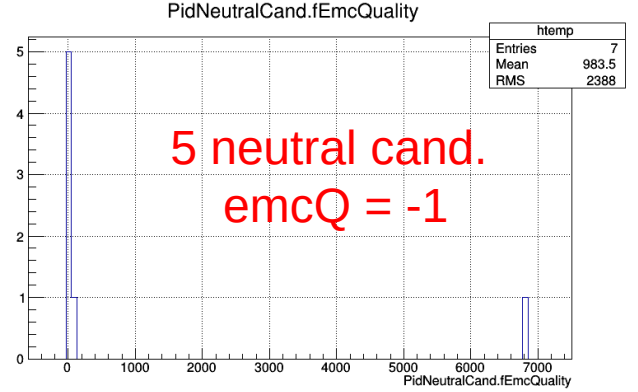
$p \in (1,4)\ GeV/c$





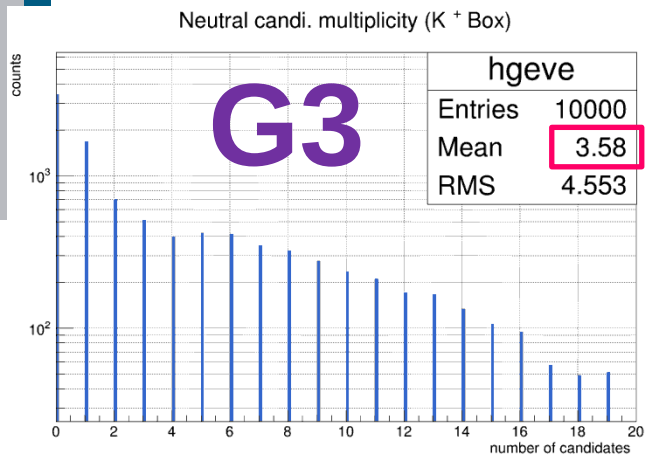


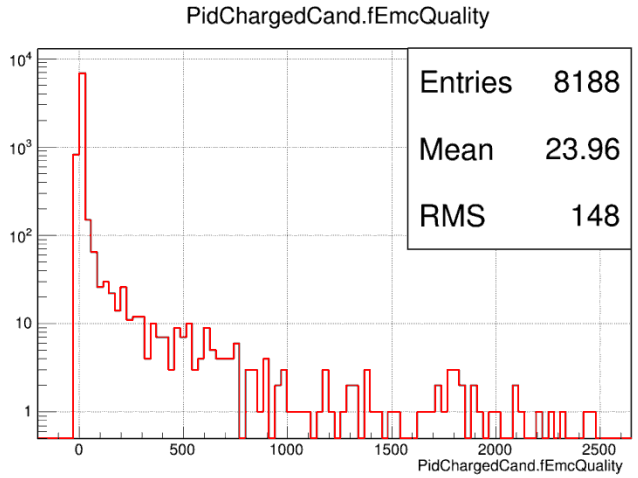


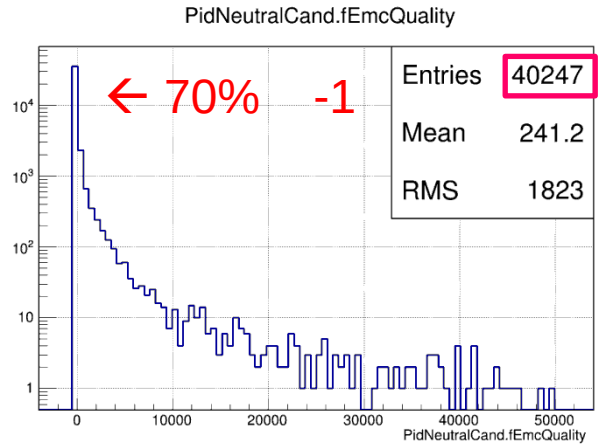


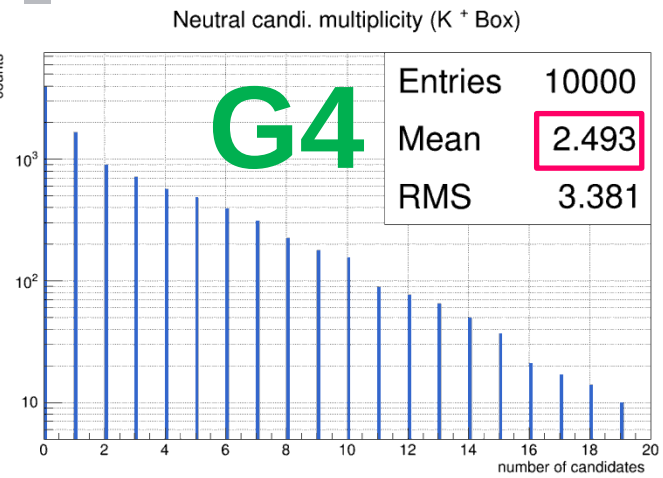
- K+ 10k evt in BoxGenerator
- PandaRoot #25800
- **Geant 3** / **Geant 4**

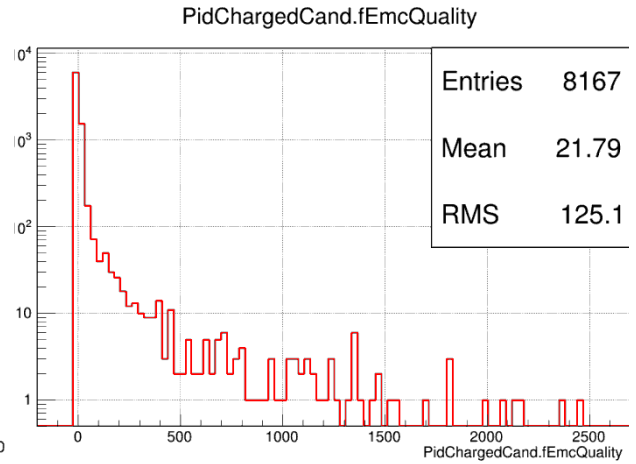
- p ∈ (1,4) GeV/c
- θ ∈ (0,180) degree
- ϕ ∈ (-180, 180) degree

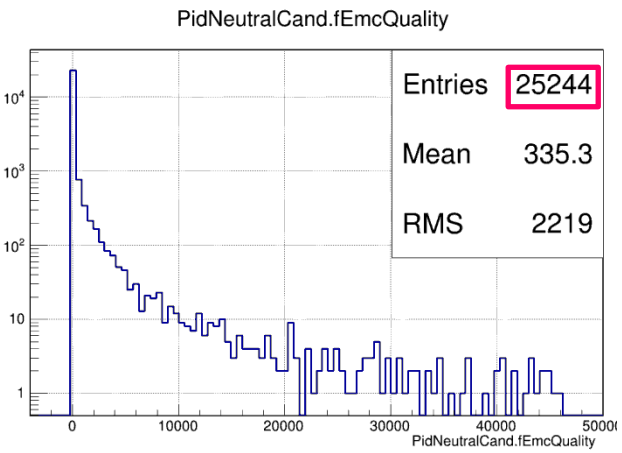




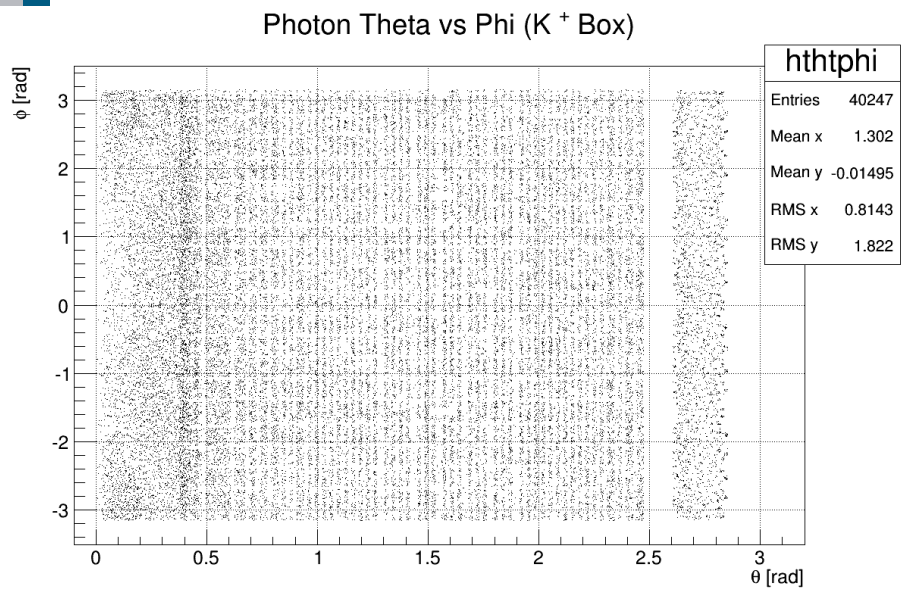


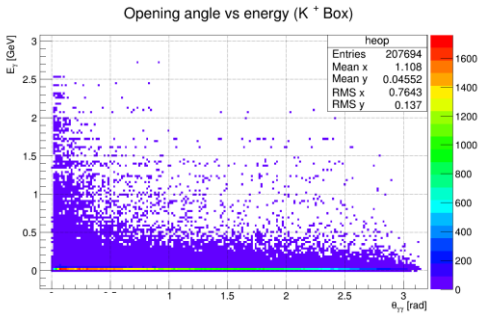


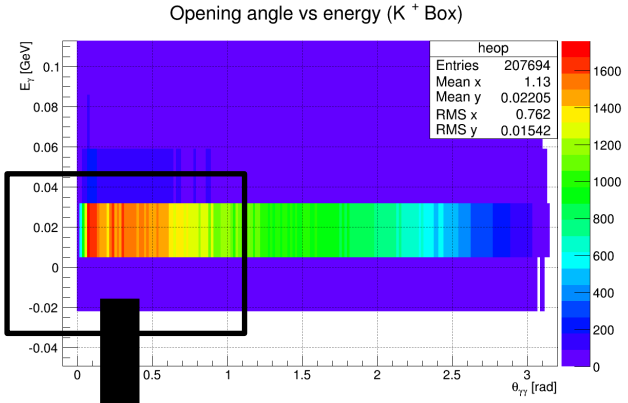




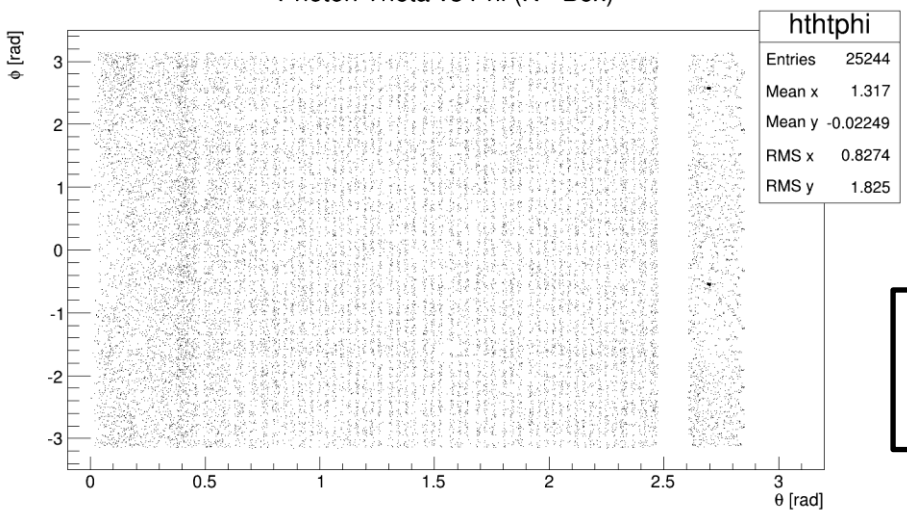
K+ in BoxGen 10k evt #25800

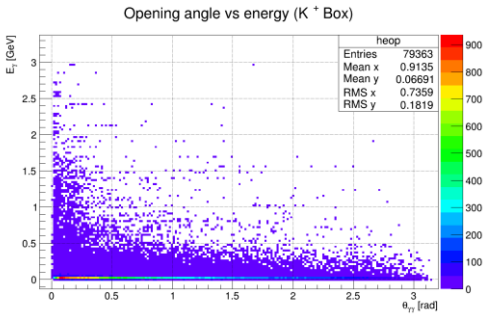


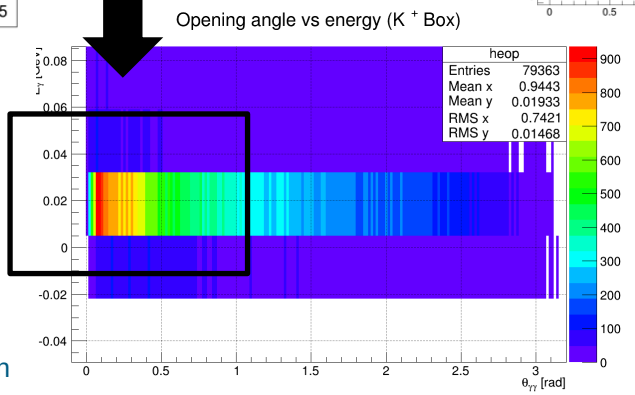




G3







G4

Reconstruction Results with G3/G4

Full sim: 10k evt (#25800) $E_\gamma \geq 30\ \mathrm{MeV}$

G3		entries	~ %
e^+		7340	**73%**
D_s^-	all	3431	
	vtx	2428	
	mcf	1682	**17%**
η	$\pi^+\pi^-$ all	9727	
	$\pi^+\pi^-$ vtx	7231	
	eta all	2191	
	eta mcf	1104	**11%**
π^0	all	55906	
	mcf	25120	
	mass window	10423	
$(e^+\nu_e)$	w/o cut	209	**2%**
	w. cut	80	**0.8%**
	sig : bkg	**0.62 : 1**	

G4		entries	~ %
e^+		7216	**72%**
D_s^-	all	3465	
	vtx	2450	
	mcf	1673	**17%**
η	$\pi^+\pi^-$ all	9893	
	$\pi^+\pi^-$ vtx	7441	
	eta all	2150	
	eta mcf	1122	**11%**
π^0	all	43822	
	mcf	21263	
	mass window	9204	
$(e^+\nu_e)$	w/o cut	201	**2%**
	w. cut	83	**0.8%**
	sig : bkg	**0.70 : 1**	

Reconstruction Results with G3/G4

Full sim: 10k evt (#25800) $E_\gamma \geq 30\ \mathrm{MeV}$

		Mass resolution (vtx) [MeV/c²]	Vertex resolution [μm]			Momentum resolution [%]		$Ds^-\ c\tau$ [μm] PDG: 150
			X	Y	Z	Pt	Pz	
G3	*Ds*	16	73	72	169	2.8	1.3	188 ± 4
	η	11.2	335	327	938	1.9	1.5	
	ν_e	11.4						
G4	*Ds*⁻	15.5	67	63	144	2.9	1.3	174 ± 3
	η	10.9	294	273	790	2.0	1.5	
	ν_e	9.3						

- Similar entries amount, but better resolutions of mass and vertex with G4

Summary and Outlook

Done

- EMC PID checked with event display
- Neutral candidates multiplicity compared in G3 / G4
- Full simulation result updated

To Do

- Improve EMC cluster correlator in PID
- Modify present simulation if possible
- Investigate background channels

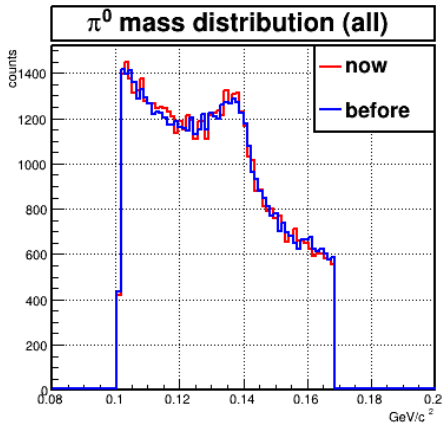
Picture cited from internet

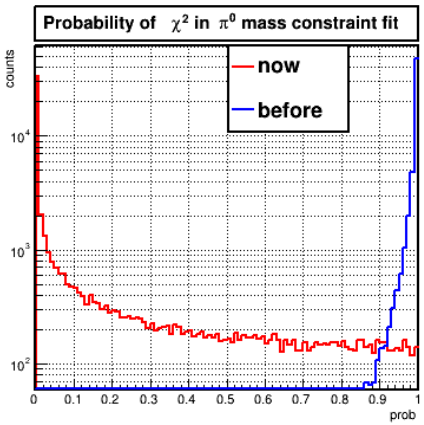
Thank you

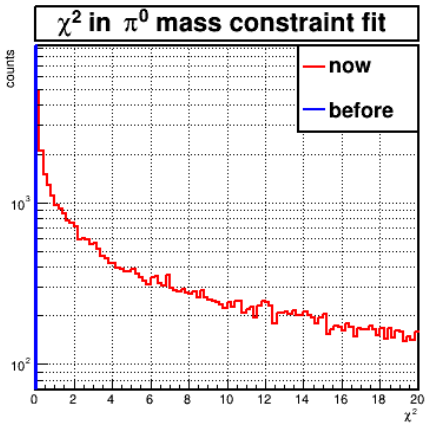
l.cao@fz-juelich.de

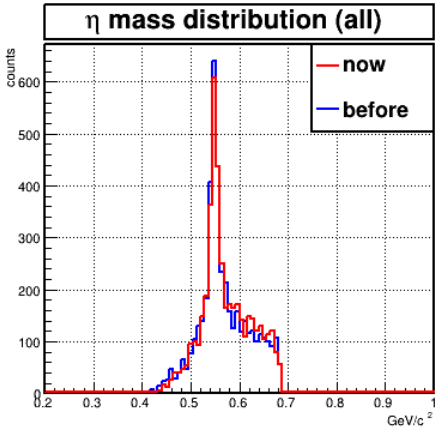
Backup Slides

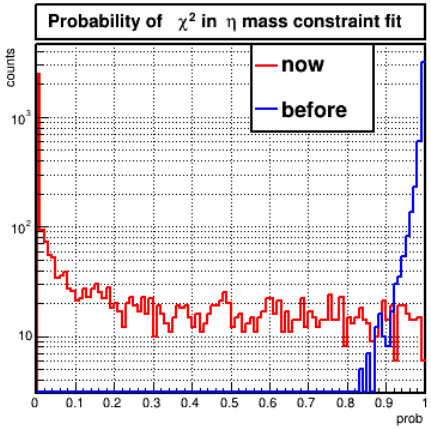
#25009(before) vs #25628(now)

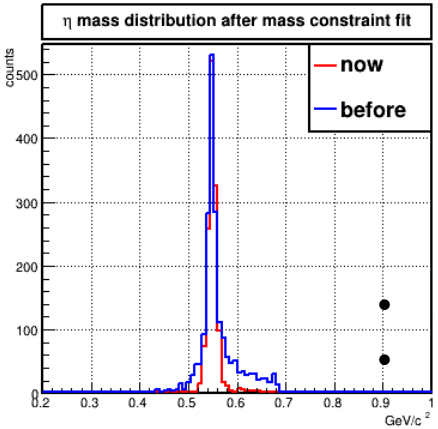








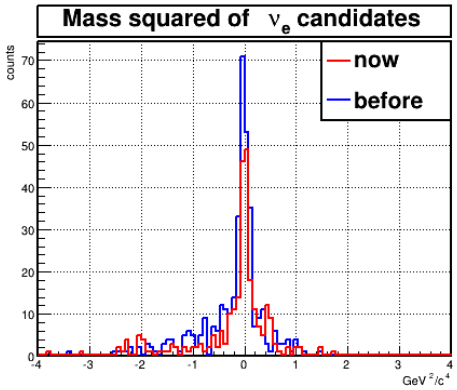


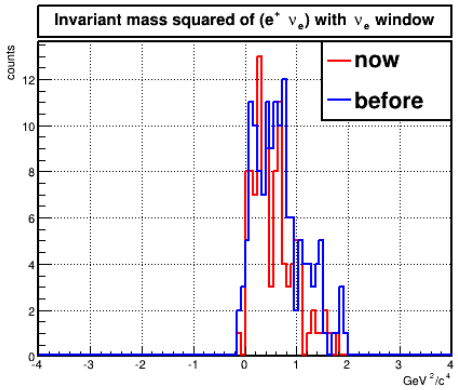


- 10k evt
- Ideal PID
- Mass window width [MeV/c^2]
  Ds: 500
  pi0: 67
  eta: 300

Select Criteria

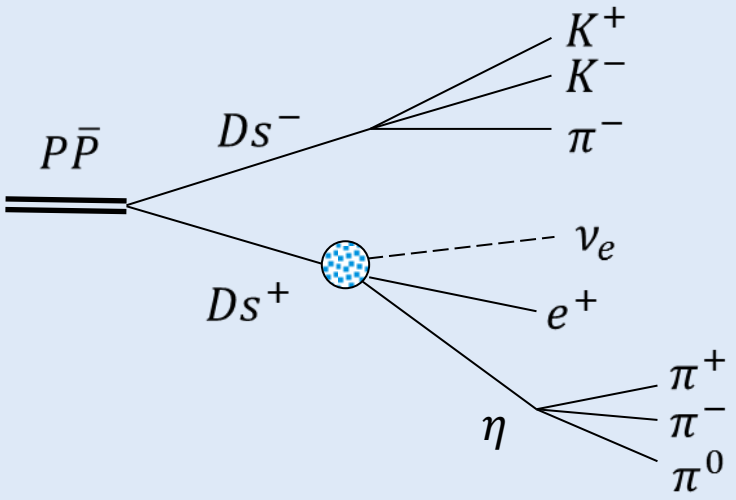
- $E_\gamma > 20$ MeV
- $\theta_{\gamma\gamma} > 0.1$ rad





- pi0 mcf p>0.01
- eta vtx p>0.01
- eta mcf p>0.01
- Ds vtx p>0.01
- Ds mcf p>0.01
- select “best” candi.
- $|M^2(\upsilon_e)|$< 0.1 GeV/c^2

Check with BoxGen

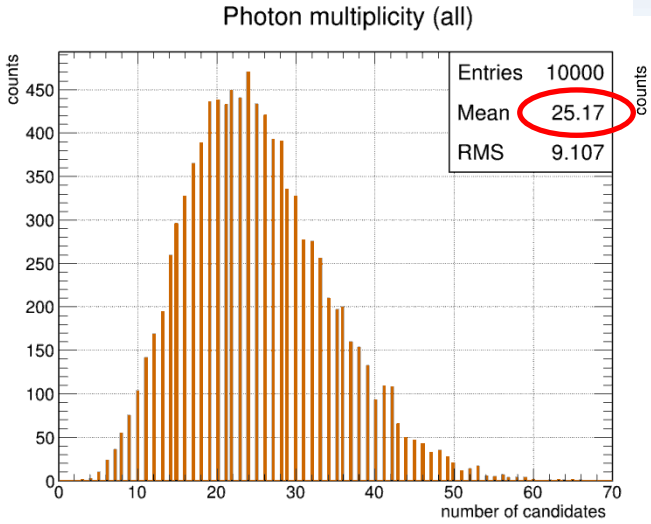


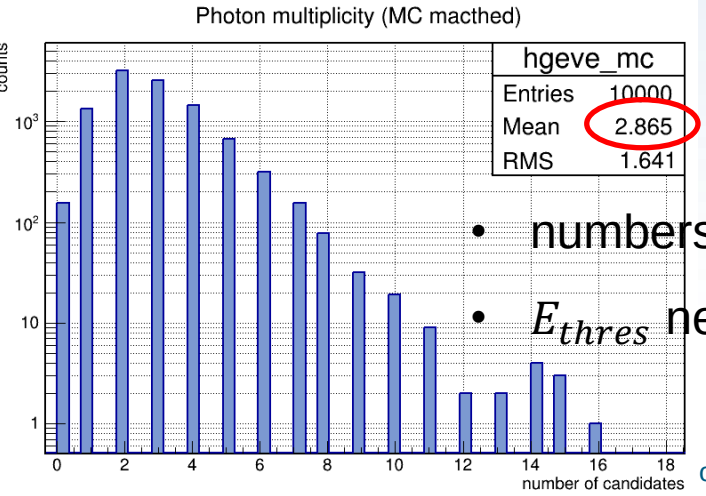
Avg. Photon Multiplicity

K+	3.7
K-	5.6
pi-	5.1
e+	2.2
pi+	4.6
pi-(eta)	4.8

gamma sum = 26 in 10k evt

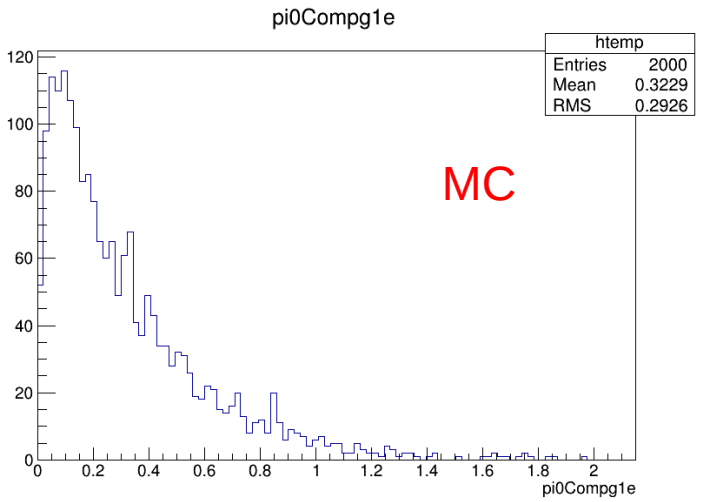
pi0 3.6

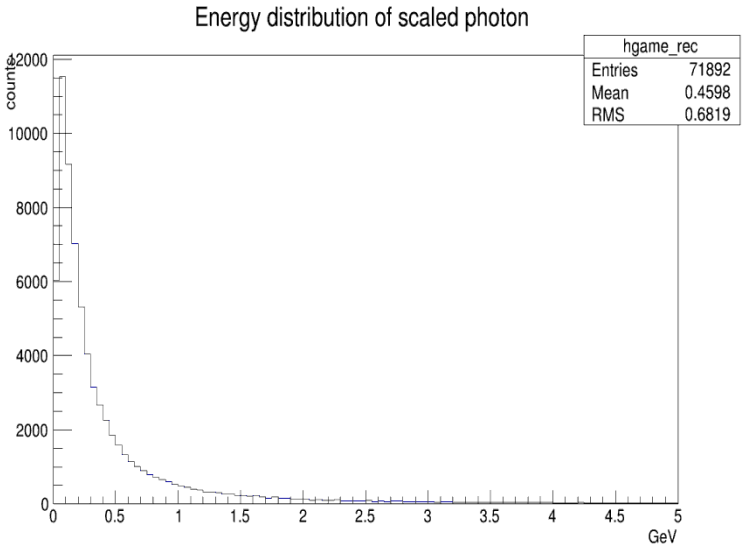




- numbers roughly consistent
- E_{thres} needs to be 35~40 MeV

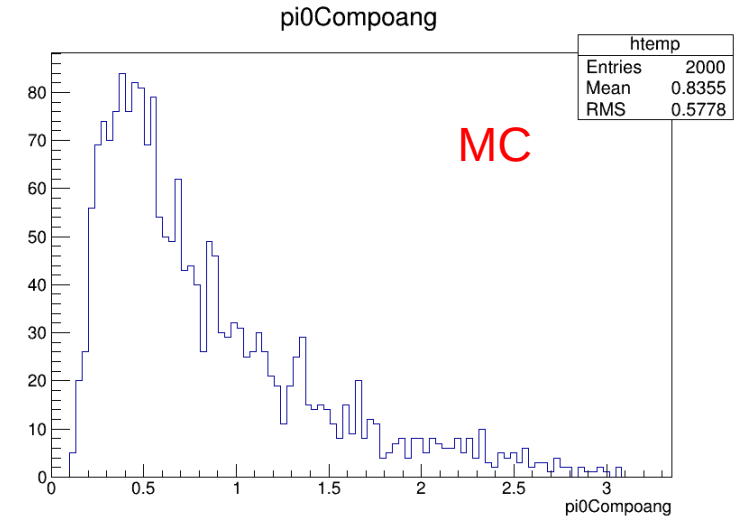
Cutting 1: photon energy > 0.02 GeV

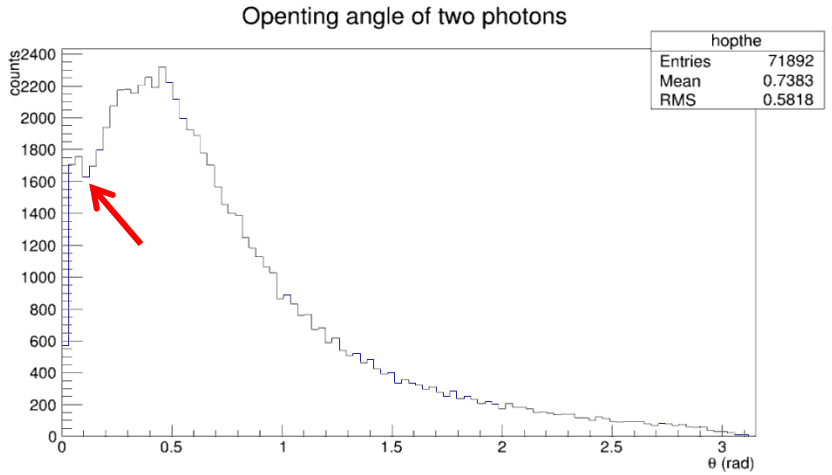




Cutting 2: opening angle > 0.1 rad

2k evt
#24910





reset: clusterQ[i] = -1
clusterList[i] = kFalse

track loop

emcQ = 10^6 cm^2 : 10 m in length

continue

cluster loop

calculate distance^2 between emcHit and track vertex: dist

continue

if (emcQ > dist) emcQ = dist

if (clusterQ <0 || dist < clusterQ) clusterQ = dist

if (emcQ < 2500)
SetChargedCandi.emcQuality (emcQ), clusterList (kTrue), etc.

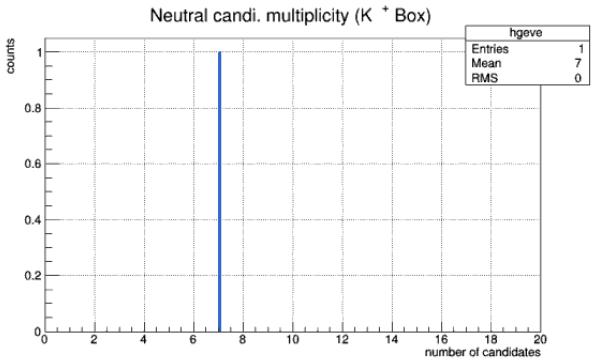
cluster/bump loop

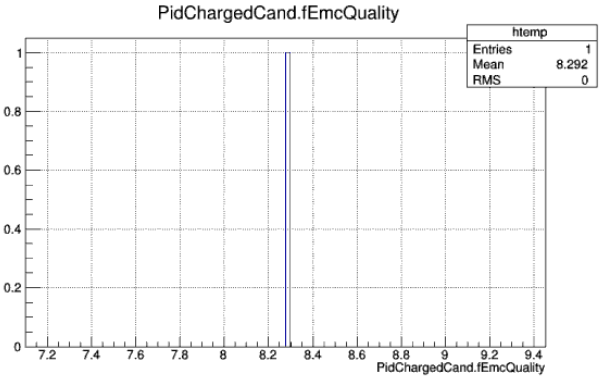
if (!clusterList (kTrue))

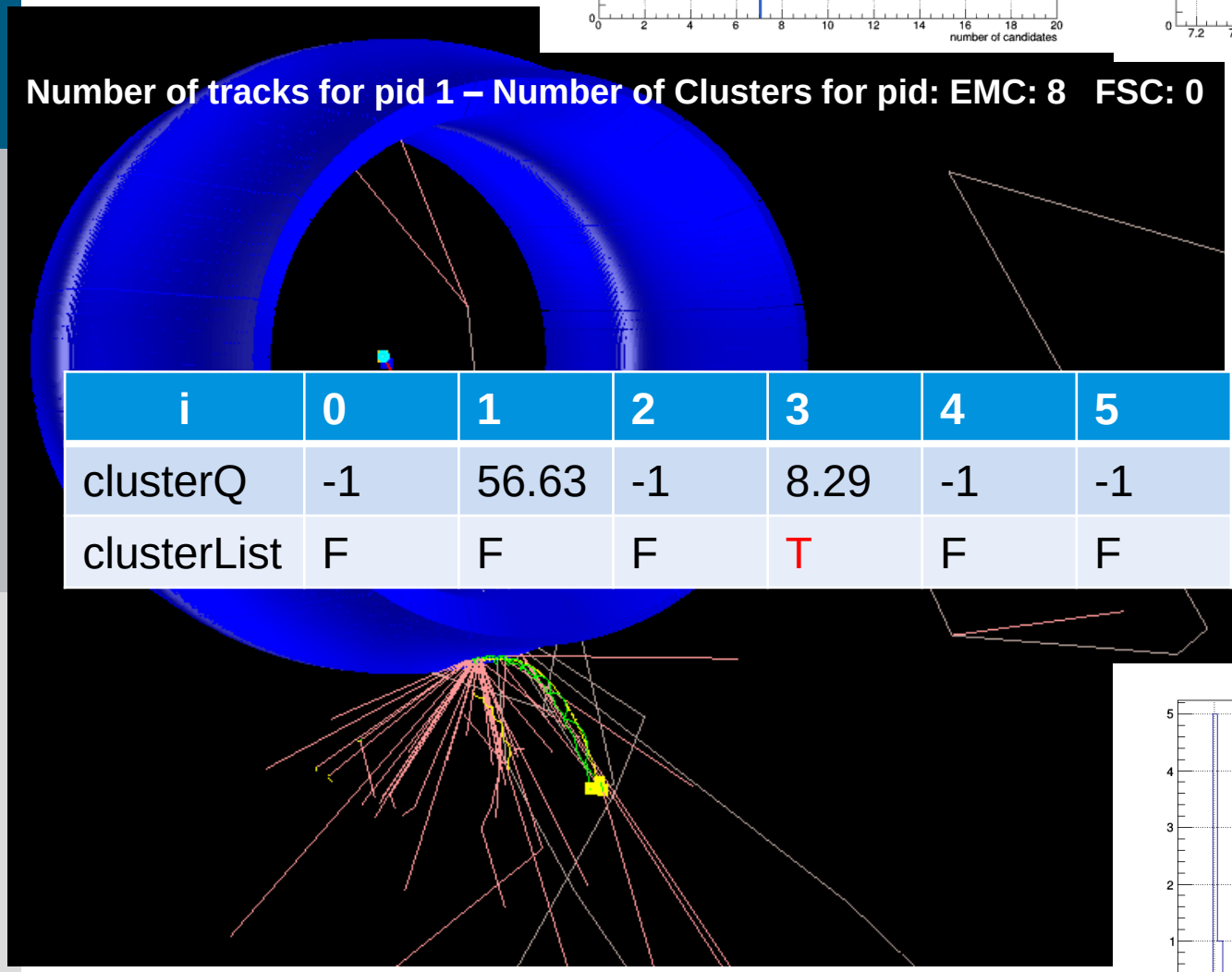
SetNeutralCandi.emcQuality (clusterQ), etc.

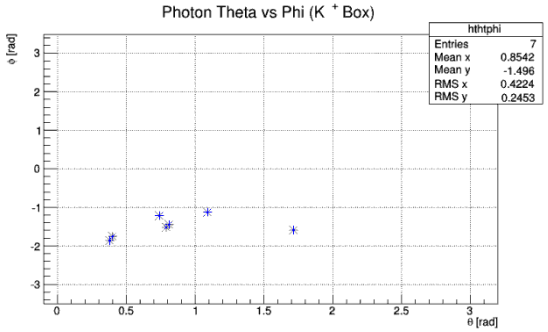
Single event K+

G3

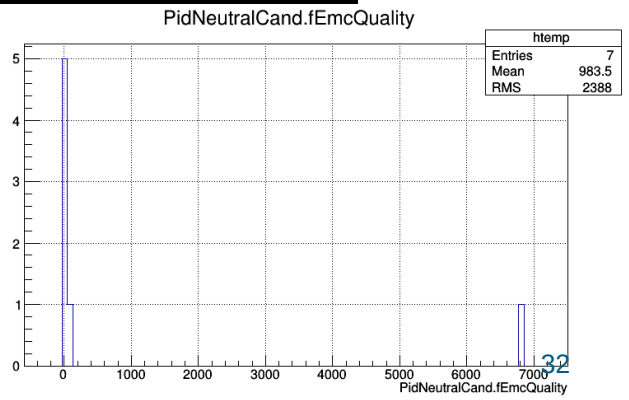




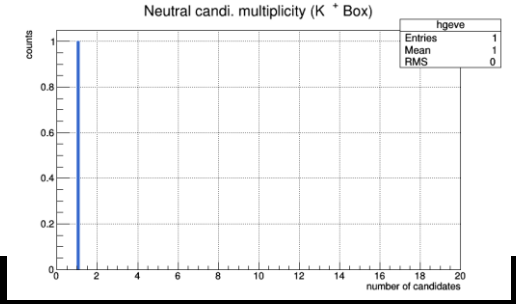


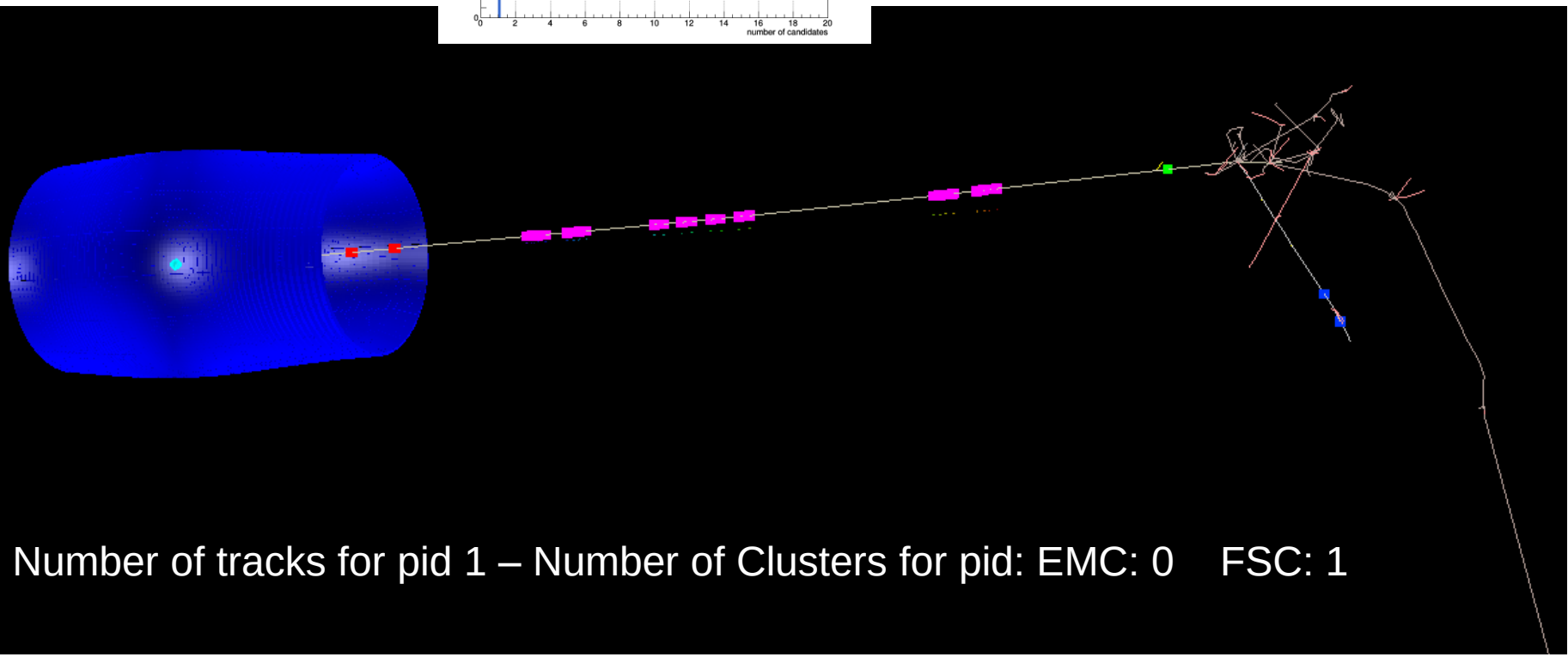


i	0	1	2	3	4	5	6	7
clusterQ	-1	56.63	-1	8.29	-1	-1	6832	-1
clusterList	F	F	F	T	F	F	F	F

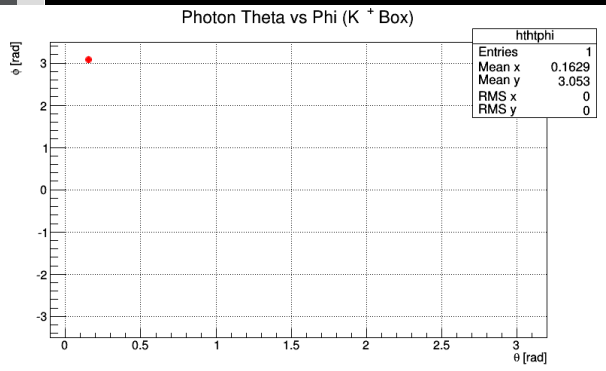


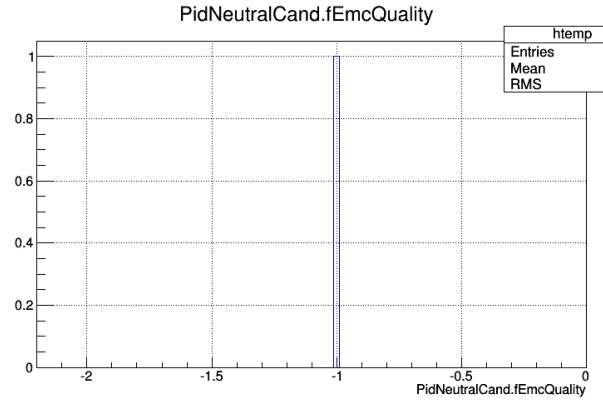
G4

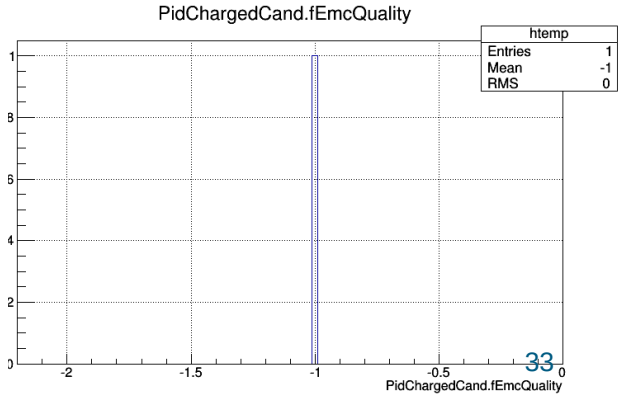




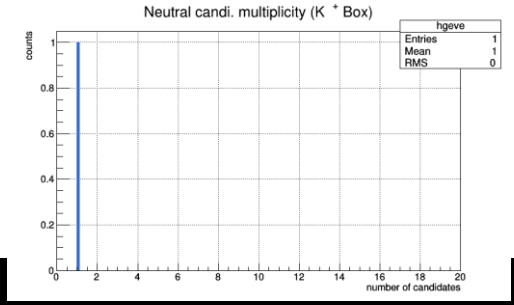
Number of tracks for pid 1 – Number of Clusters for pid: EMC: 0 FSC: 1

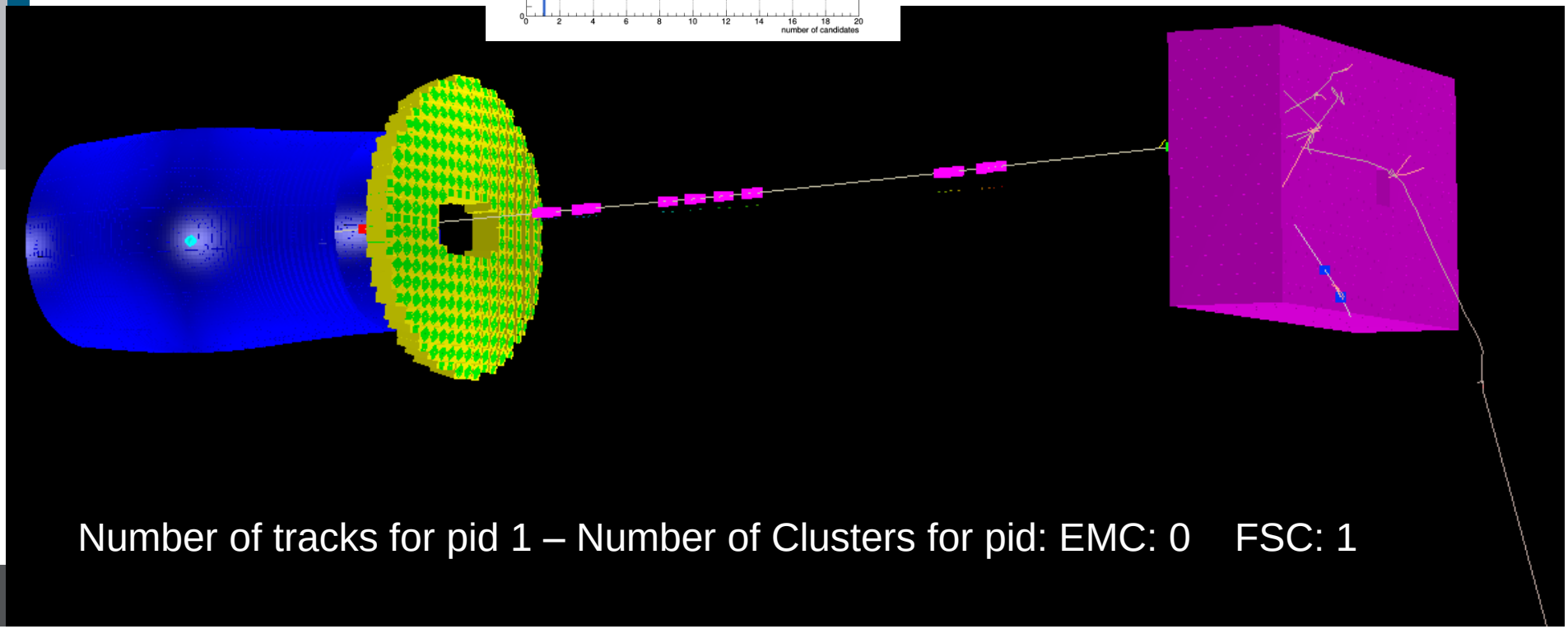




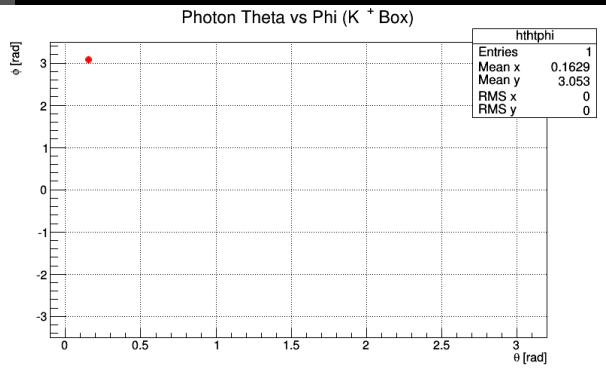


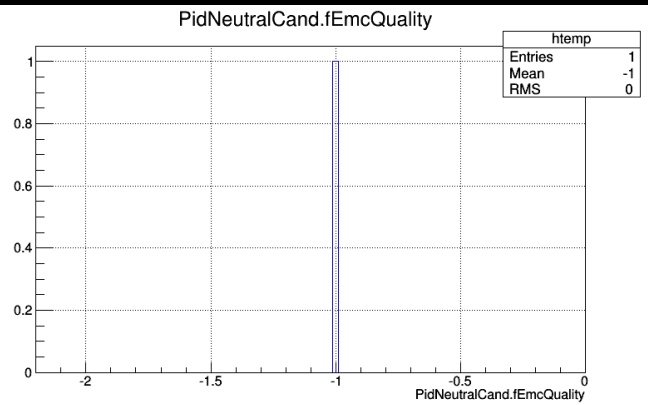
G4

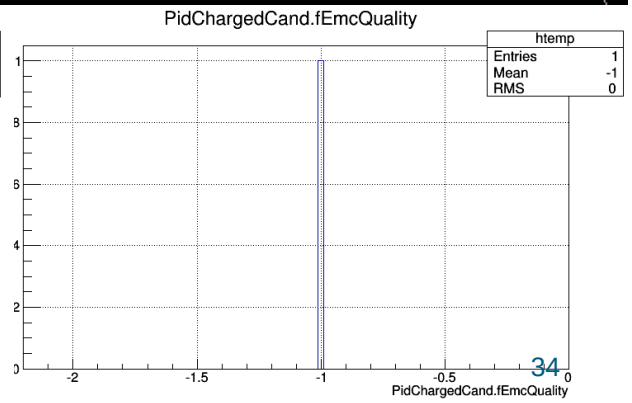




Number of tracks for pid 1 – Number of Clusters for pid: EMC: 0 FSC: 1







Reconstruction Results with G3/G4

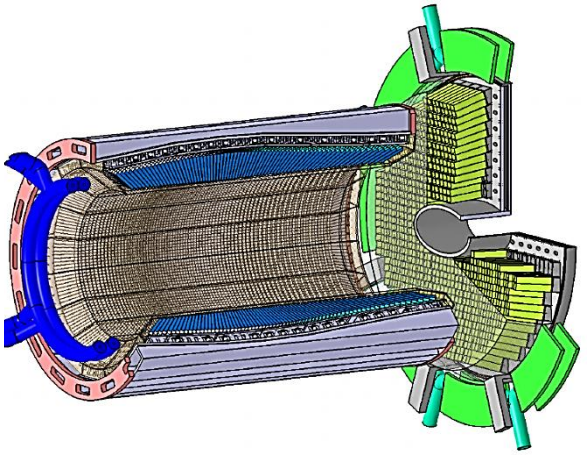
Setting & Cut:

- 10k evt $\sqrt{s} = 4.108$ GeV (#25800)
- Ideal hypothesis in Kalman track finder
- Ideal PID
- photon energy threshold: 30 MeV
- $\gamma\gamma$ mass window: 135 ± 5 MeV/c^2
- D_s^- mass window: 1968 ± 100 MeV/c^2
- η mass window: 548 ± 50 MeV/c^2

- pi0 mcf p>0.01
- eta vtx p>0.01
- eta mcf p>0.01
- Ds vtx p>0.01
- Ds mcf p>0.01
- select “best” candi. for each event
- $|M^2(\upsilon_e)|$< 0.1 GeV/c^2

Main requirements for EMC

	Required performance value		
Common properties			
energy resolution σ_E/E	$\leq 1\,\% \oplus \frac{\leq 2\,\%}{\sqrt{E/\mathrm{GeV}}}$		
energy threshold (photons) E_{thres}	10 MeV (20 MeV tolerable)		
energy threshold (single crystal) E_{xtl}	3 MeV		
rms noise (energy equiv.) $\sigma_{E,noise}$	1 MeV		
angular coverage $\%\,4\pi$	99 %		
mean-time-between-failures t_{mtbf} (for individual channel)	2000 y		
Subdetector specific properties	backward ($\geq 140°$)	barrel ($\geq 22°$)	forward ($\geq 5°$)
energy range from E_{thres} to	0.7 GeV	7.3 GeV	14.6 GeV
angular equivalent of crystal size θ	4°		1°
spatial resolution σ_θ	0.5°	0.3°	0.1°
maximum signal load f_γ ($E_\gamma > E_{xtl}$)	60 kHz		500 kHz
($p\bar{p}$-events) maximum signal load f_γ ($E_\gamma > E_{xtl}$)	100 kHz		500 kHz
(all events) shaping time t_s	400 ns		100 ns
radiation hardness (maximum annual dose $p\bar{p}$-events)	0.15 Gy	7 Gy	125 Gy
radiation hardness (maximum annual dose from all events)	10 Gy		125 Gy



Barrel and forward end-cap EMC

Reconstruction thresholds

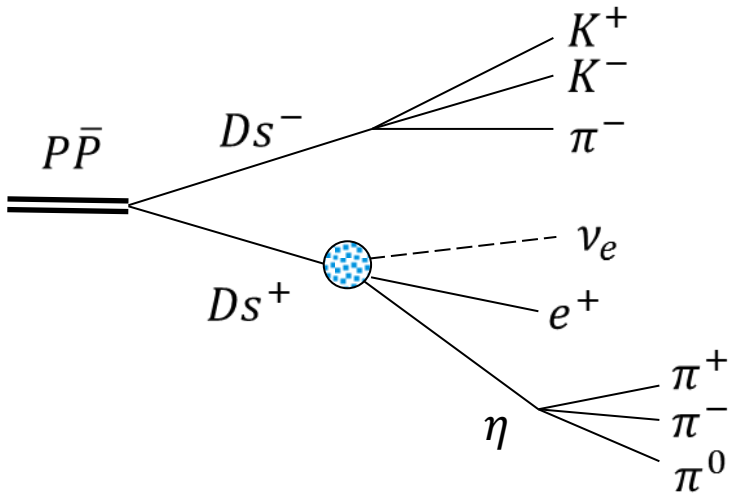
- $E_{xtl} = 3\,\mathrm{MeV}$
- $E_{cl} = 10\,\mathrm{MeV}$
- $E_{max} = 20\,\mathrm{MeV}$

Dynamical Energy Range

- backward endcap EMC: 10(20) MeV- 0.7 GeV
- barrel EMC: 10(20) MeV- 7.3 GeV, and
- forward endcap EMC: 10(20) MeV- 14.6 GeV.

pbarpSystem

-> Ds- Ds+	BR_{PDG}
| |-> eta e+ nu_e	2.67%
| |->pi+ pi- pi0	22.74%
|-> K- K+ pi-	5.49%



Production Rate of Ds pair

with high luminosity mode in 35 days

$$R = \mathcal{L} \cdot \sigma \cdot \varepsilon \cdot t \cdot \mathcal{BR} \qquad \sigma = A\ nb = A \times 10^{-9}\ b \qquad \varepsilon = B\%$$

$$= 2 \times 10^{32}(cm^{-2}s^{-1}) \cdot \boldsymbol{A}(nb) \times 10^{-24}(cm^2/b) \cdot \boldsymbol{B} \times 10^{-2} \cdot 3 \times 10^{6}(s) \cdot 2.67\% \times 5.49\% \times 22.74\%$$

$$\sim 2\boldsymbol{AB} = \mathbf{2 \times 20 \times 3.7 = 148}$$