Effect of Material on electron measurements in eEMCal (PWO). Simplified Studies

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For ATHENA-Calorimetry Discussion

August 30, 2021

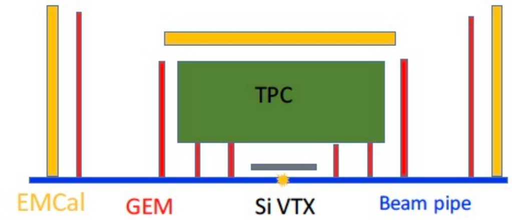
For ATHENA-Tracking Discussion (updated)

August 31, 2021

For ECCE-Calorimetry Discussion (updated)

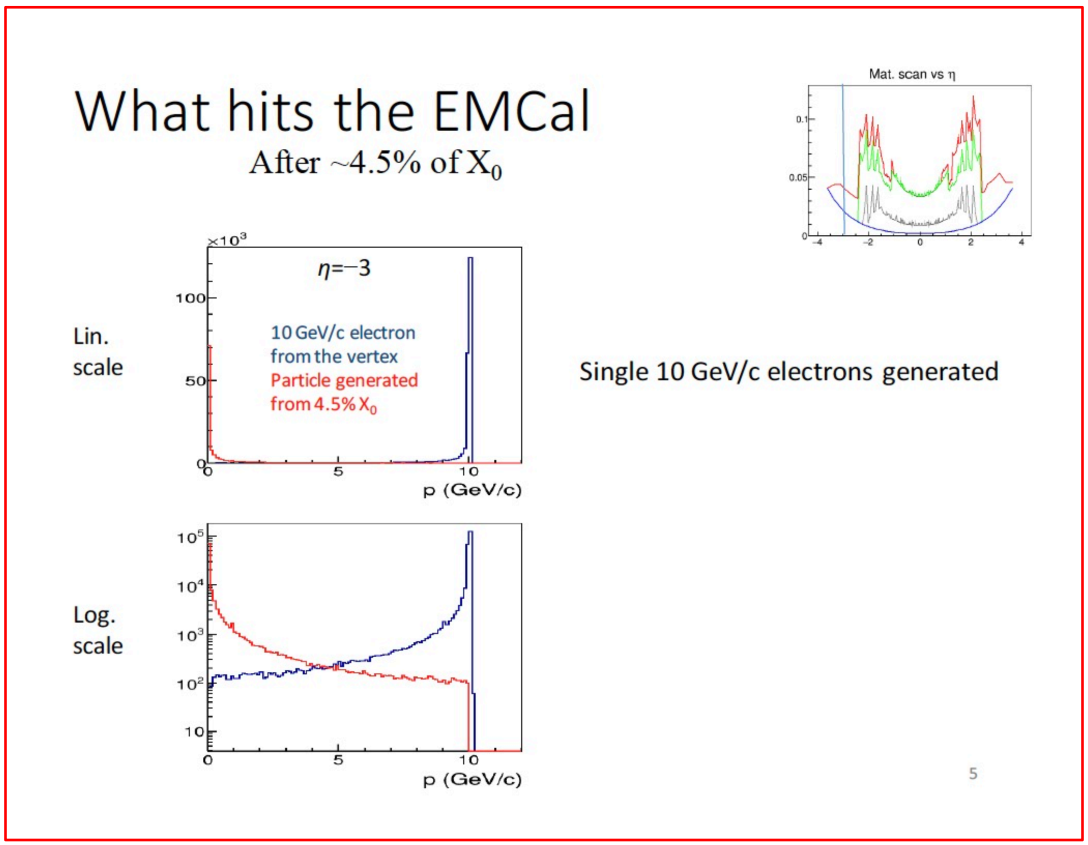
September 28, 2021

Back to YR studies



No PID detectors
No support/service material

From my presentation for YR-Calorimetry, Jun 30, 2020



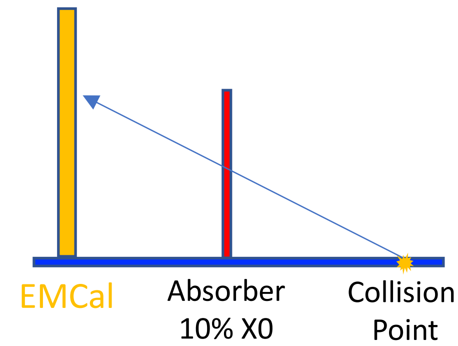
Original electron reaches EMCal with part of its energy radiated

Long and flat tail towards lower energy

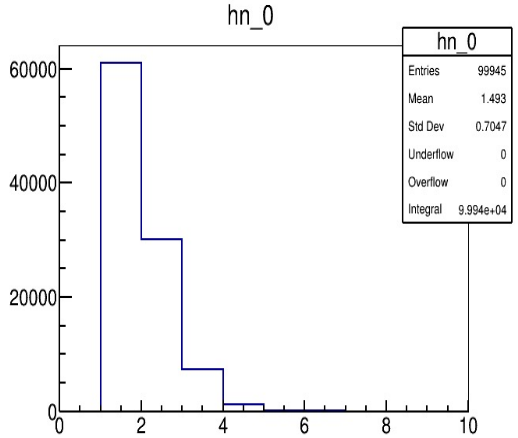
A lot of soft particles, mainly photons

Making setup simpler

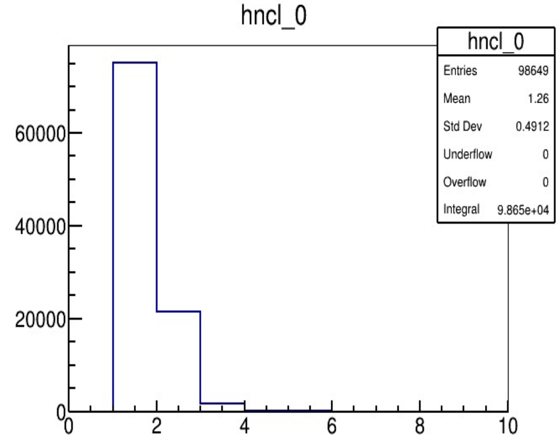
1 GeV/c electron



Number of particles hitting the EMCal (>20 MeV)



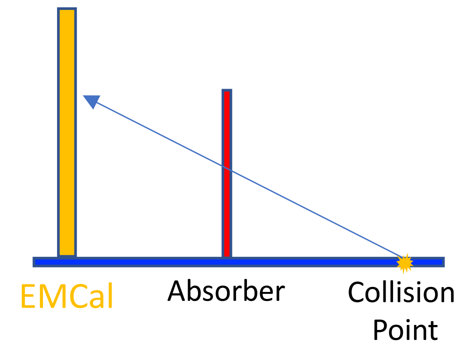
Number of clusters in the EMCal (>20 MeV)



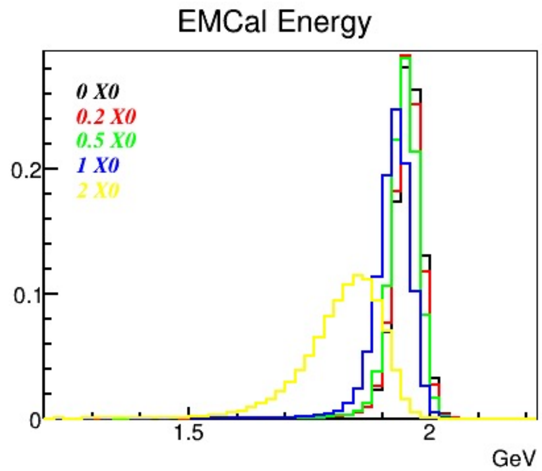
~40% of events with >1 particle hitting the EMCal (>20 MeV)

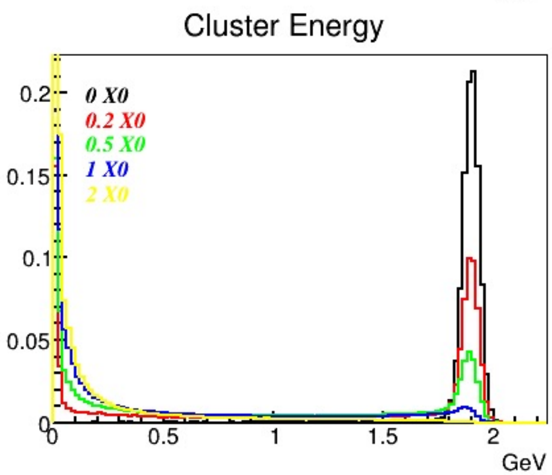
¼ of events with >1 cluster (> 20 MeV)

Making setup simpler



2 GeV/c electron





Energy is not lost for the thickness <0.5*X0
(Consistent with EM shower long. profile)

But energy gets redistributed in the EMCal
(Electron + radiated γ and e^+e^-)

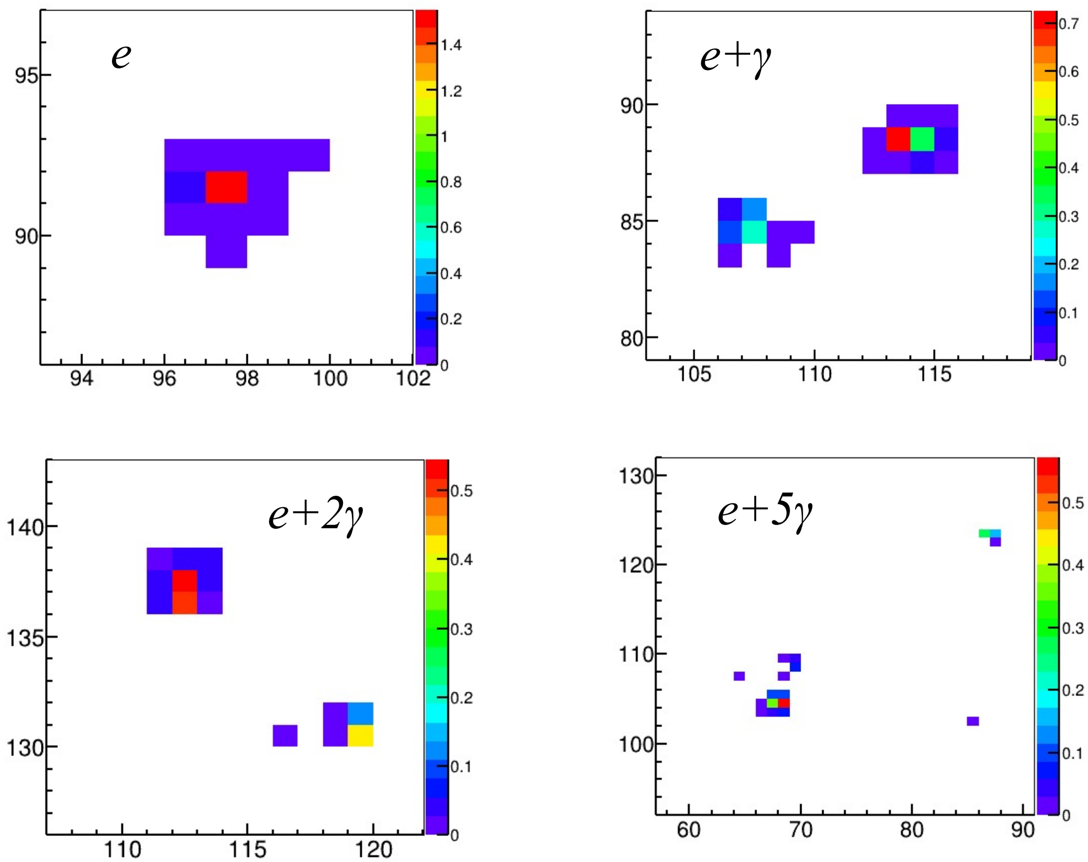
For the material of <0.5*X0, no energy is missing

The key question is how well we can reconstruct/associate the energy related to original electron

eReco in EMCal with material on the way

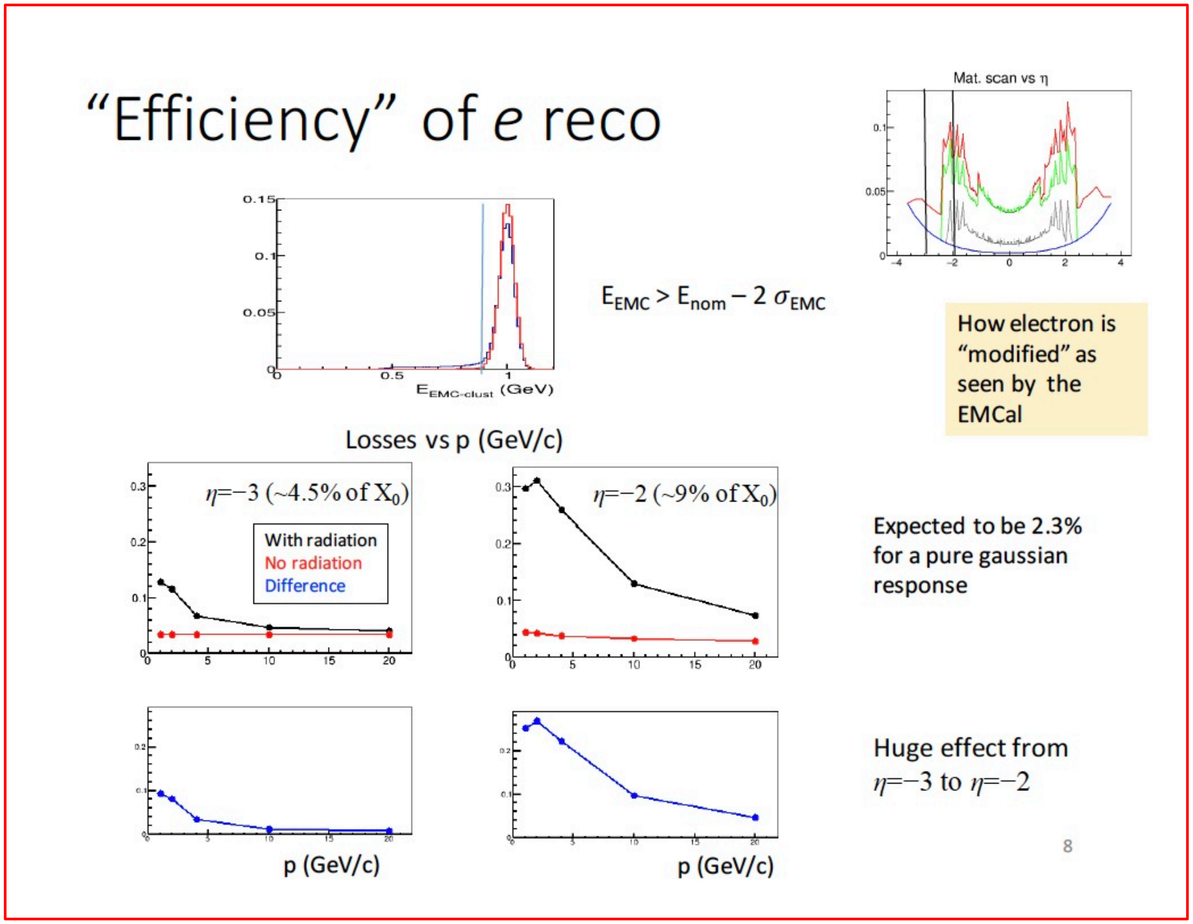
Single 2 GeV electrons simulation
with ~5% material on the way to EMCal

Energy in EMCal towers



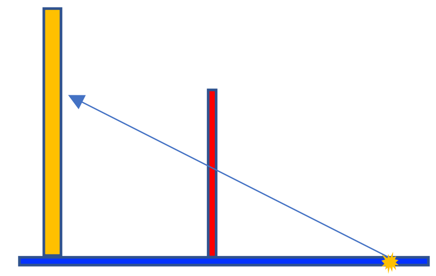
Quantifying the effect

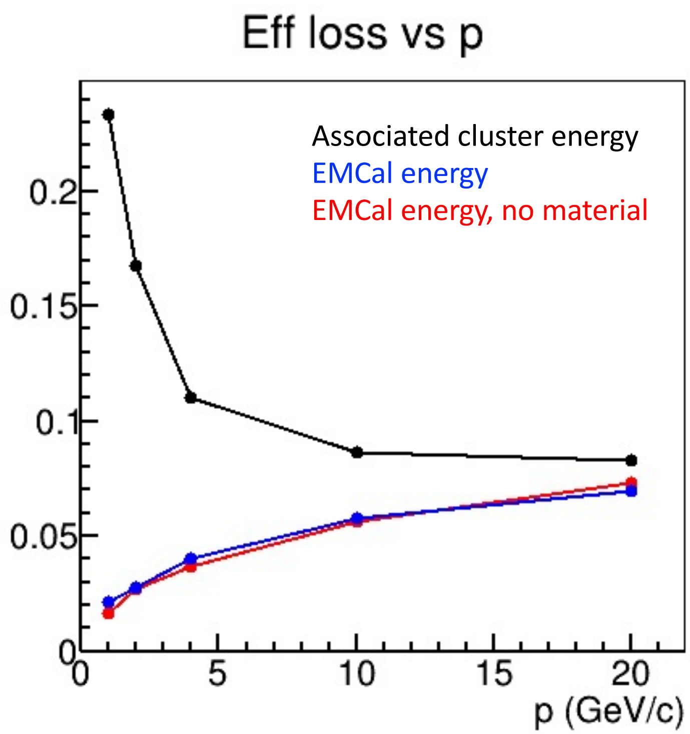
From my presentation for YR-Calorimetry, Jun 30, 2020



Now, do the same in the following

Associated cluster vs energy sum

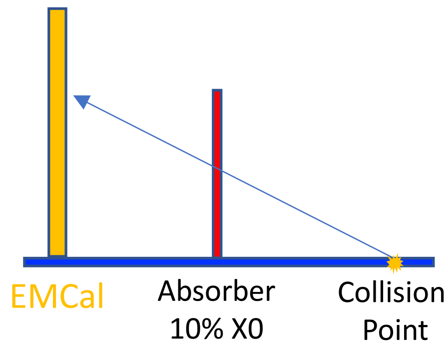




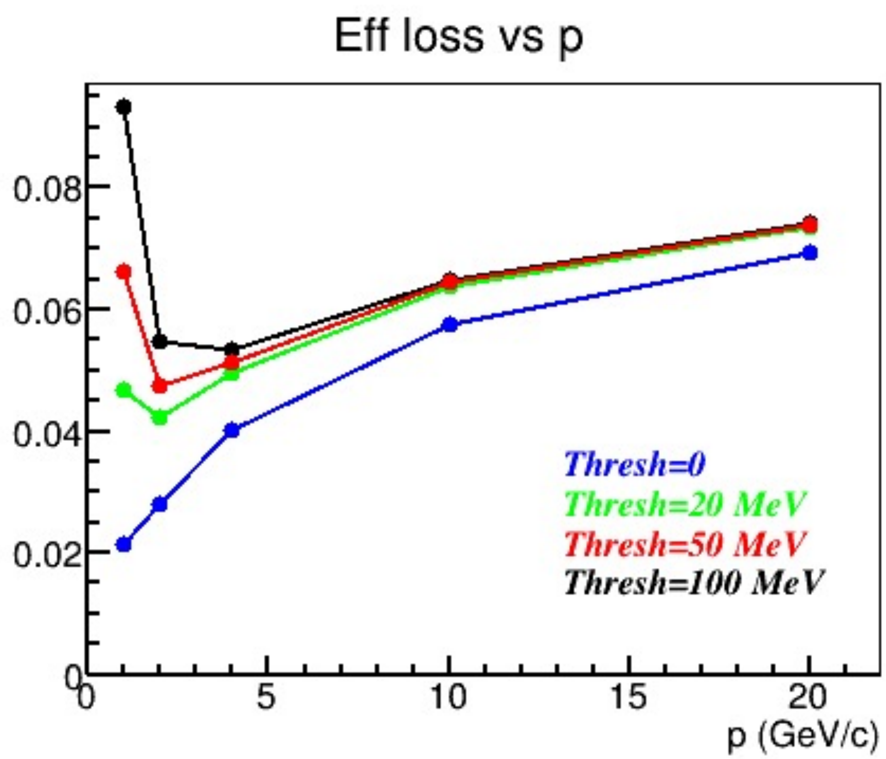
Single (track associated) cluster doesn't represent well the electron energy, particularly at low momenta

Need to combine electron cluster with accompanying radiation (including very low energy one)

Energy sum: cluster threshold effect



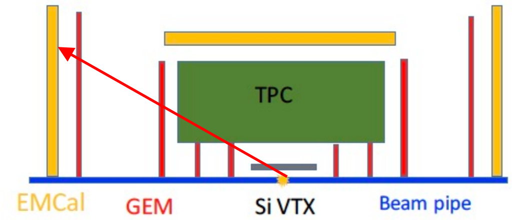
A lot of low energy radiated photons
=> sensitivity to energy threshold



Minor effect at p>5 GeV/c
Sharply increasing effect at p<2 GeV/c

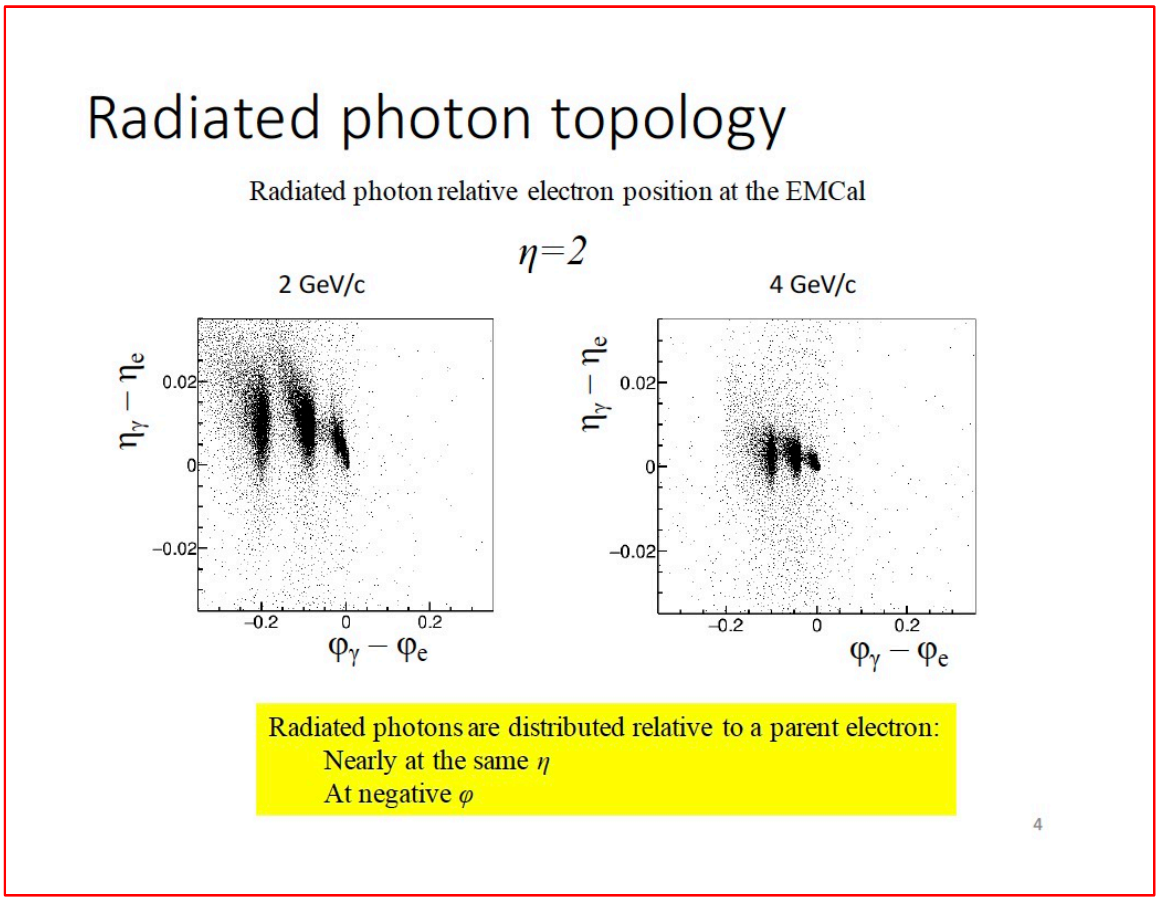
Need to measure photons to as low energy as possible (down to 20-50 MeV)

Radiated photons are not everywhere



No PID detectors
No support/service material

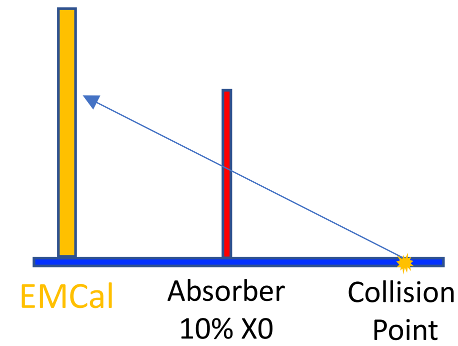
From my presentation for YR-Calorimetry, Jul 14, 2020

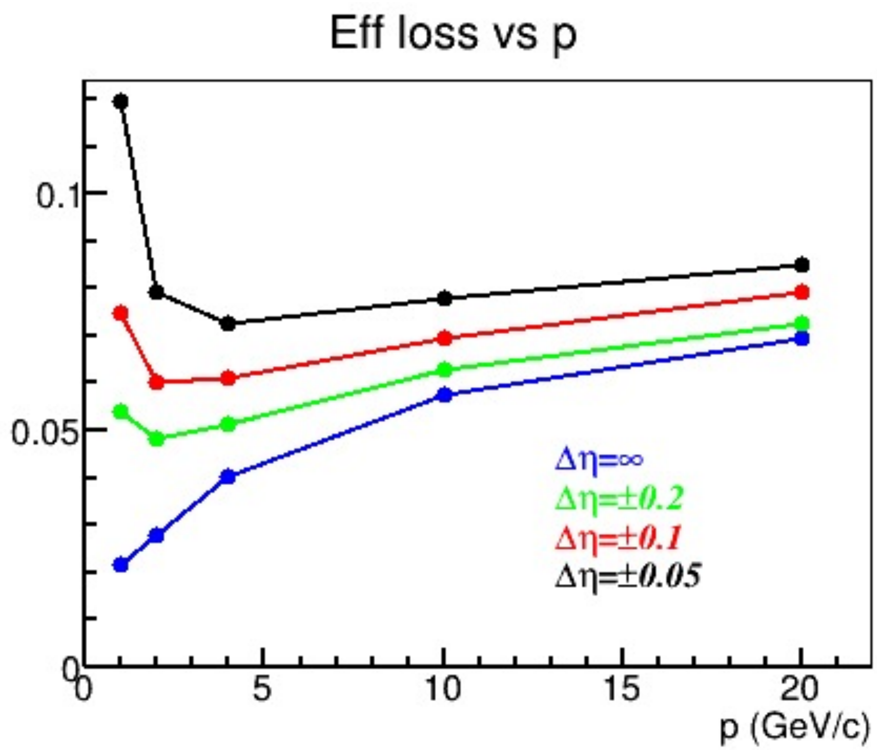


May not be able to sum up the cluster energy in the whole EMCal (will pick up not related energy)

But we may not need to: the radiated photons are distributed in arcs at pseudorapidity of the parent electron

Radiated Photon Topology Cut





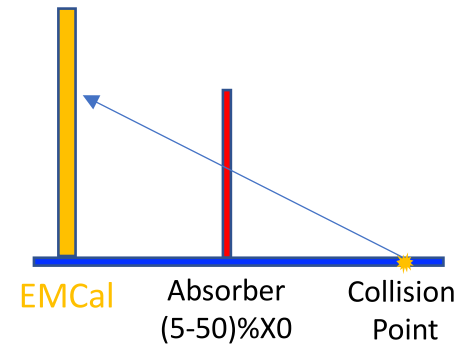
Just a very simple cut:

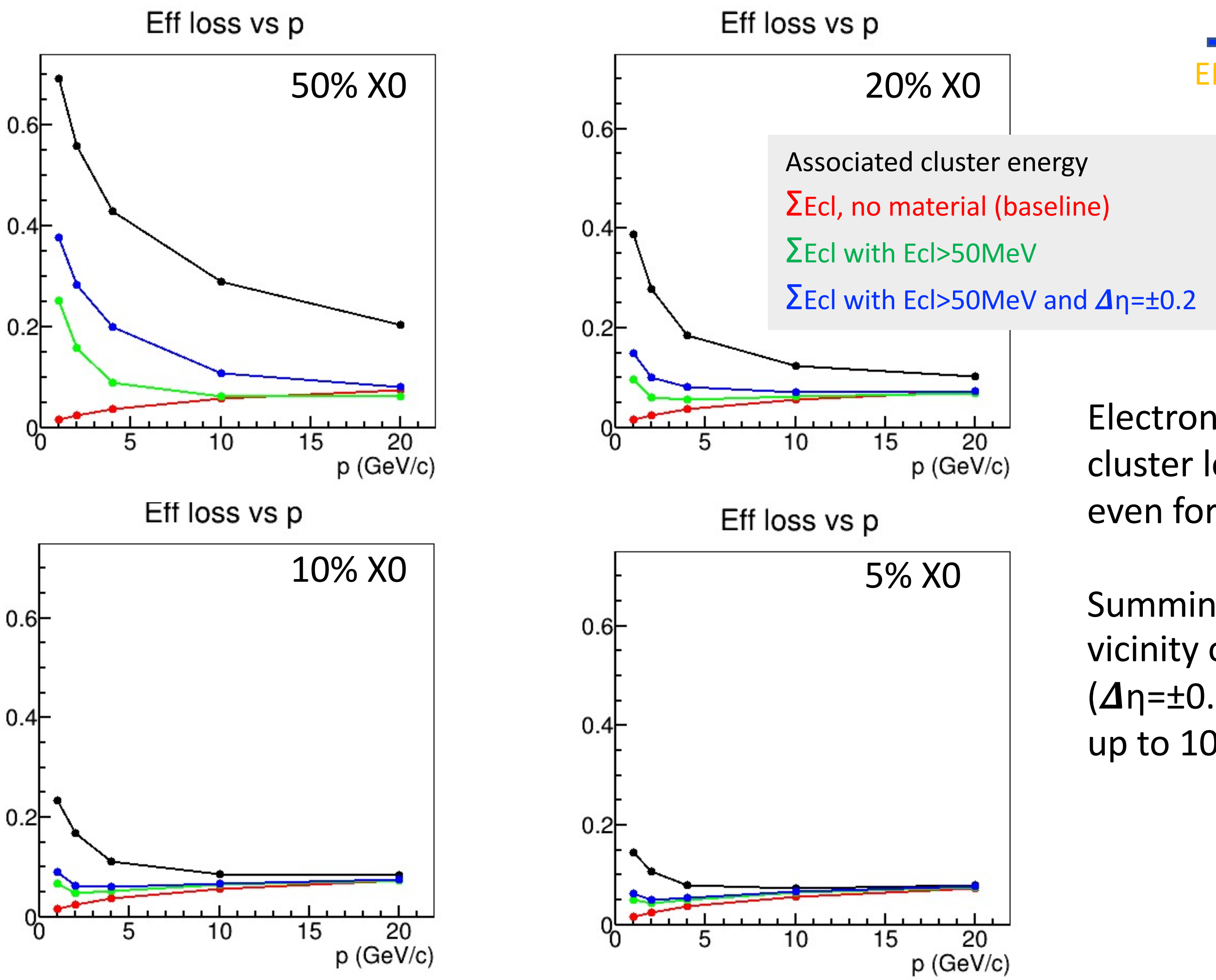
$\Delta\eta=\pm0.2$ window leads to small enough eff loss

$\Delta\varphi=\pm0.5$ doesn't introduce any losses

Smarter technique for radiated photon ID may provide better performance

Vs converter thickness

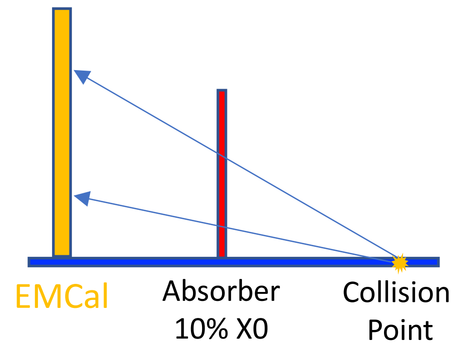


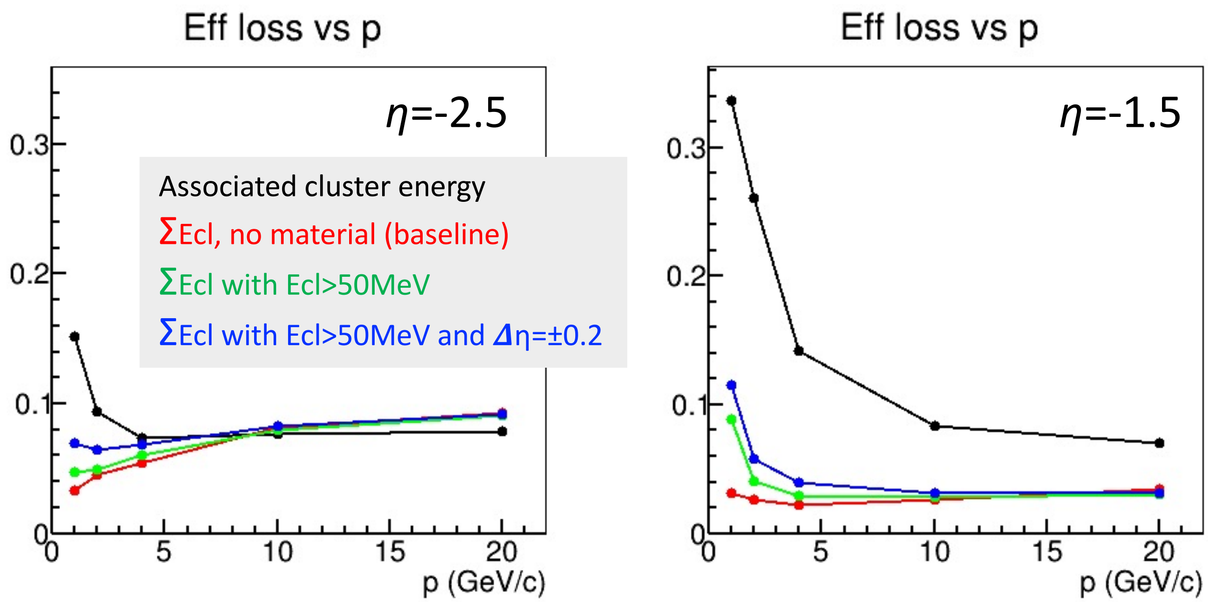


Electron reco from associated cluster leads to sizable eff loss even for 5%X0 absorber

Summing up the energy in the vicinity of the electron rapidity ($\Delta\eta=\pm0.2$) recover the eff well up to 10%X0 thickness

Vs rapidity (Bdl)





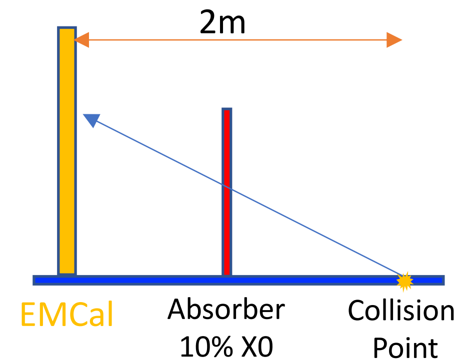
η=1.5 vs 2.5:

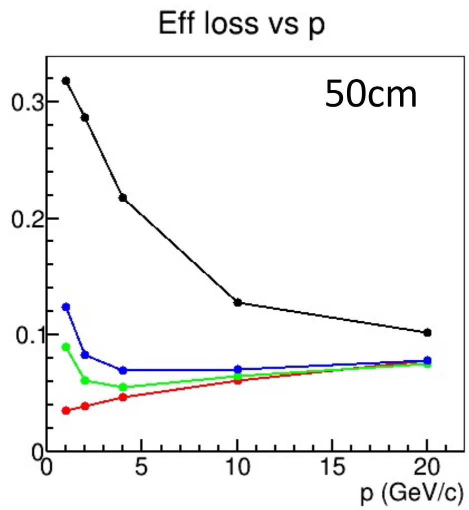
A factor of 3 larger Bdl

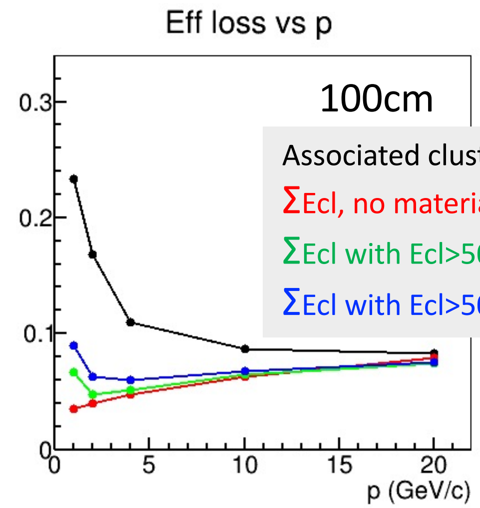
~10% larger material thickness

Lager eff loss for larger Bdl

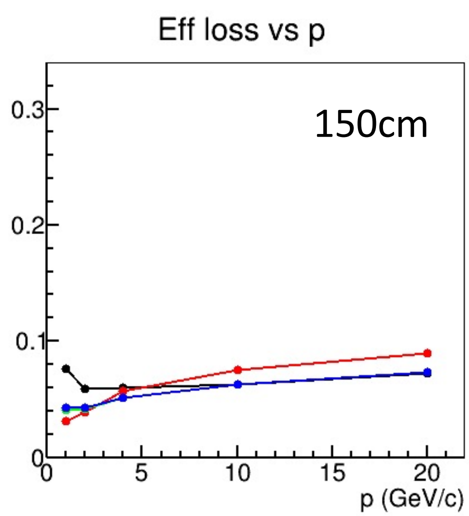
Vs location

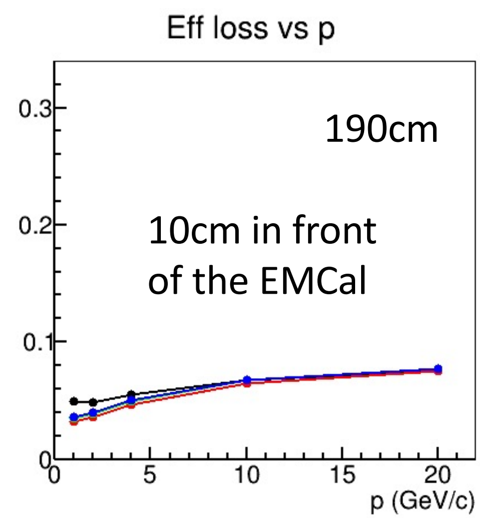






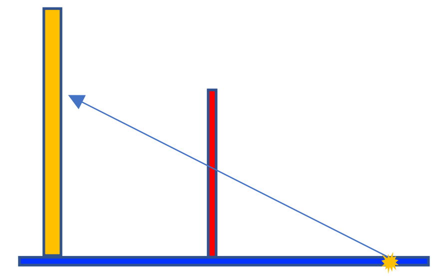
Associated cluster energy
ΣEcl, no material (baseline)
ΣEcl with Ecl>50MeV
ΣEcl with Ecl>50MeV and *Δ*η=±0.2



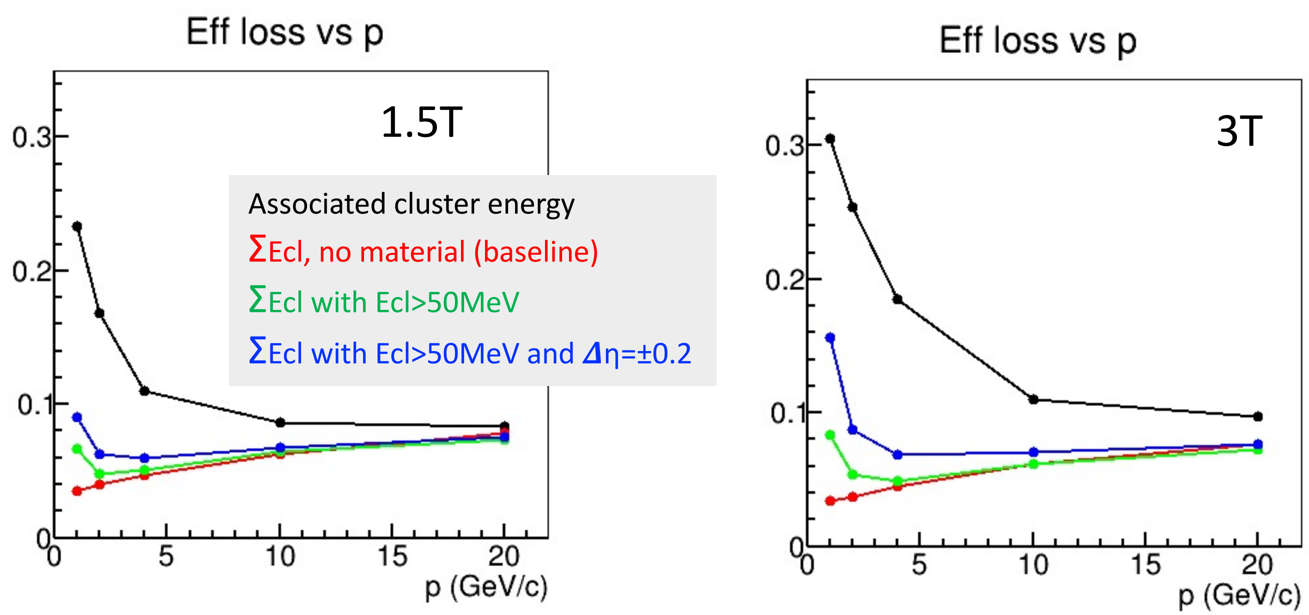


Closer to EMCal –
smaller the eff loss

Vs magnetic field

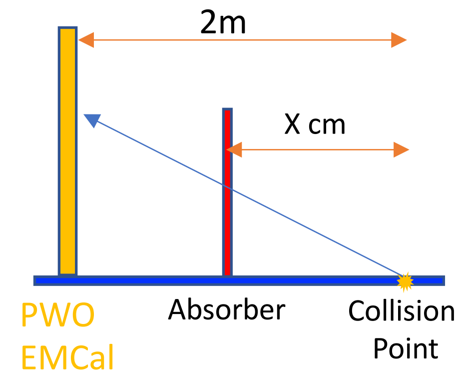


All my previous plots are for 1.5T solenoid



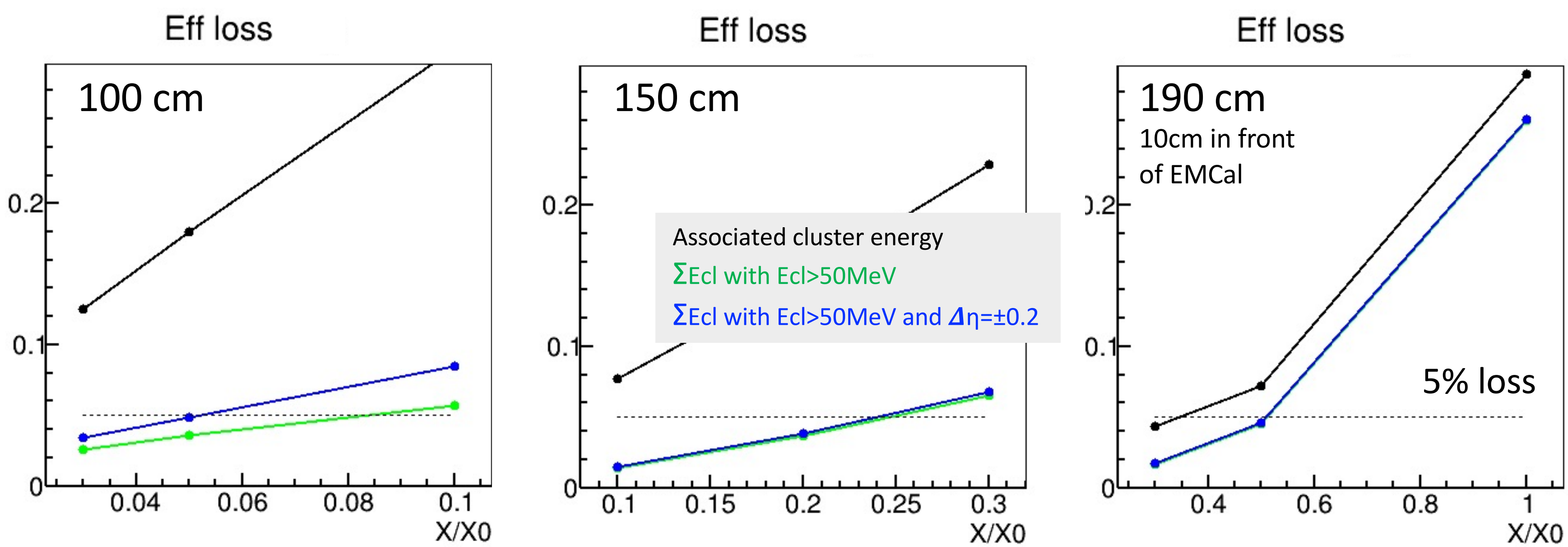
Lager eff loss for larger Bdl

Eta=-1.5, p=1 GeV, B=1.5T



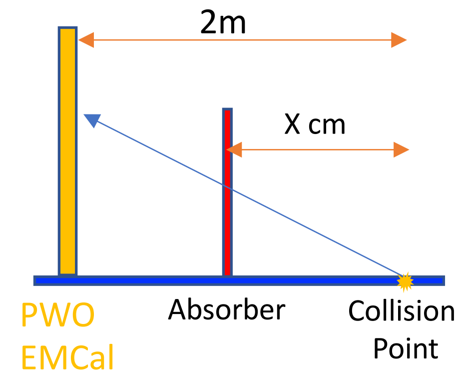
The worst case: Highest Bdl, lowest e momentum

Baseline (for no-material) subtracted



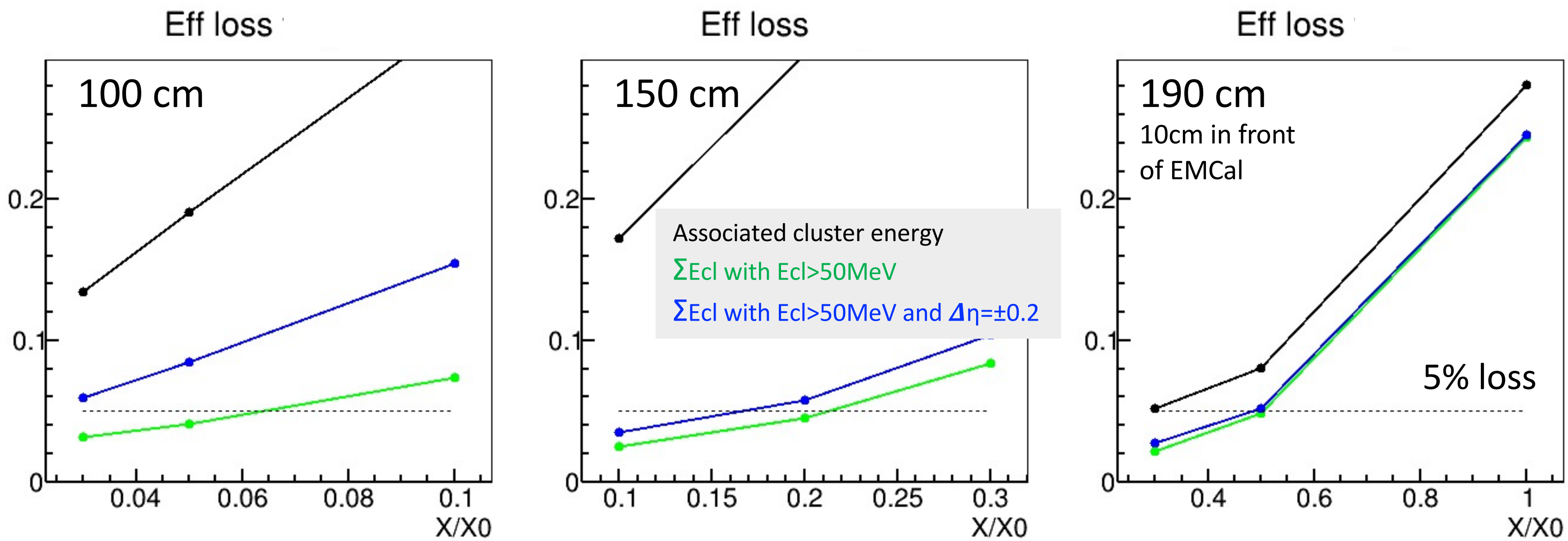
For 5% eff loss, B=1.5T:	5-8% X0	~25% X0	~50% X0

Eta=-1.5, p=1 GeV, B=3T



The worst case: Highest Bdl, lowest e momentum

Baseline (for no-material) subtracted



For 5% eff loss, B=3T: 3-6% X0 ~20% X0 ~50% X0

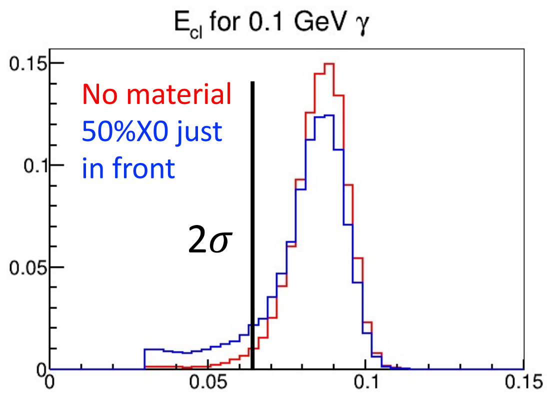
Low energy photons

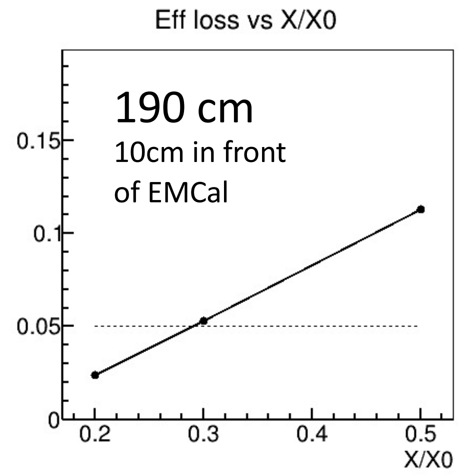
Low energy photon measurements (down to 100 MeV?) may impose tougher requirements:

High probability for a converted photon to be lost (too low energy e+e- to reliably track)

7%X0 => 5% photons converted (lost?)

Low energy (shallow) shower => more energy absorbed on the way





May require <30%X0 in front of EMCal

(because of energy loss in it)

Summary for PWO-like EMCal in e-endcap

- Electron reco from associated cluster leads to sizable eff loss even for 5%X0 absorber
  - $\Rightarrow$ Need to include clusters from radiated photons

- EMCal should be capable to measure radiated photons down to at least 50 MeV (or, better, down to 20 MeV)
  - => The level of noise should be minimized

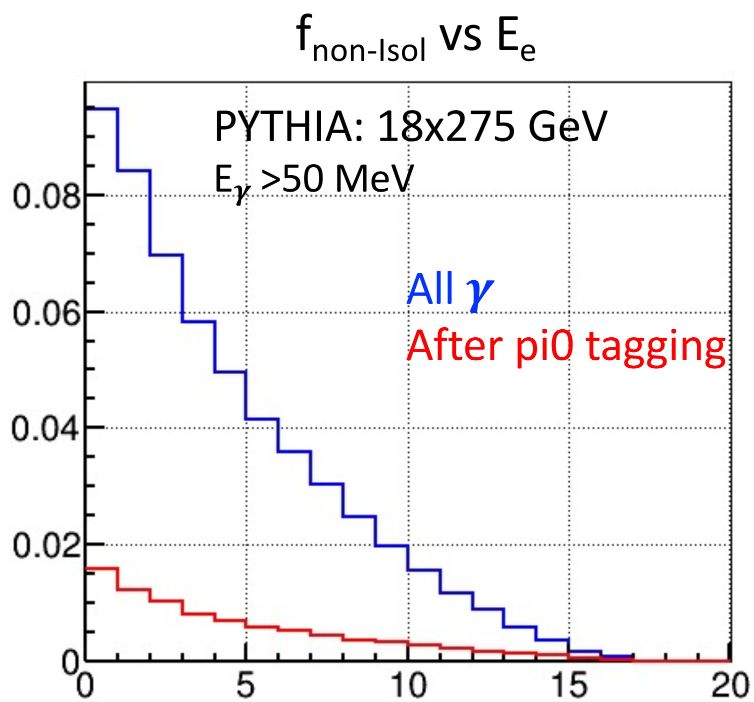
- Effect of material after electron reco:
  - Larger for larger Bdl
  - Increases from high to low p
  - ~5%X0 acceptable within 100 cm from the vertex
  - ~20%X0 acceptable if at ~150cm (within 50cm from EMCal)
  - Minimized if just in front of EMCal (up to 50%X0 is tolerable)
  - Low energy photon measurement requirements may be tougher: <10%X0 on the way and <30%X0 just in front (within 10cm) of EMCal

These limitations are exclusive

- For lower resolution EMCal, the material limitations are relaxed

- More developed techniques for e-reco (plus rad. photons) and considering other backgrounds may modify the conclusions in some way

Decay γ from PYTHIA



Fraction of events with decay photons in the vicinity of DIS electron:

$\Delta\eta$=±0.2

$\Delta\varphi$=±0.5

The contribution of decay photons within topology cut (used for radiated photons) may be kept at low enough level

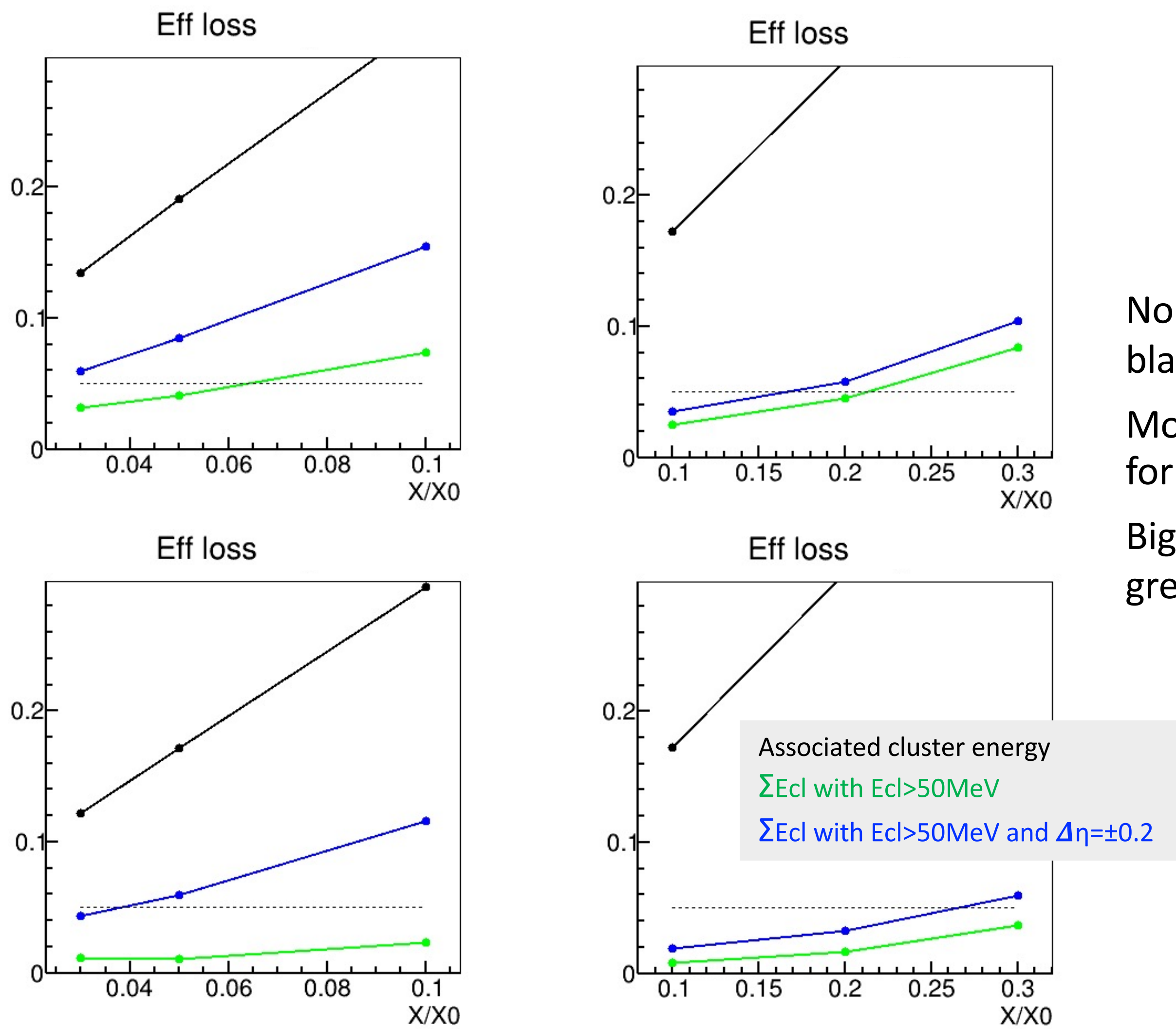
The other backgrounds need to be evaluated too (e.g. synchrotron rad.)

2sigma vs 3sigma

100cm | 150cm

2sigma

3sigma



No dependence for black

Moderate dependence for blue

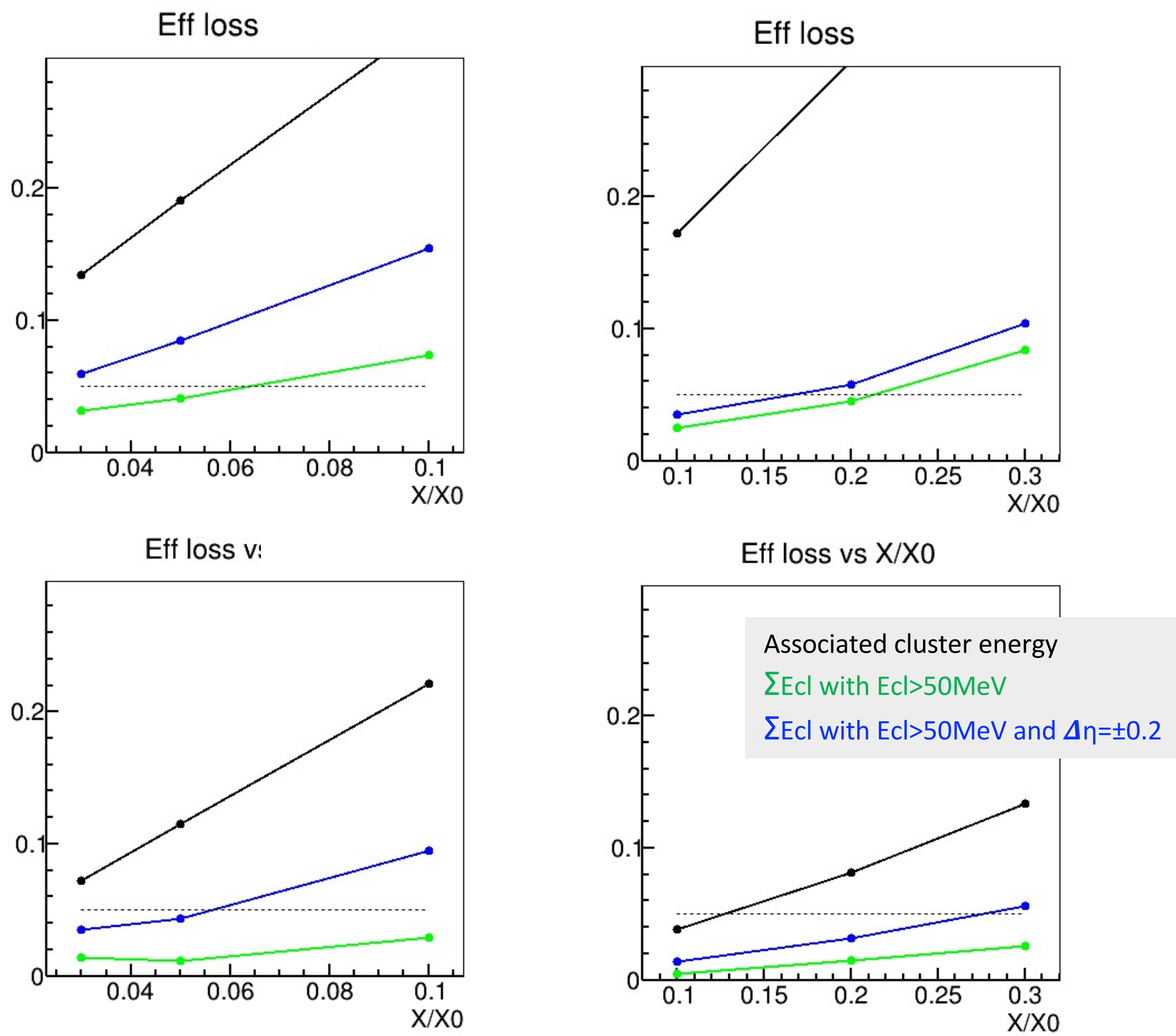
Bigger dependence for green

Eta= -1.5 vs -2.5

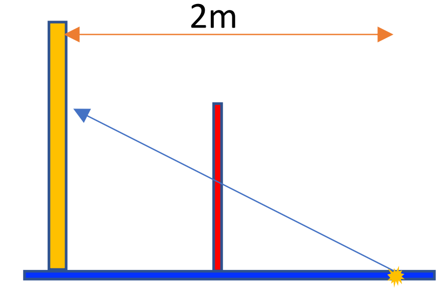
100cm | 150cm

Eta=-1.5

Eta=-2.5

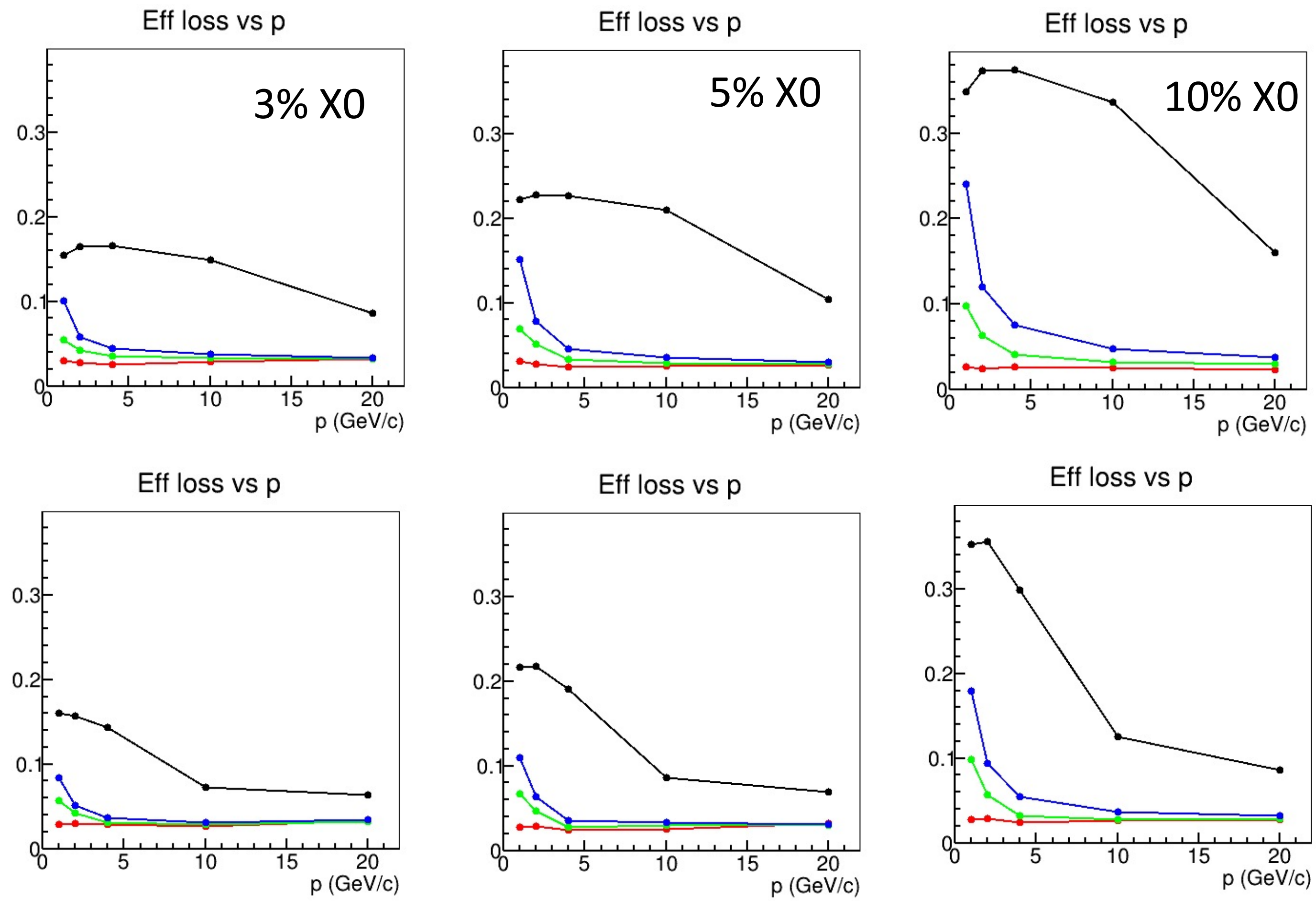


Eta=-1.5, 3T, 50&100 cm



50cm

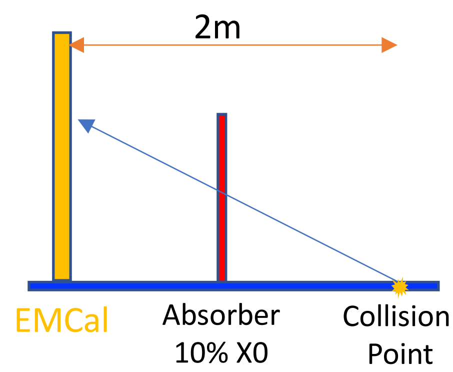
100cm



3% X0
is ok

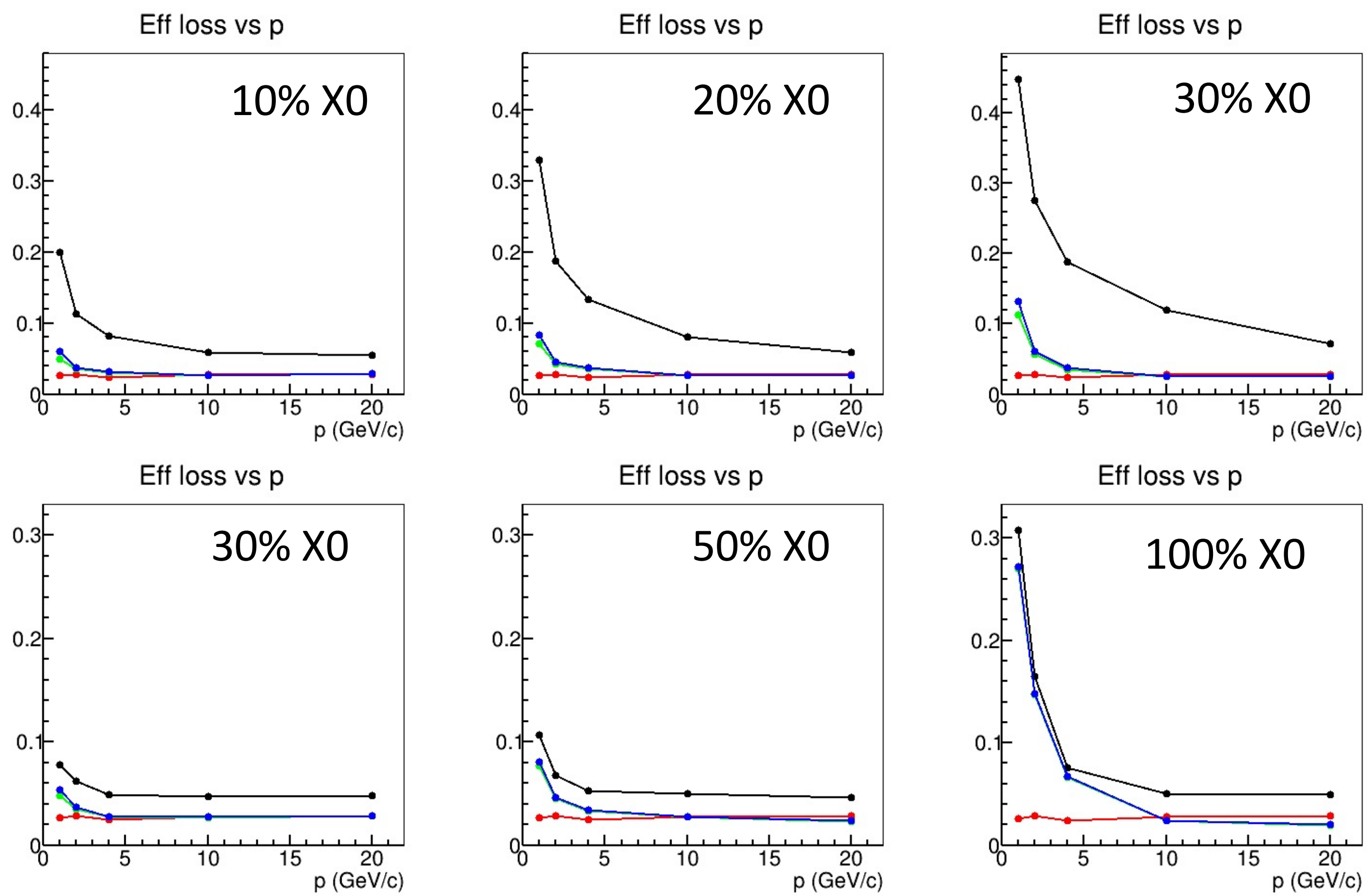
5% X0
is ok

Eta=-1.5, 3T, 150&190 cm



150cm
(50 cm in
front of
EMCal)

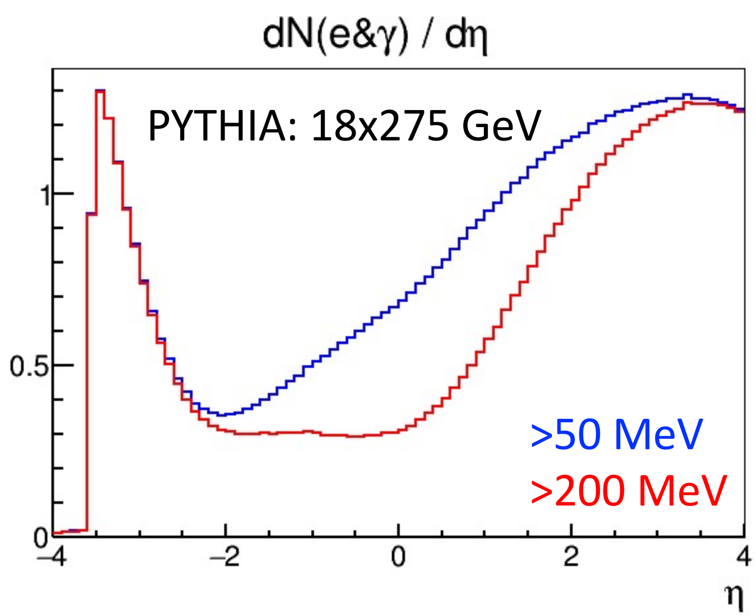
190cm
(10 cm in
front of
EMCal)

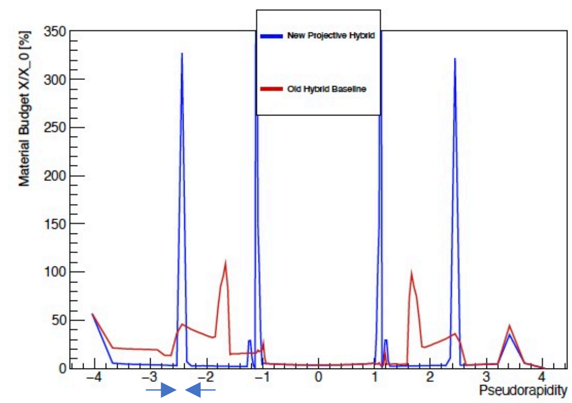


20% X0
is ok

50% X0
is ok

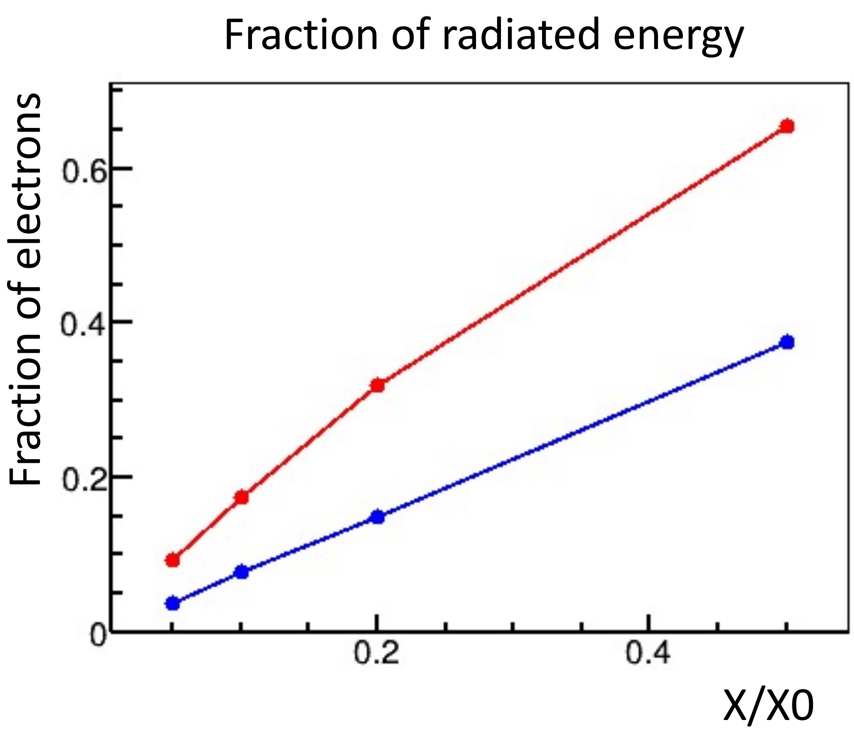
PYTHIA: e&$\boldsymbol{\gamma}$ rapidity density





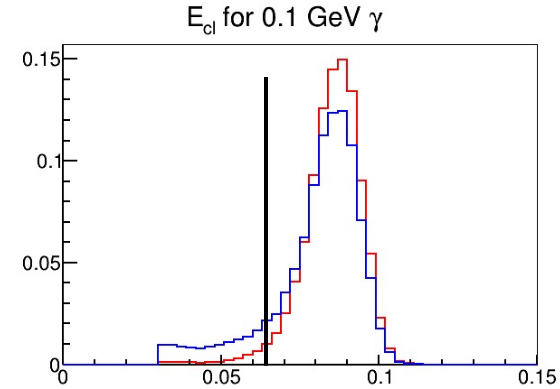
For $\boldsymbol{\Delta}\eta$=0.2 the probability to have a shower from e or $\boldsymbol{\gamma}$ may be >10%

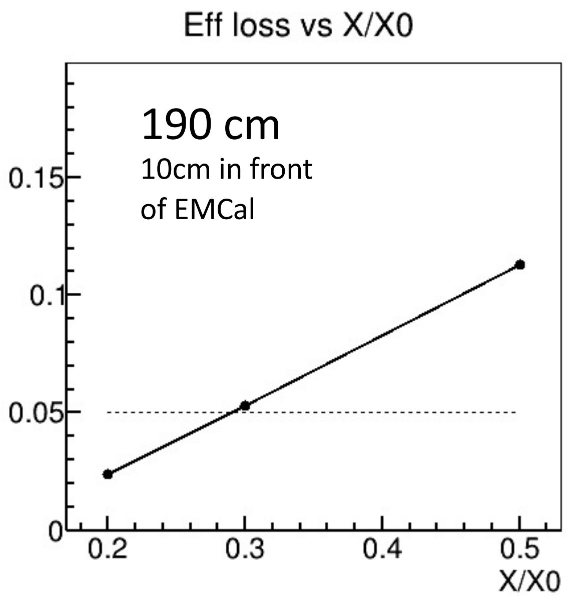
Electron radiated energy



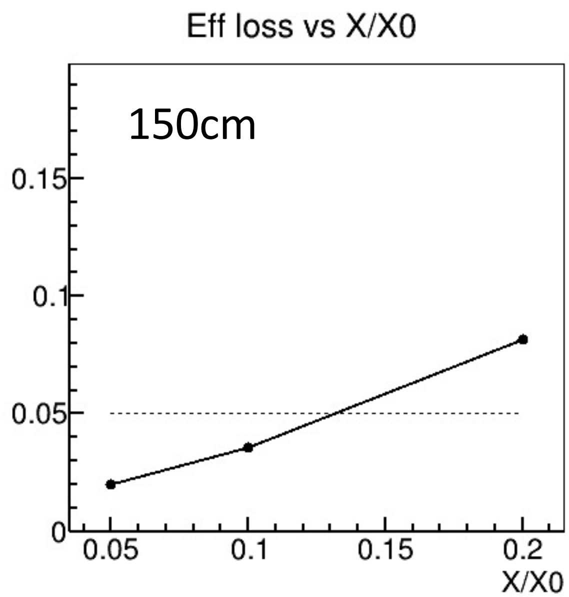
Fraction of electrons loosing:
20% of its energy
50% of its energy

Photons 0.1 GeV





May require <30%X0 in front of EMCal



May require <15%X0 at 150cm