Background calculations for G_M^n + Tracking

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SBS collaboration meeting
Jefferson Lab, July 13-14, 2017

Overview

* G4SBS simulation: additions / updates of geometries

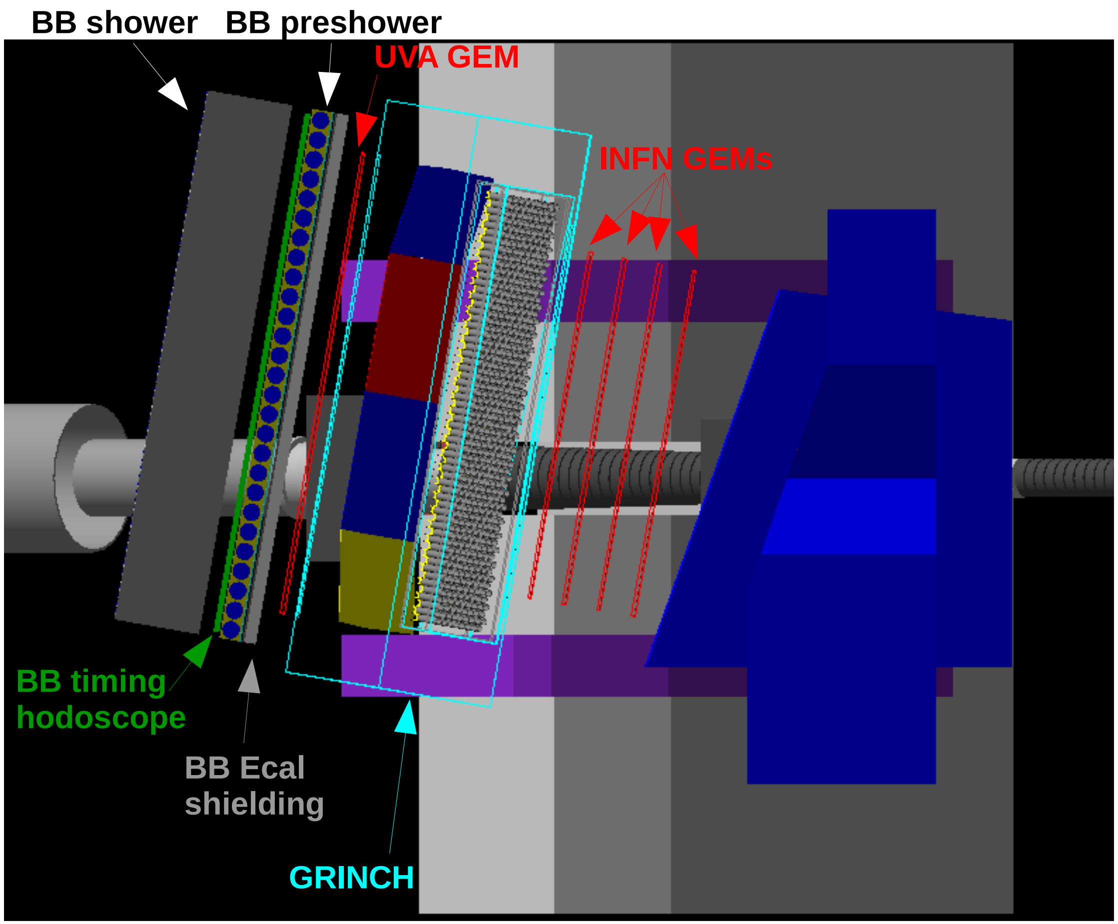
* Recent background calculations for G_M^n ERR

* Tracking

* Summary

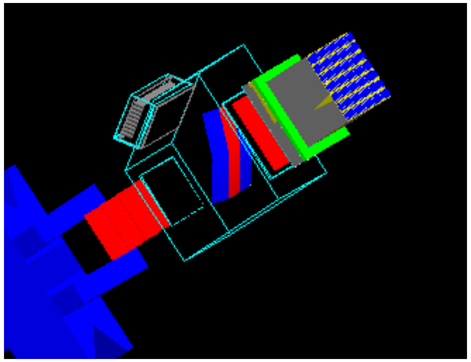
Geometry updates in G4SBS

Big Bite detector package :



* Updated BB detector package according to drawings from Joyce Miller

* GRINCH tank more realistic;
+ GRINCH PMT geoemtry fixed (was overestimating backgrounds by a factor 10!)



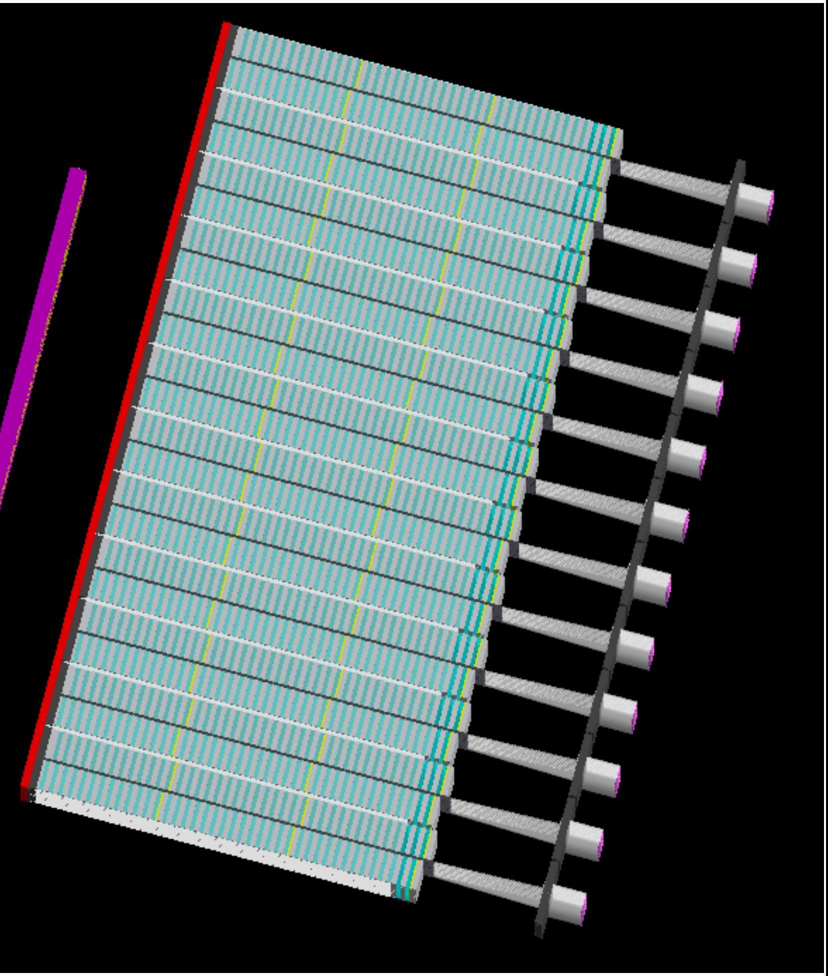
* Added a simplified version of BB timing hodoscope

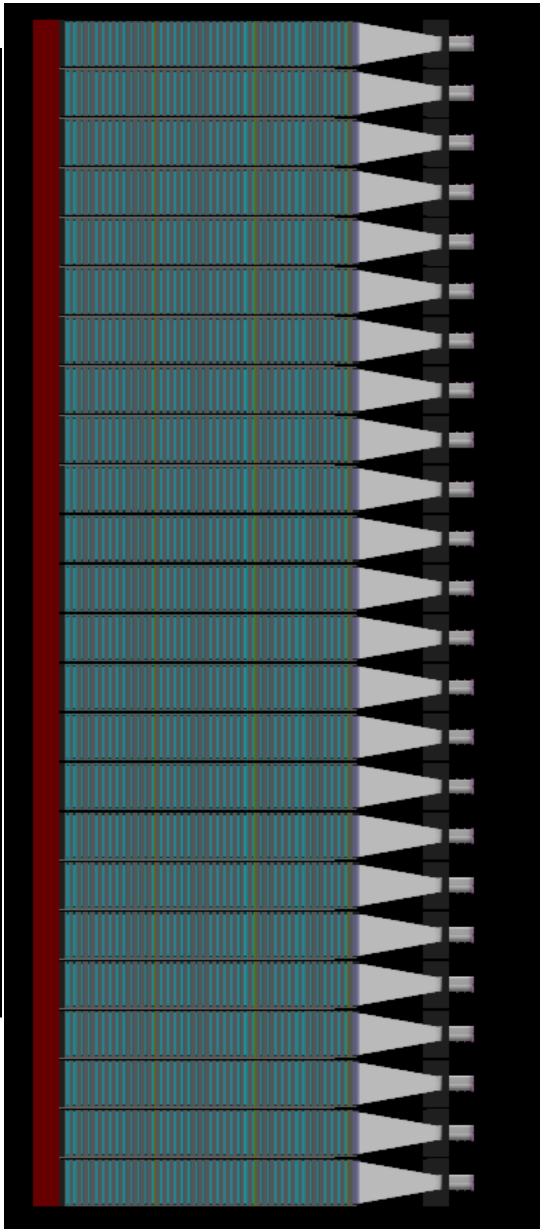
* Optional BB Ecal shielding

NB : new g4sbs command to switch shielding easily:
/g4sbs/bbshieldconfig 1
0 : no shielding
1 : 1/4'' steel + 0.5mm mu-metal (default)
4 : (1) + Steel + Al (1 cm + 5cm)

Geometry updates in G4SBS

HCal (credit : Juan Carlos)



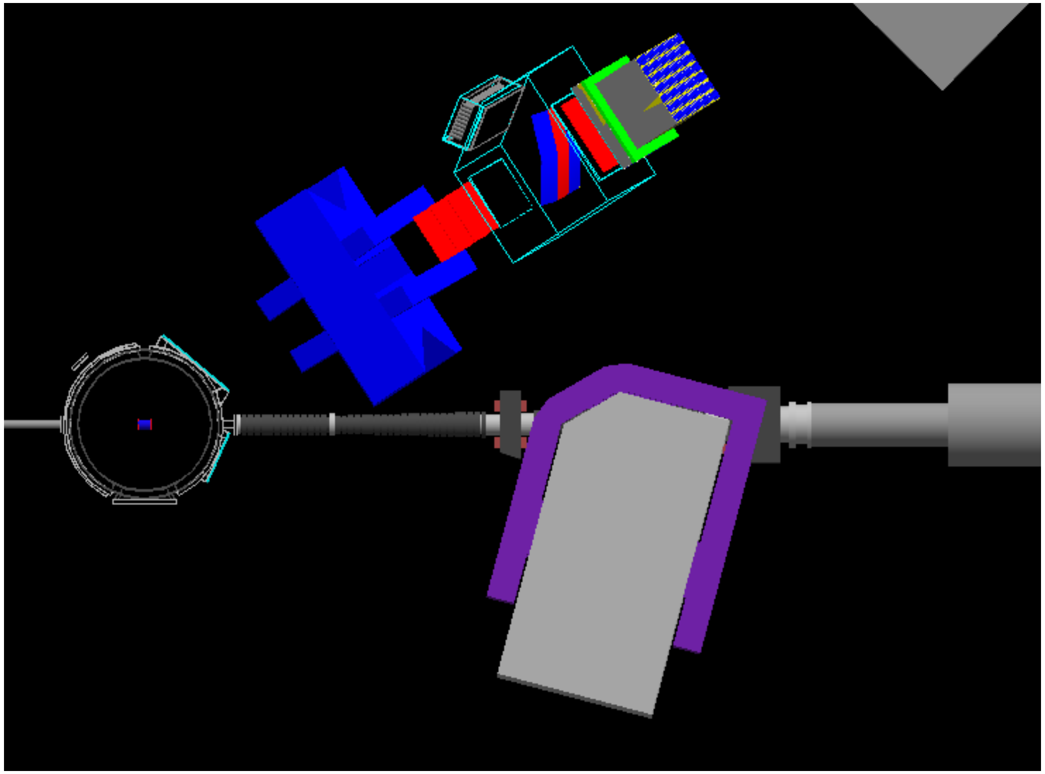


* More relastic geometry of
The HCal modules

* Added 3/4 inches steel plate in
front of Hcal.

Geometry updates in G4SBS: G_M^n setup

Scattering chamber + beamline with the engineers current design:

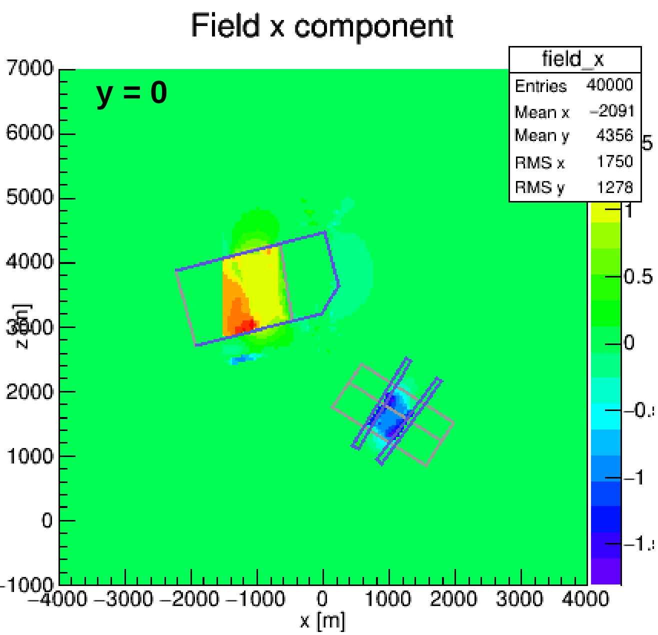


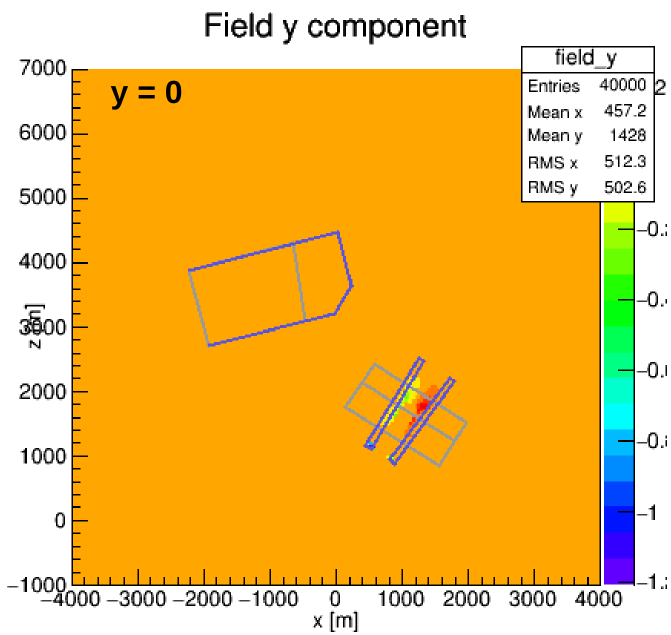
- Conic vacuum line weldment;
- spool piece;
- inner and outer magnetic shieldings;
- beam corrector magnets;

Configuration of the two later items can be changed with a new command:
/g4sbs/beamlineconfig <int>
The integer being equal to the beamline configuration number convention used by the engineers:
1 for G_E^p, 2 for G_E^n,
3 for G_M^n (all Q2 but higher),
4 for G_M^n (higher Q2 + calibrations).

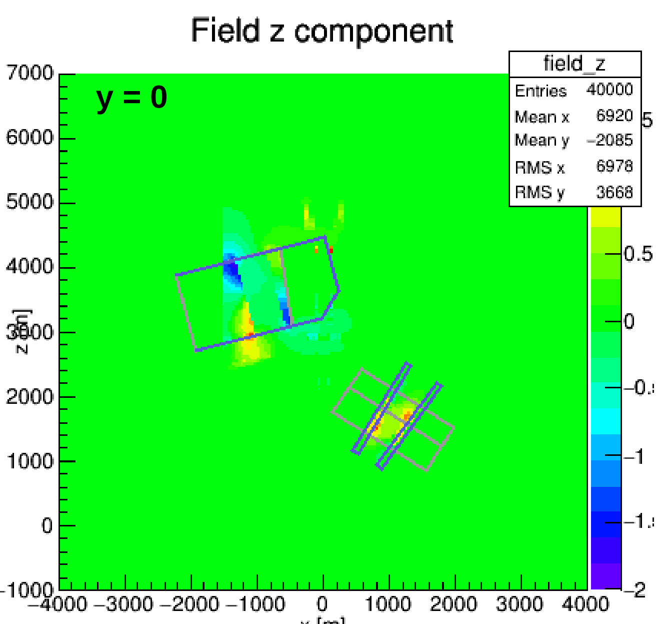
Other updates in G4SBS: G_M^n setup

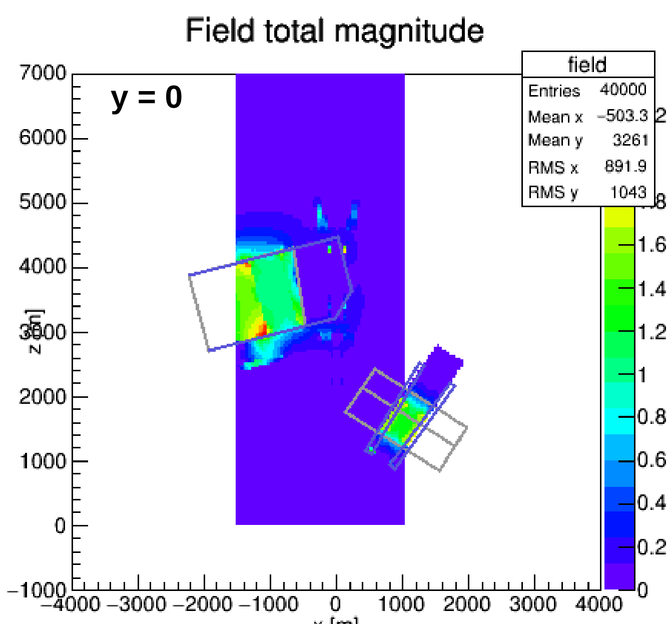
Tosca field map for Q^2 = 13.5 GeV^2



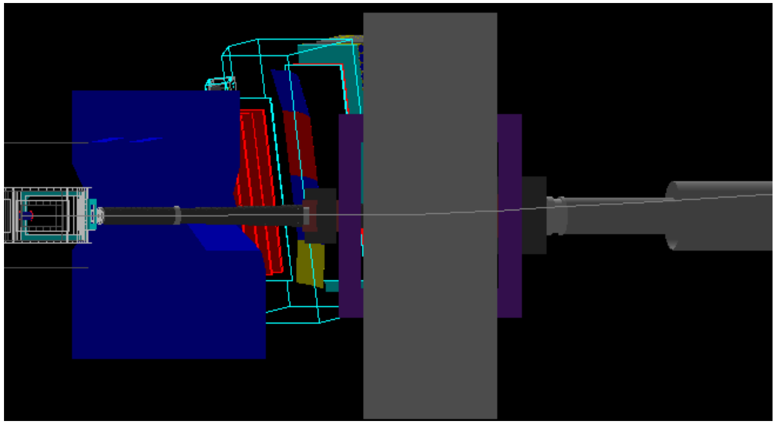


(calculated by Bogdan)



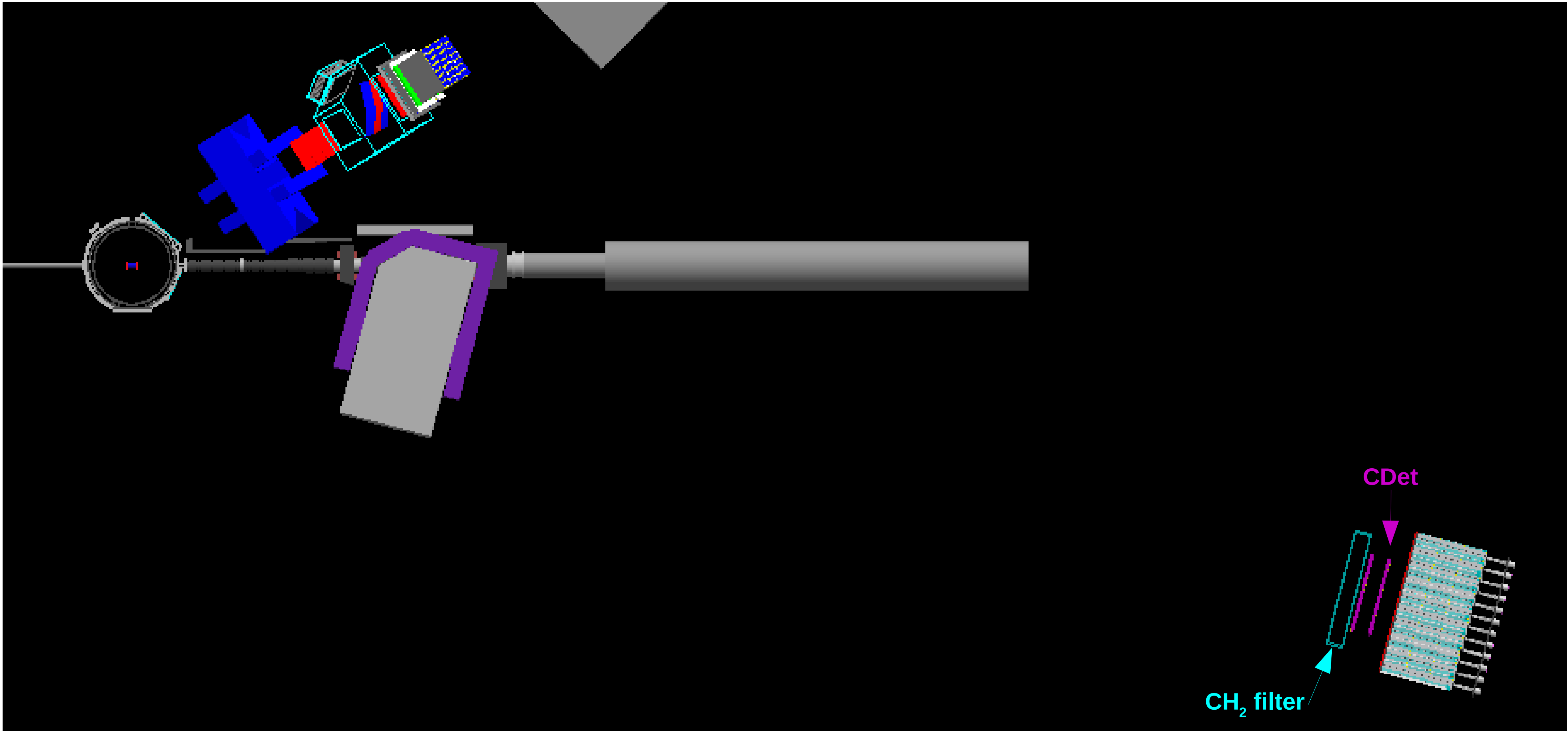


Charged geantino trajectory (charge +)



Geometry updates in G4SBS: G_M^n setup

Beam line shielding (see also section on backgrounds).



Added CDet (with CH_2 filter in front).

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Geometry updates in G4SBS: G_M^n setup

GEM electronics shield hut (credit: Freddy)

GEOMETRY

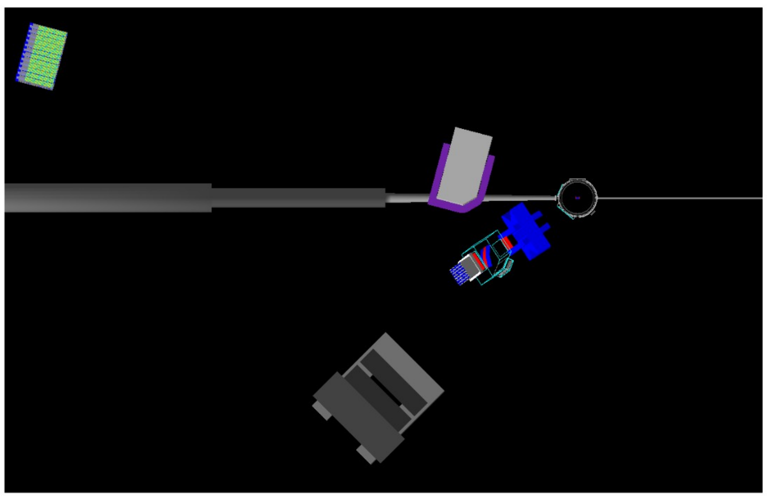

Figure: The hut face is located roughly 7.2 m from the target in the xz plane at a central angle of 45 degrees. All hut materials are steel.

GEOMETRY II

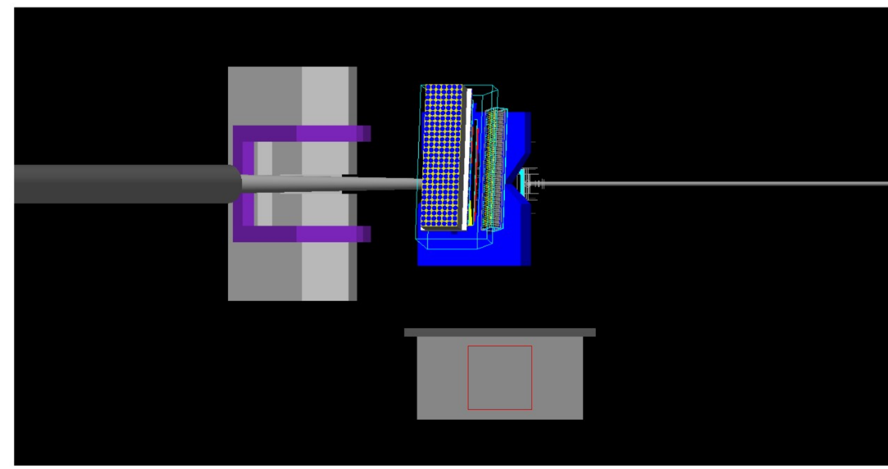

Figure: Hut sits on the floor, or roughly -3 m in the y direction. The red box represents the sensitive region for the purposes of this simulation.

Geometry updates in G4SBS

NB : all this work has been made in git uconn_dev or cmu_dev branches (which have been merged recently).

I forget :

* work on TDIS RTPC setup by Rachel;
* other independent contributions (?) ;

Not yet incorporated into uconn_dev nor master branch (to be done eventually – likely nothing urgent).

TODO :

* Merge uconn_dev and master branch soon ;
* Update G_E^p ECal design;
* Add polarized target installation (magnets, magnetic field shieldings, etc) for ^3He experiments (G_E^n, SIDIS).

Overview

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G_M^n detector backgrounds: beamline shielding

Q^2 = 13.5 GeV^2, I_{beam} = 44μA, 10 cm LD_2

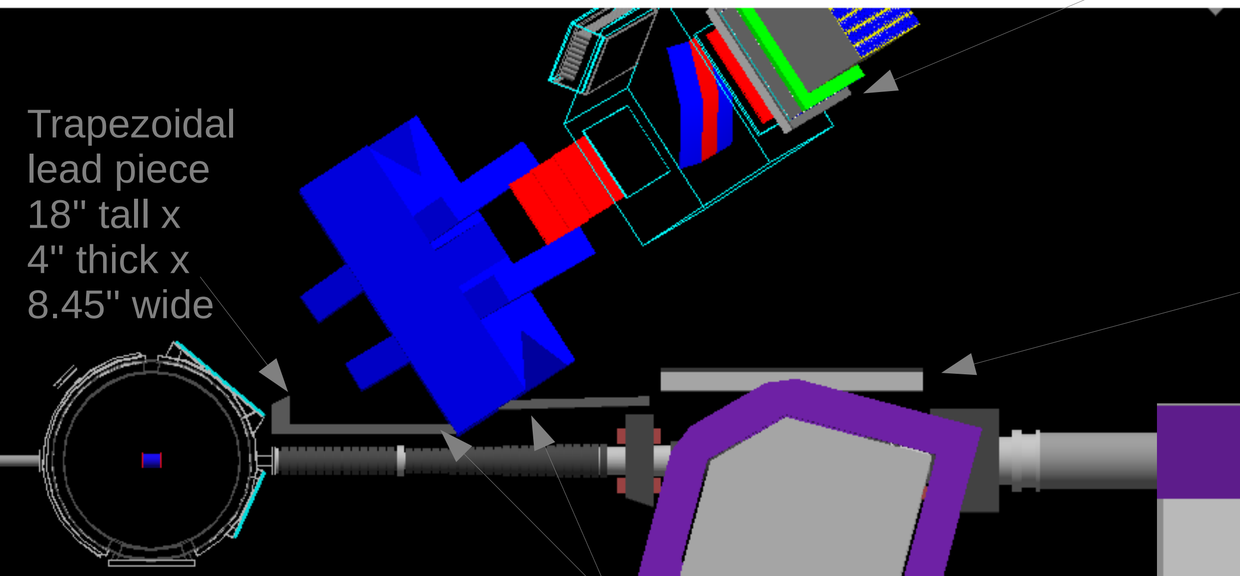
Focussed study on Q^2 = 13.5 GeV^2: worst case scenario

Shielding design « Iteration 3 »

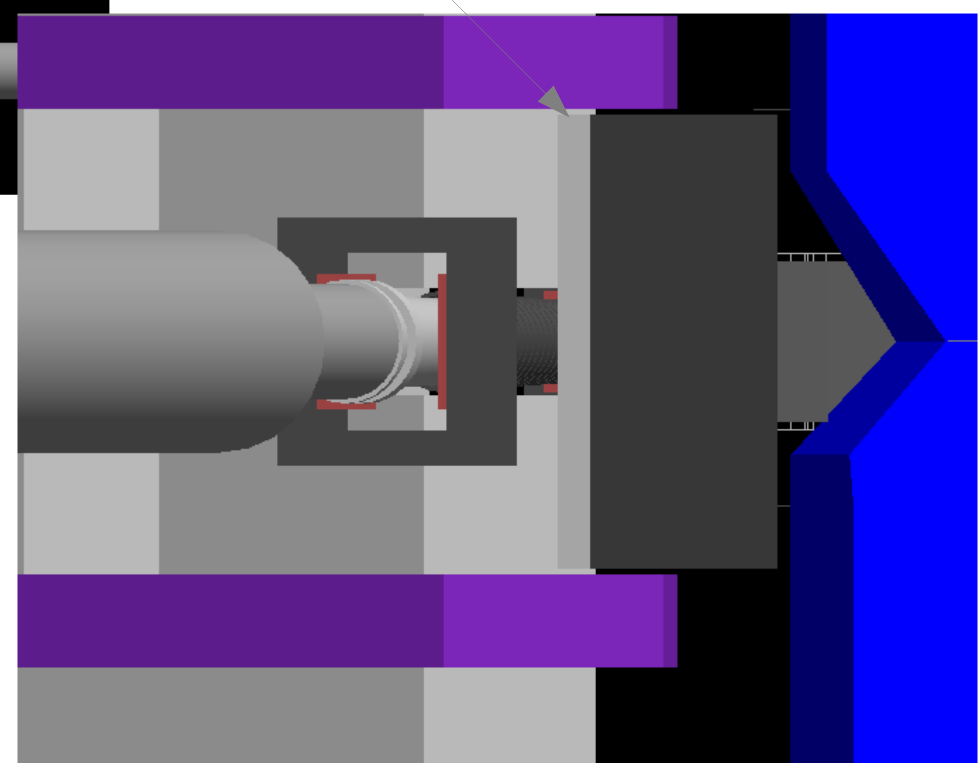
shielding for ECal : 5cm Al + 1cm steel

Trapezoidal
lead piece
18" tall x
4" thick x
8.45" wide

4" thick Al + 1" thick lead
(L = 130 cm, h = 150 cm for both)



Lead plates
(18" tall x 2" thick,
L = 37.78" (upstream)
L = 34" (downstream)

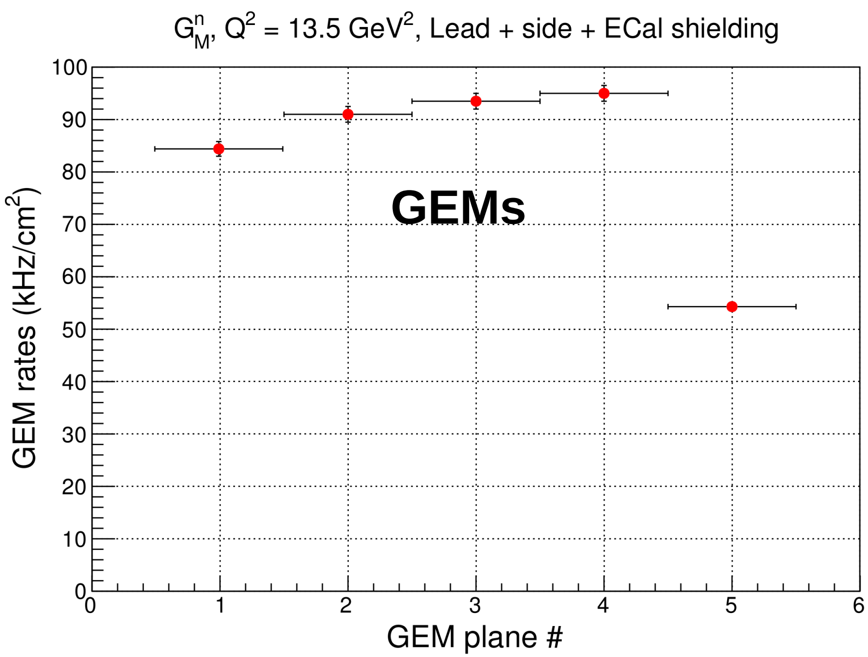


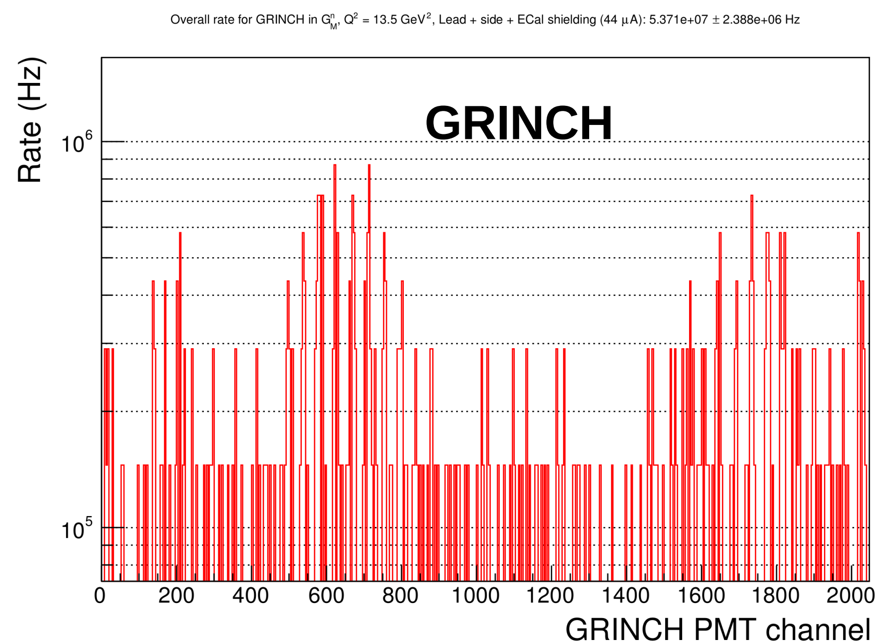
NB : this shielding design is yet to be submitted to the engineers

July 14th 2017

GEM, GRINCH background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, Beamline + BB Ecal shielding



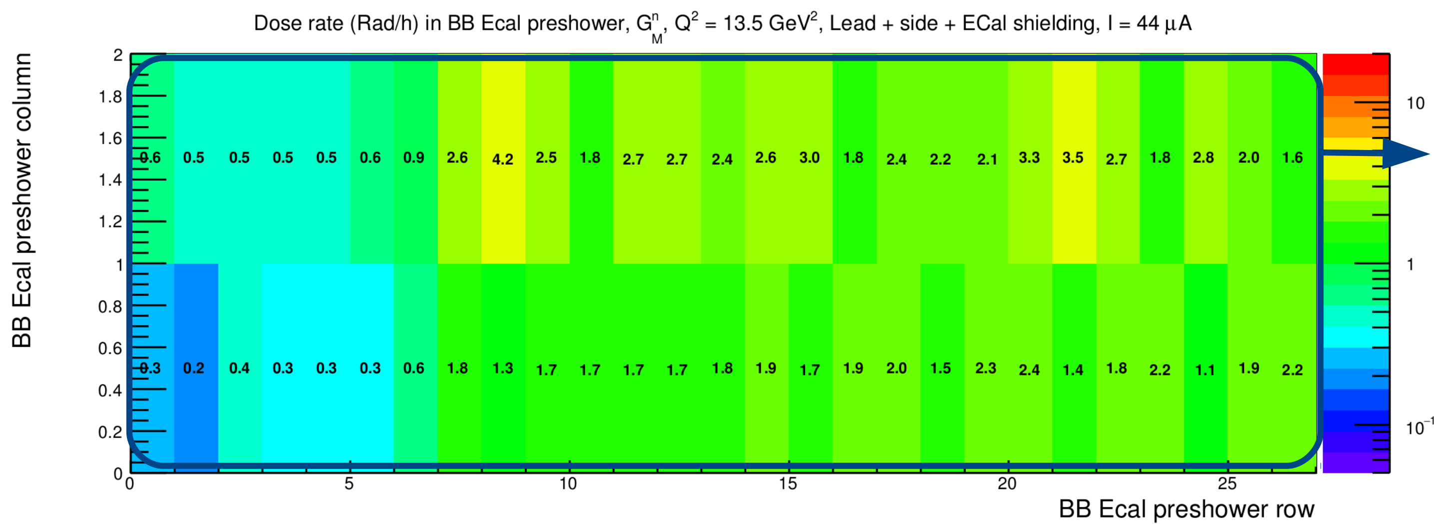


Rates < 100 kHz/cm2 for all planes:
~90 kHz/cm2 for INFN GEM (planes 1-4),
40 % lower than w/o shielding
~55 kHz / cm2 for UVA GEM (plane 5)
4x lower than w/o shielding
~73 % from **target**,
~2% from 48D48,
~6% from BL,
~4% from SC;
Rest (15%) from shielding

54 MHz over detector
=> average rate per PMT: 106 kHz
6x lower than w/o shielding
~58% (~70 kHz/PMT) from **target**,
~13% (~16 kHz/PMT) from 48D48
~18% (~22 kHz/PMT) from BL,
~8% (~10 kHz/PMT) from SC
Rest (3%) from shielding

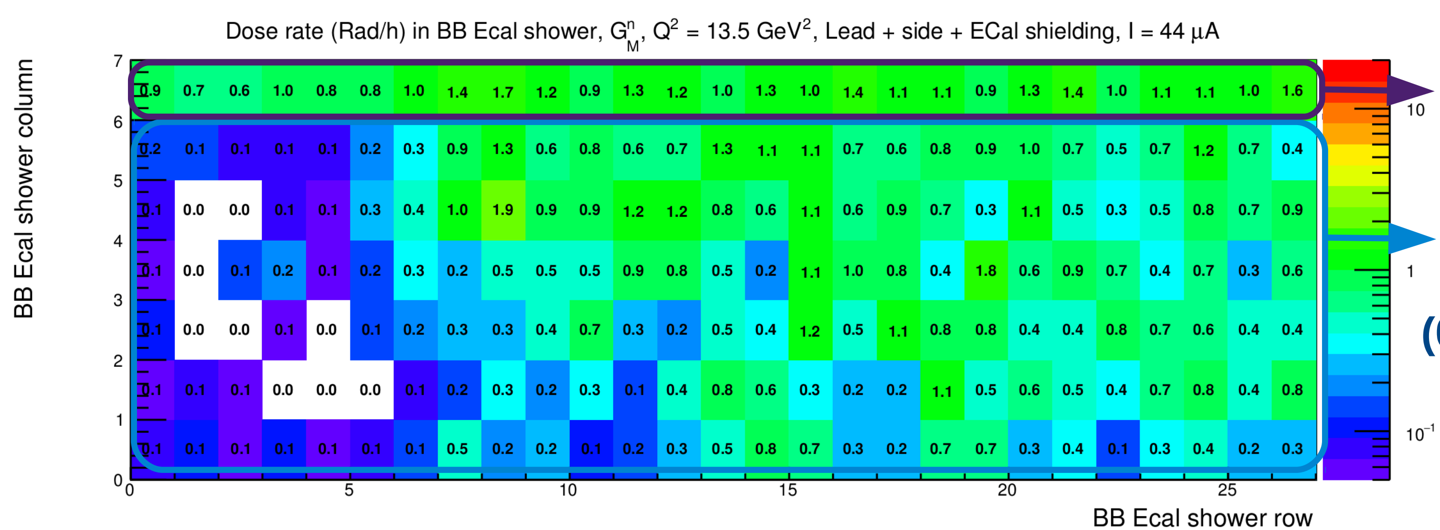
BB Ecal dose rate for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44μA, 10 cm LD_2, Beamline + BB Ecal shielding



1.7 Rad/h/block avg over PS

x100 h beam time:
< 200 Rad integrated *for this kinematic*. (20 % of maximal acceptable)



1.1 Rad/h/block avg

0.5 Rad/h/block avg

(0.6 Rad/h/block avg over SH)

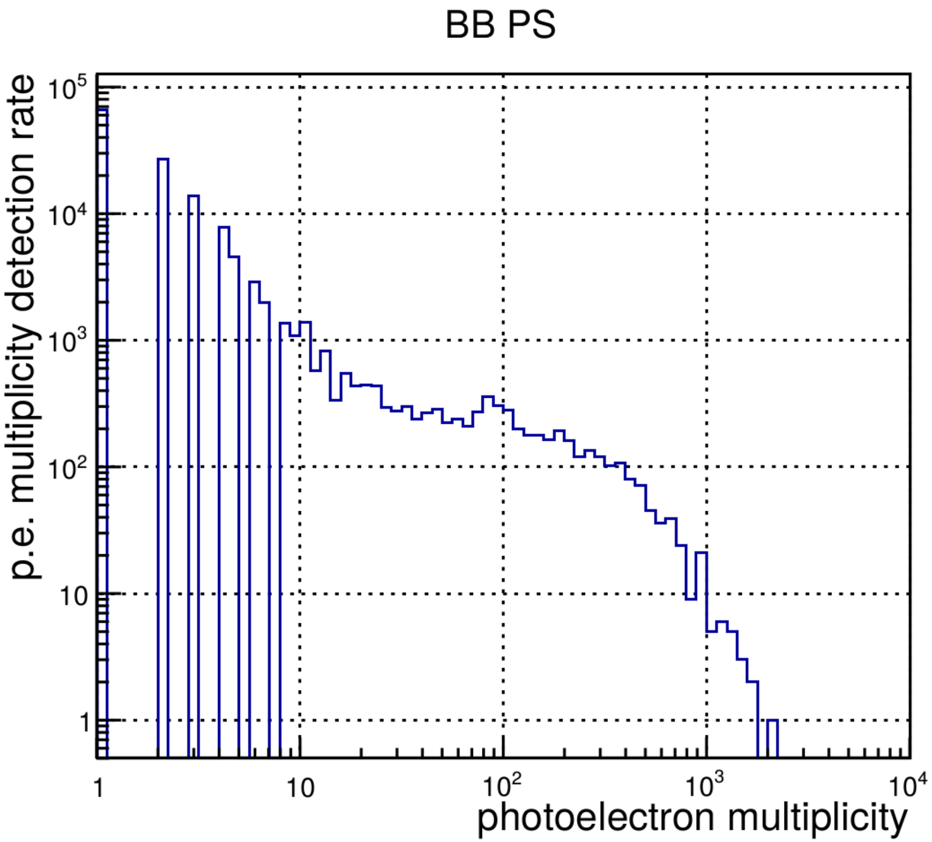
All numbers are ~3x lower than w/o shielding

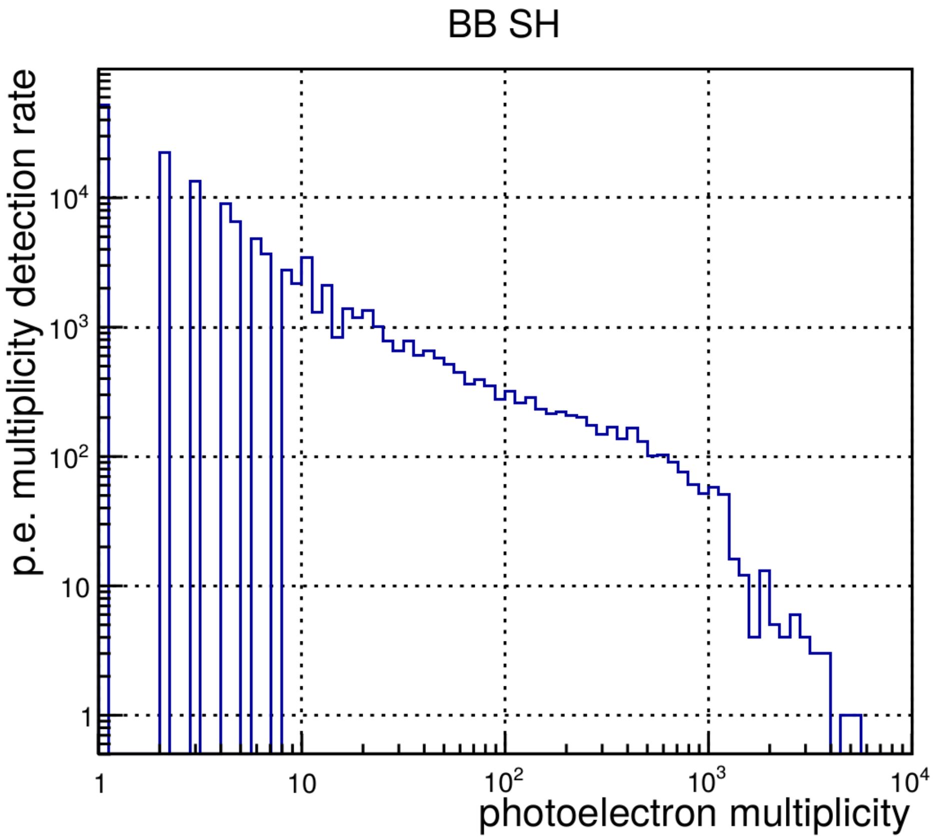
NB : Lead glass performance starts to deteriorate for cumulated radiation dose ≥ 1kRad

Average energy deposit in a PS block per second (MeV): 3.3 10^8;
Average energy deposit in a SH block per second (MeV): 1.1 10^8.

BB ECal background photoelectron rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter



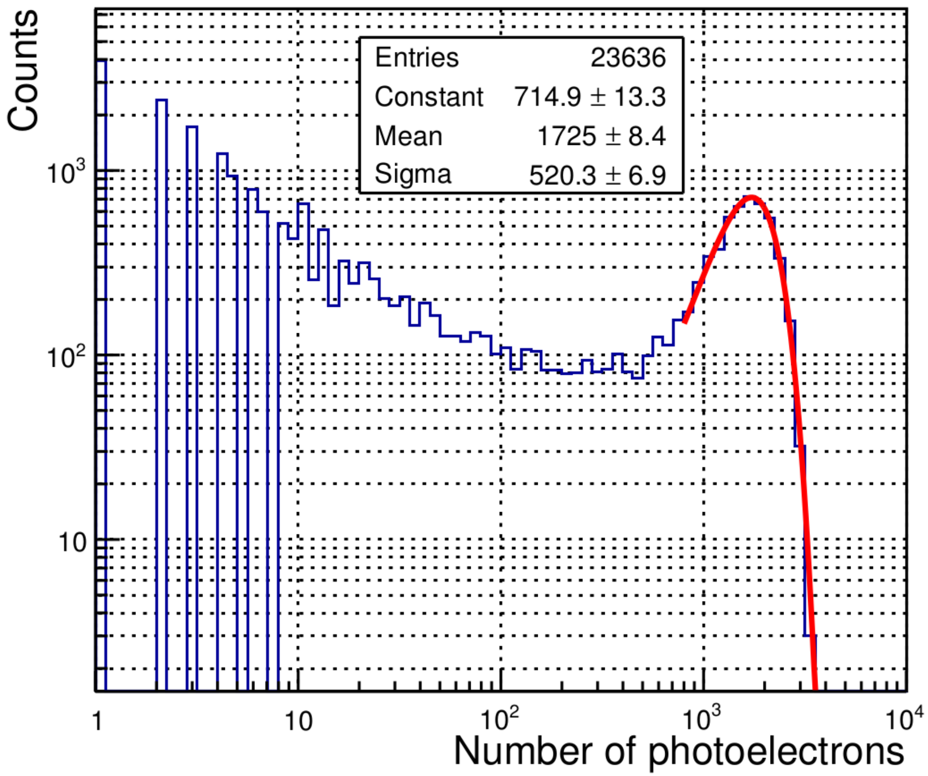


To estimate signal over background ratio, we integrate these photoelectron rates, to obtain an average photoelectron yield over a given period of time (e.g. here, 50 ns), then we compre those photoelectron yields with the photoelectron yields provided by the signal (next slide)

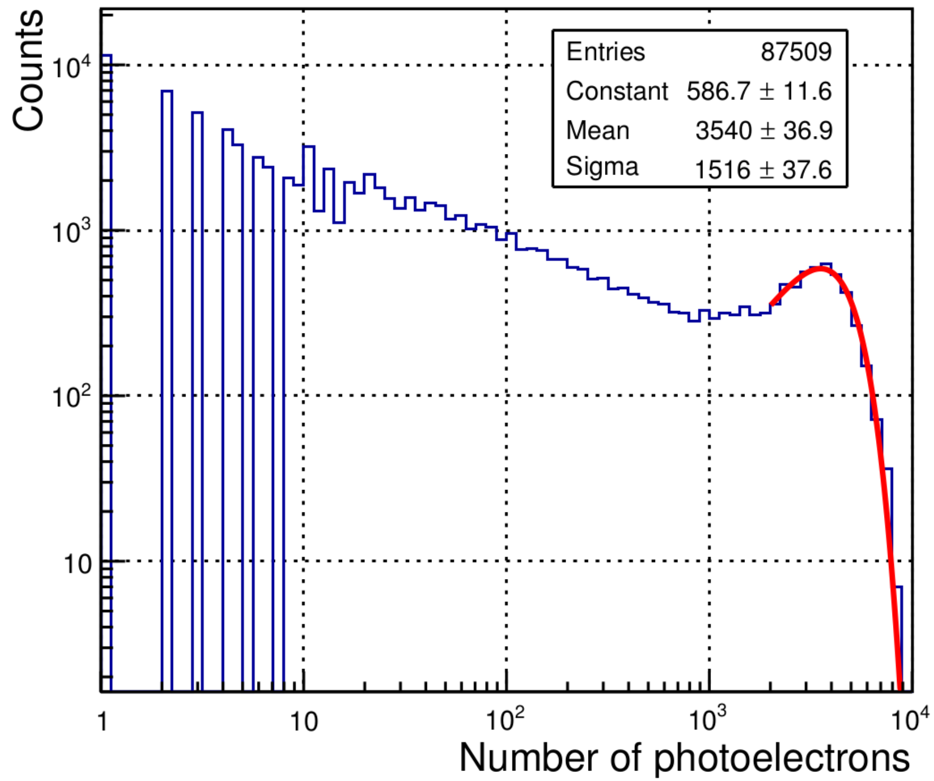
BB Ecal response to Quasi-elastic electrons

Q^2 = 13.5 GeV^2, I_{beam} = 44μA, 10 cm LD_2, Beamline + BB Ecal shielding

QE electrons (3.8 GeV)



QE electrons (3.8 GeV)



We consider 1 GeV electrons (to be conservative)

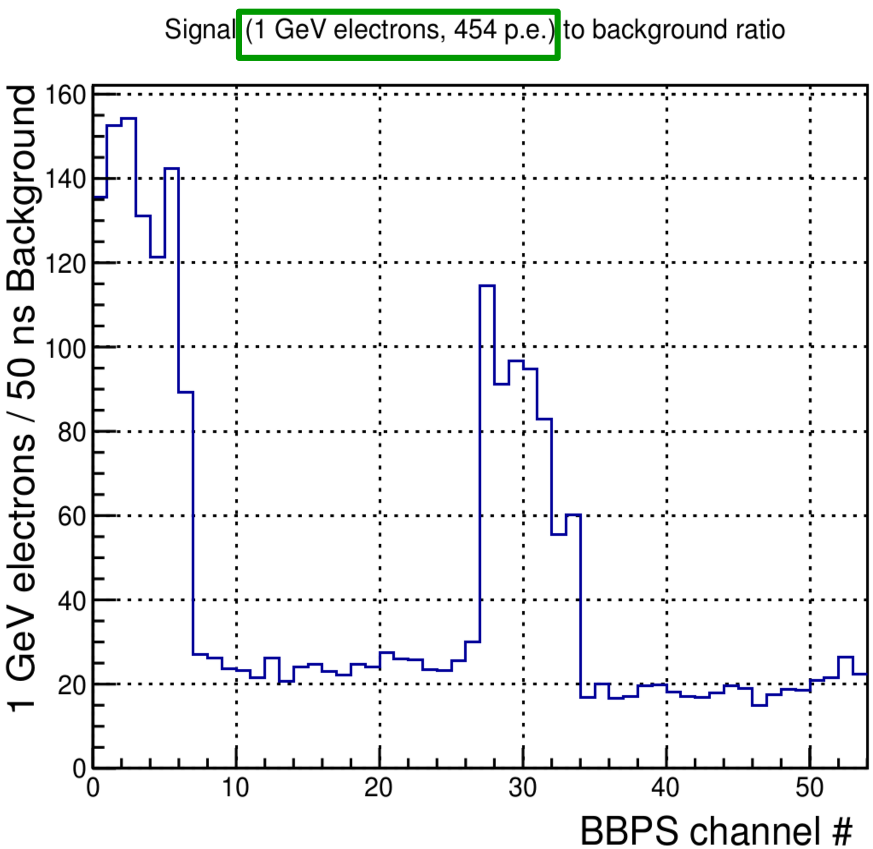
PreShower:
Np.e. (3.8 GeV) = 1725 p.e.
Np.e. (1 GeV) = 454 p.e.

SHower:
Np.e. (3.8 GeV) = 3540 p.e.
Np.e. (1 GeV) = 932 p.e.

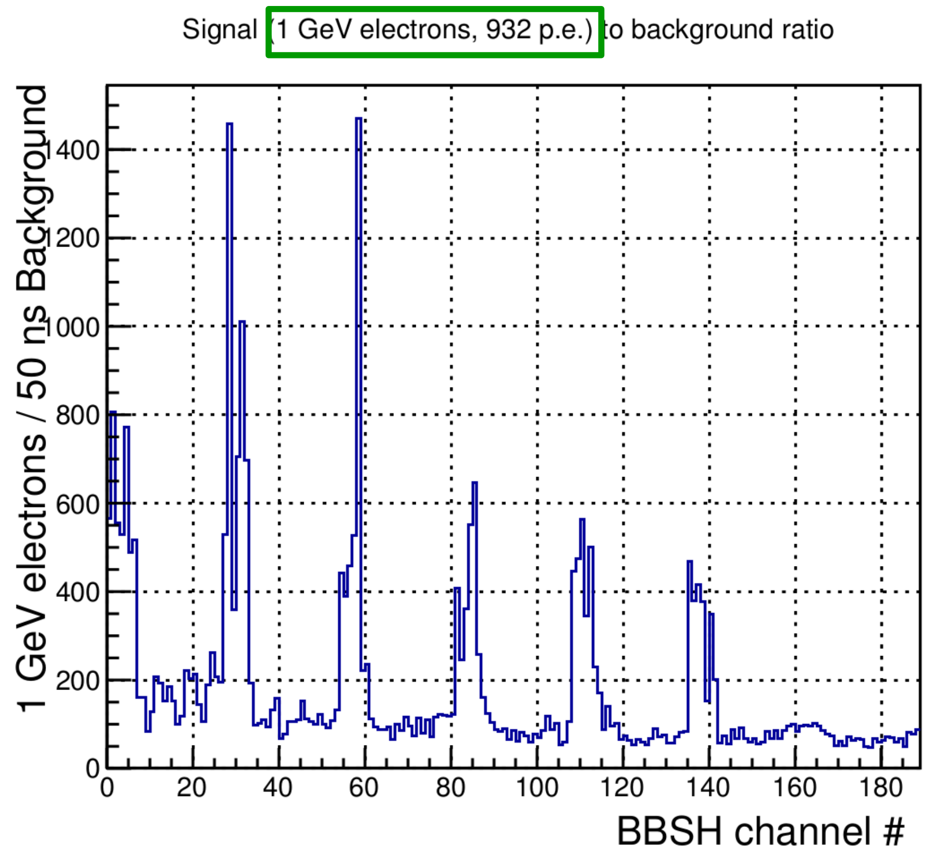
BB Ecal Signal over background ratio

Q^2 = 13.5 GeV^2, I_{beam} = 44μA, 10 cm LD_2, Beamline + BB Ecal shielding

PreShower:



SHower:



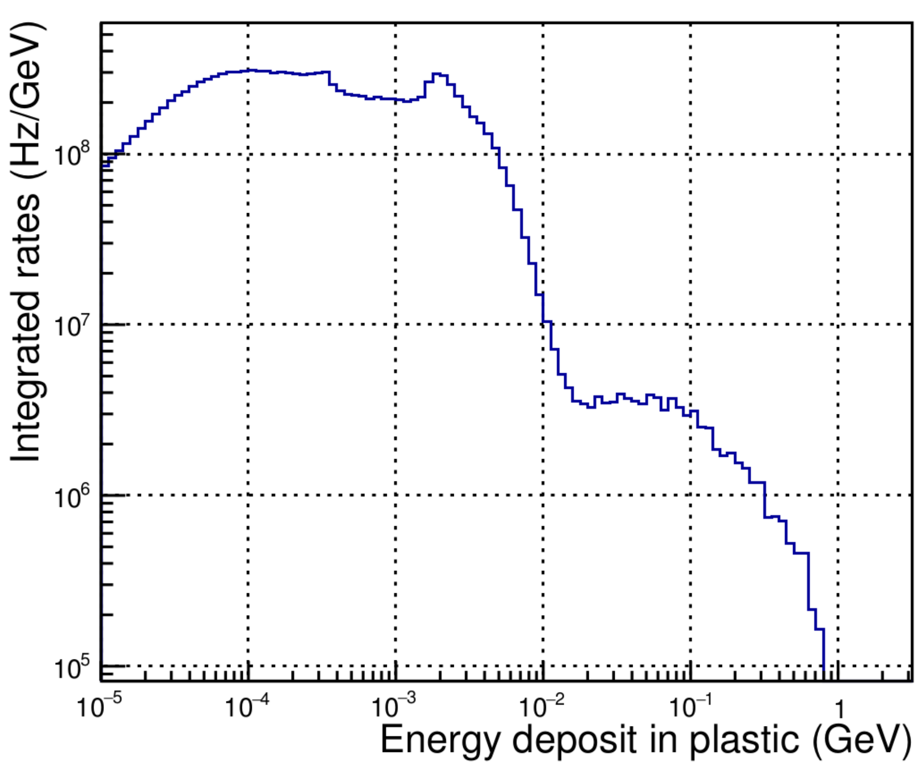
Δt(background): 50 ns
S/B ratio ≥ 20

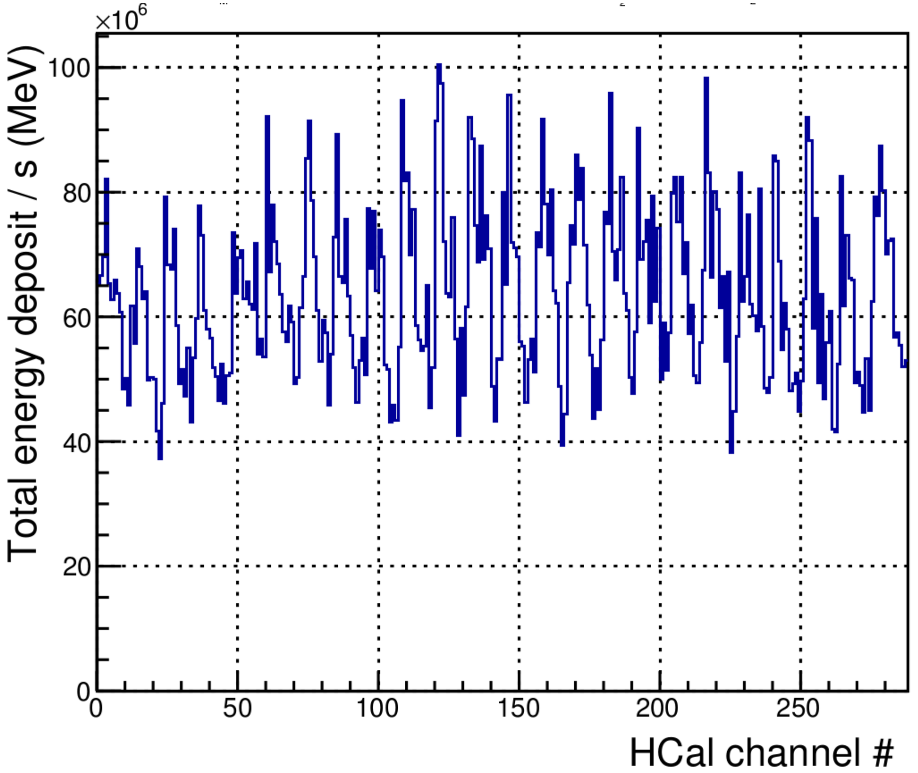
Δt(background): 50 ns
S/B ratio ≥ 100

```
> Channel numbering conventions for BBPS-SH:
> channel # 0: top, furthest from the beam
> channel # 26: bottom, furthest from the beam
> channel # 27 (PS) 161 (SH): top, closest to the beam
> channel # 53 (PS) 188 (SH): bottom, closest to the beam
```

HCal background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter





MIP (100 GeV μ) energy: **84 MeV**;

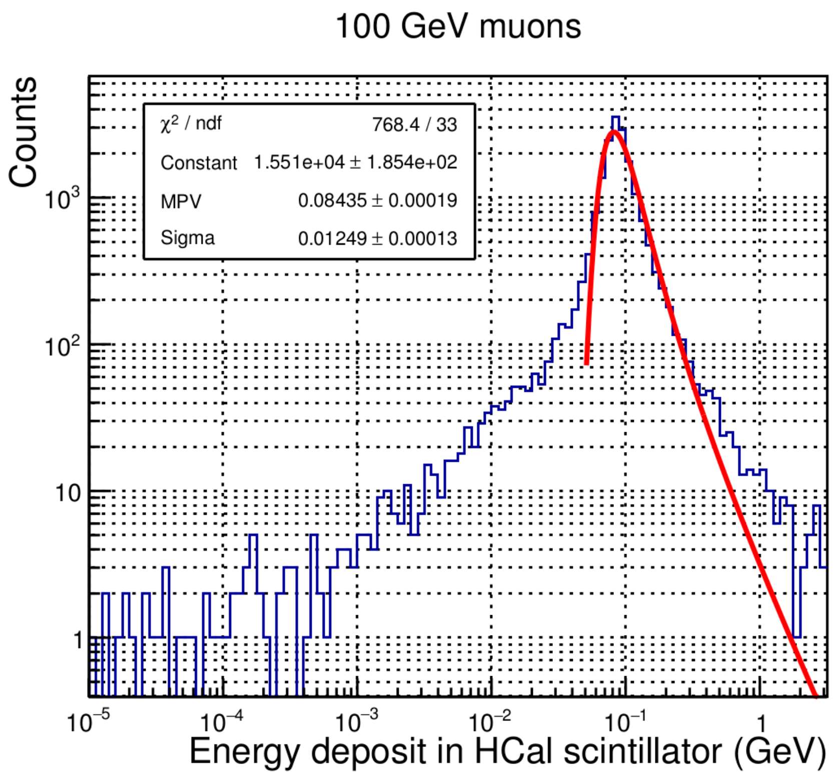
1GeV neutron energy: **87 MeV**;

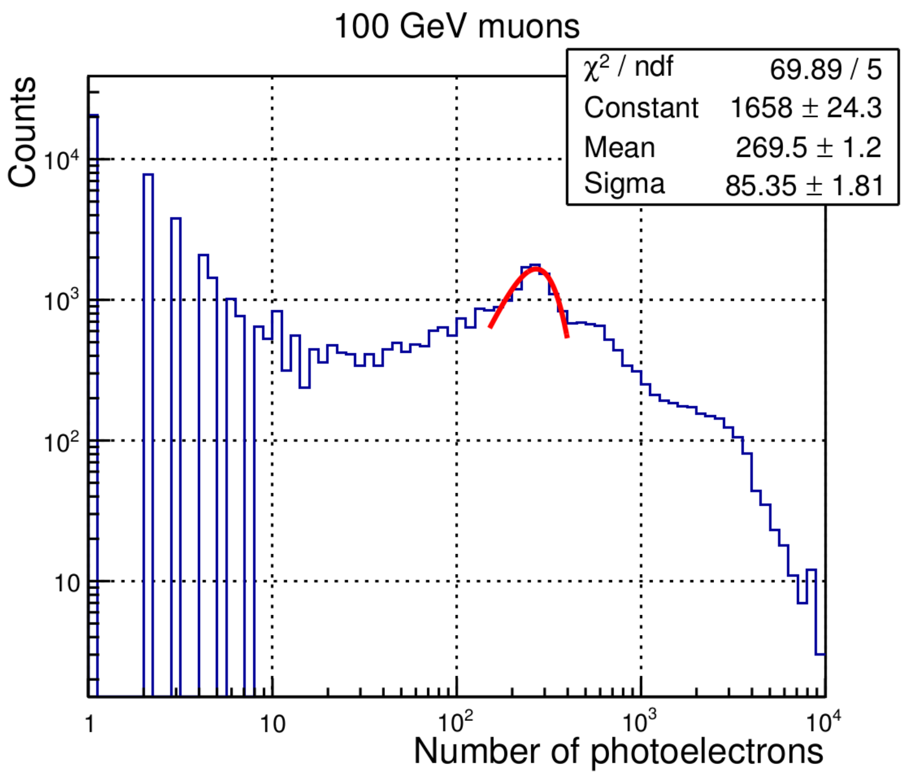
Total energy deposited in plastic: **~1.8 10^{10} MeV/s = 6.35 10^7 MeV/s/block**

Background energy deposit / block over 50 ns: 3.1 MeV

HCal response to 100 GeV muons

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map





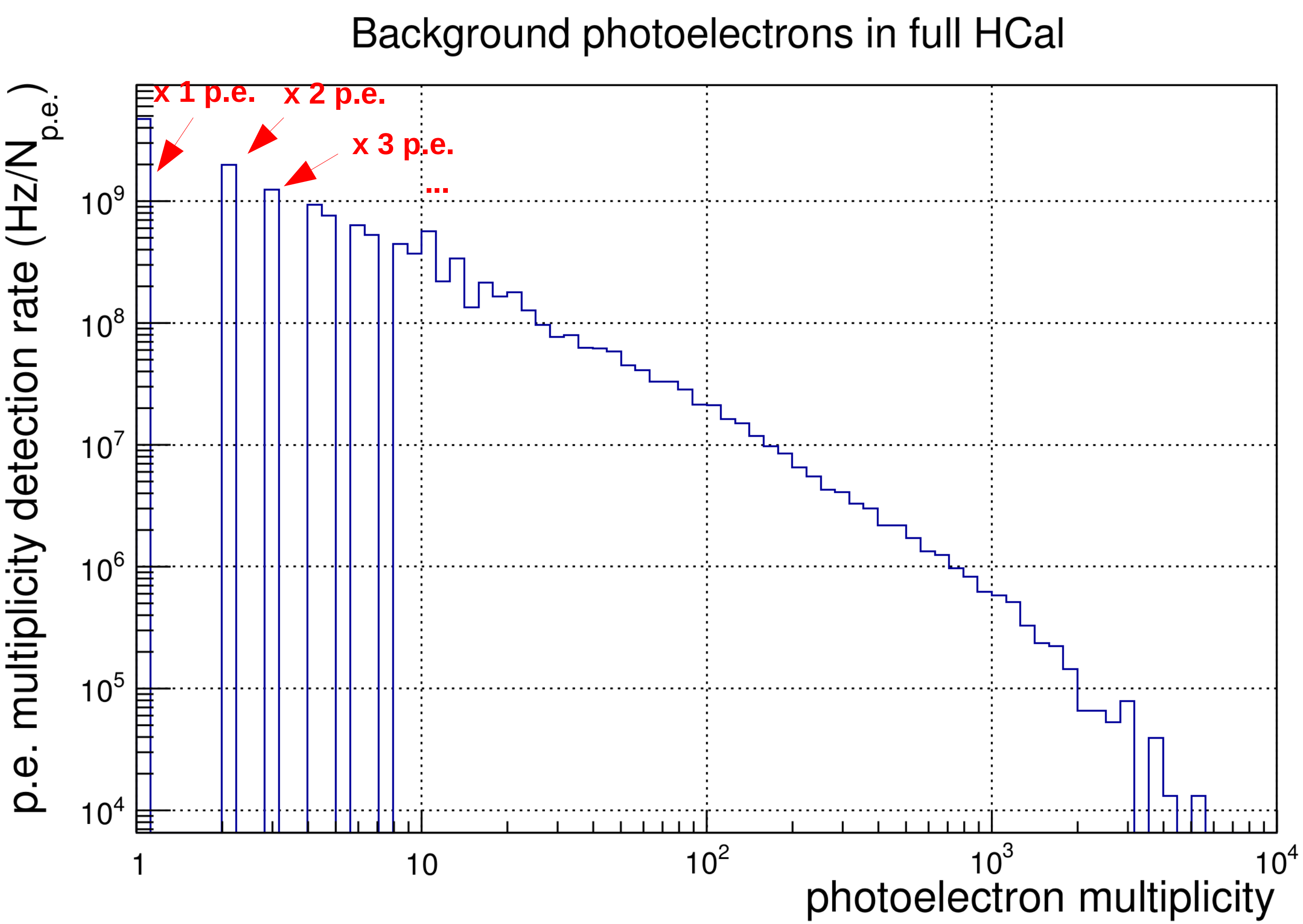
Energy MPV: **84 MeV**

Np.e. = 270 p.e.

(Measurements from CMU :
400 p.e. for cosmics)

HCal background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 µA, 15 cm LD_2, beamline shielding + CH_2 filter



To obtain anode current $\mathbf{I_{AC}}$:

Start from p.e. multiplicity detection rates $\mathbf{R_{pe}}$;

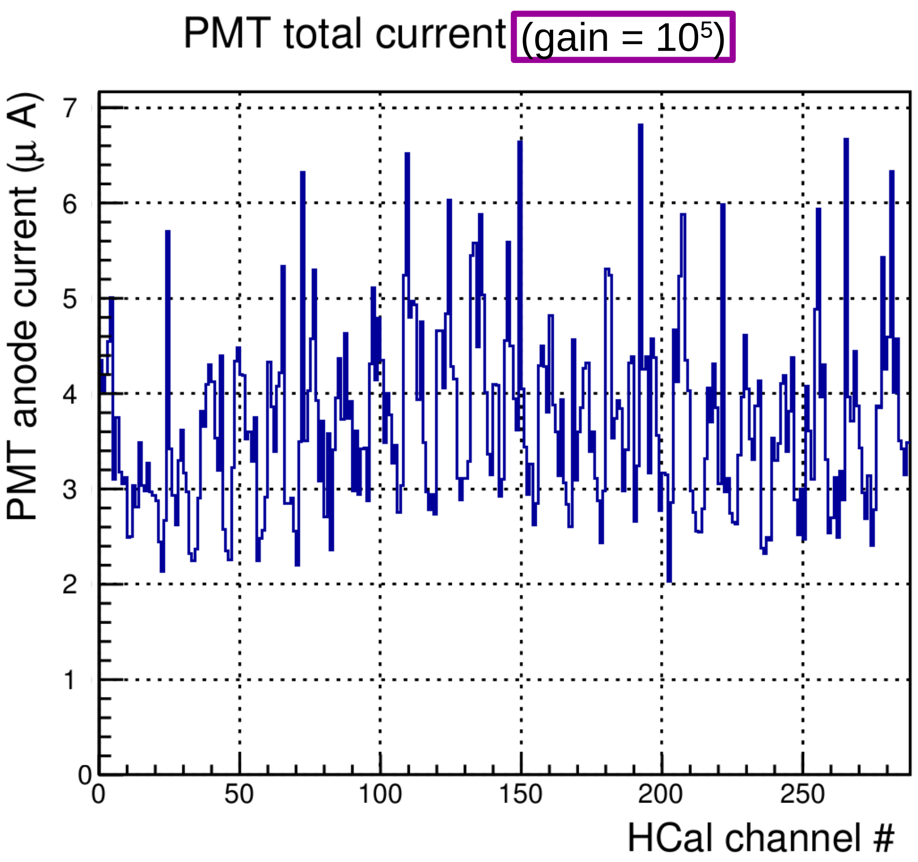
multiply them by corresponding p.e. multiplicity $\mathbf{N_{pe}}$;

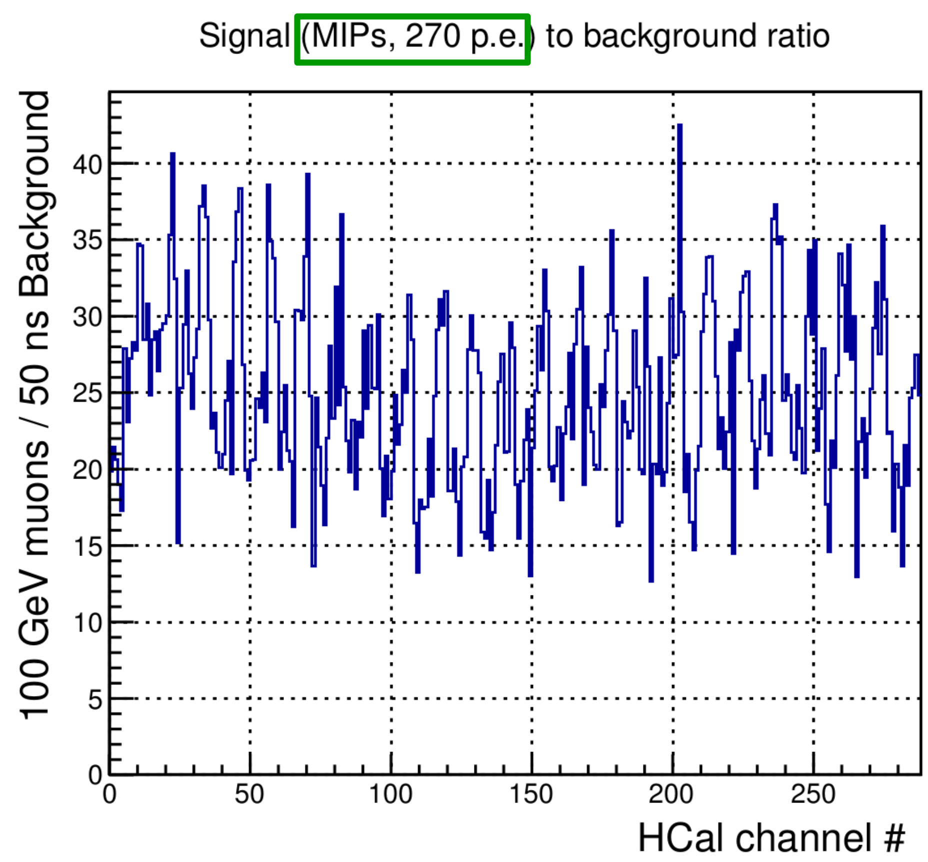
Multiply by the PMT gain $\mathbf{G_{PMT}}$ an the elementary charge $\mathbf{q_e}$

$$I_{AC} = \Sigma\,(R_{pe} * N_{pe}) * G_{PMT} * q_e$$

HCal Signal over background ratio

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter





PMT anode current 2 → 5 μA

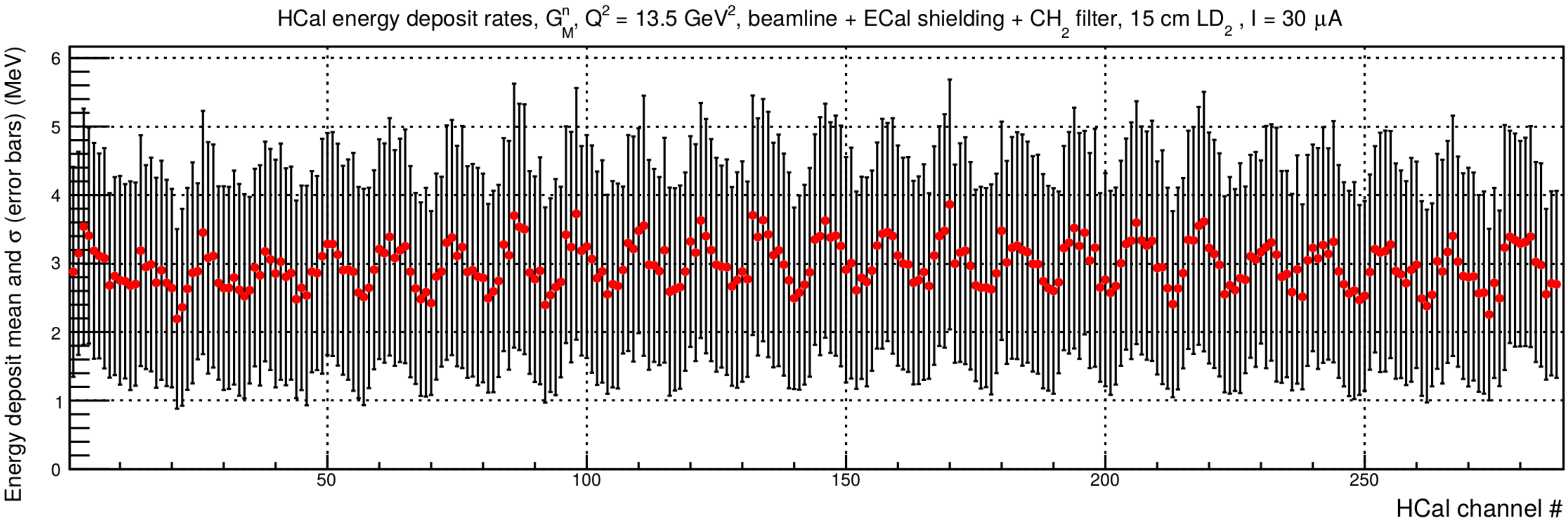
Δt(background): 50 ns
S/B ratio ≥ 15

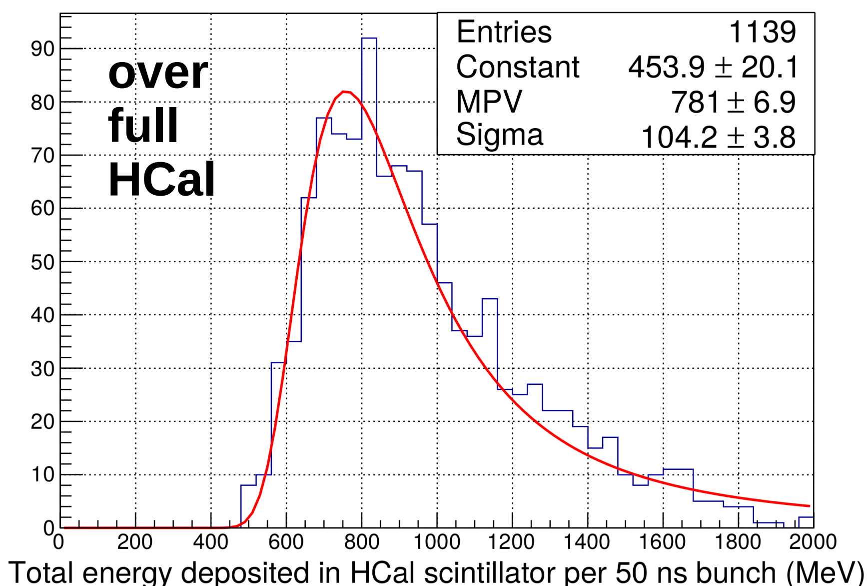
```
> Channel numbering conventions for HCal:
> channel # 0: top corner, closest to the beam
> channel # 11: top corner, furthest from the beam
> channel # 264: bottom corner, closest to the beam
> channel # 287: bottom corner, furthest from the beam
```

HCal background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter

Background in HCal: Energy deposit fluctuations per channel





Sample energy deposit by 50 ns.

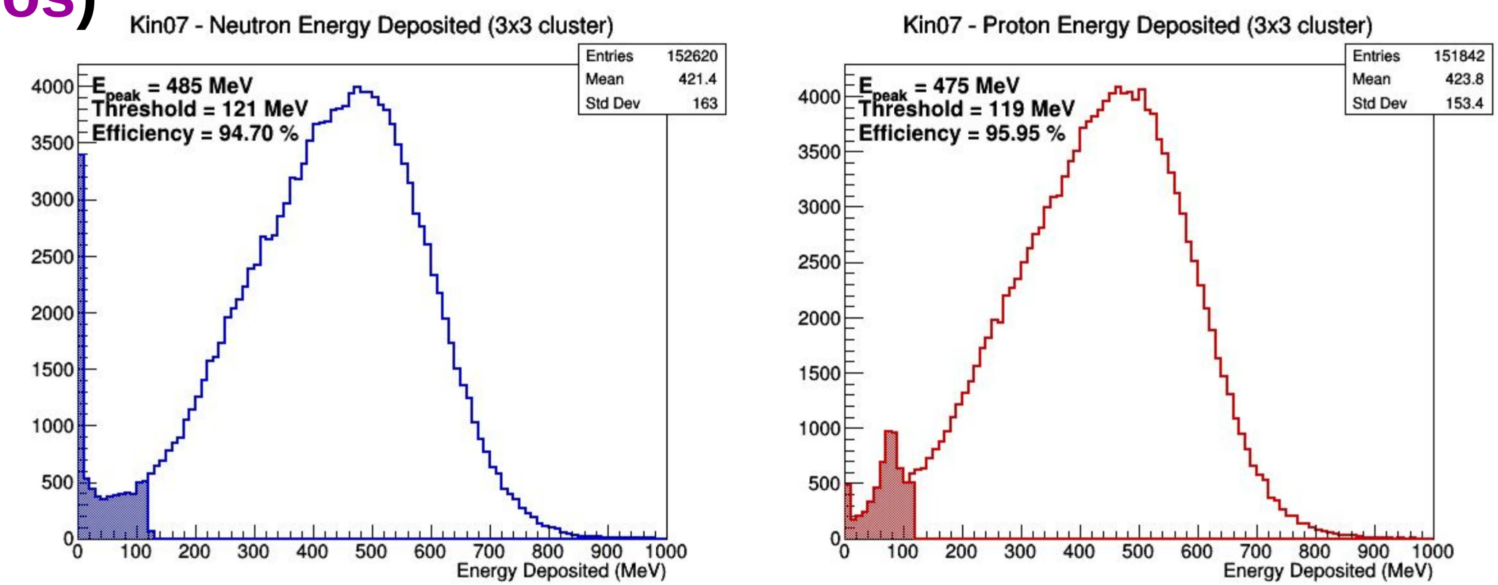
Mean energy deposit / block over 50 ns: ~3 MeV, with Mean: 1.5 MeV

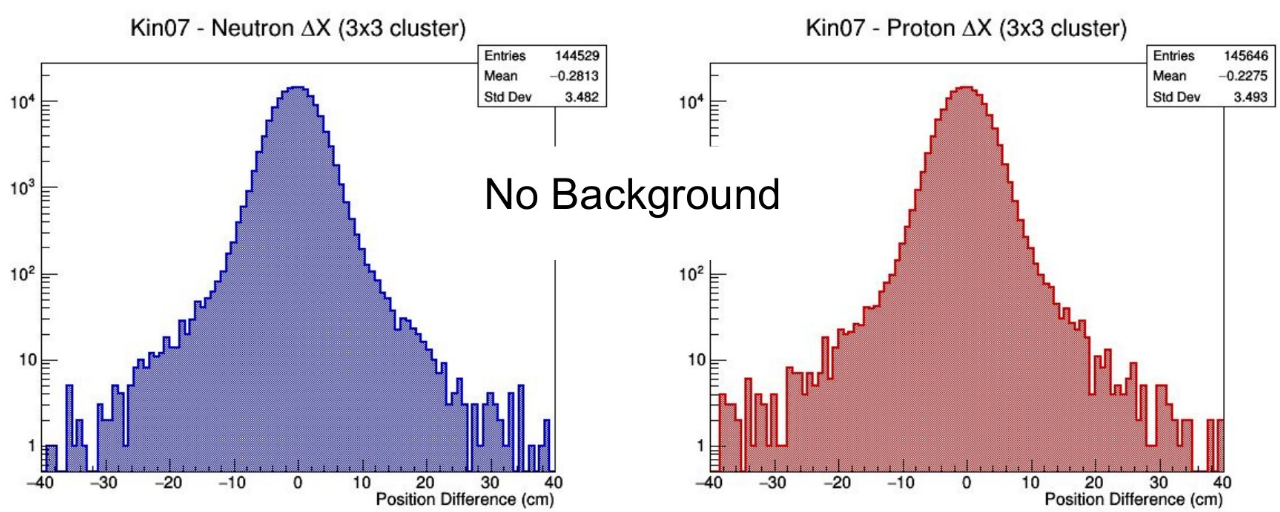
Superimposed background to quasi-elastic nucleon signal: background generated randomly, in each block sharing the QE nucleon signal, according to the respective background distribution of the block (next two slides)

HCal : impact of background in QE nucleons

Q^2 = 13.5 GeV^2, I_{beam} = 30 µA, 15 cm LD_2, beamline shielding + CH_2 filter

(credit: Juan Carlos) HCal Efficiency (3" steel front plate) **NO** background





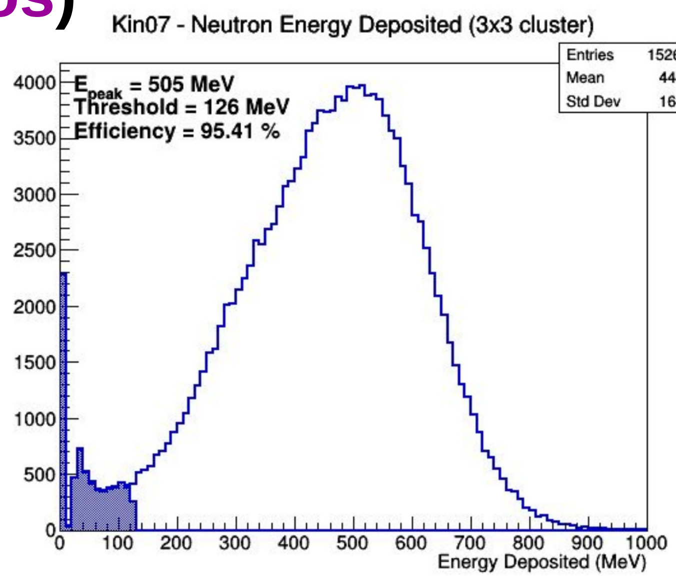
Neutrons :
E_{peak} = 485 MeV
Eff ~ 95 %
(Thr = 121 MeV)
μ_x = -0.28 cm
σ_x = 3.5 cm

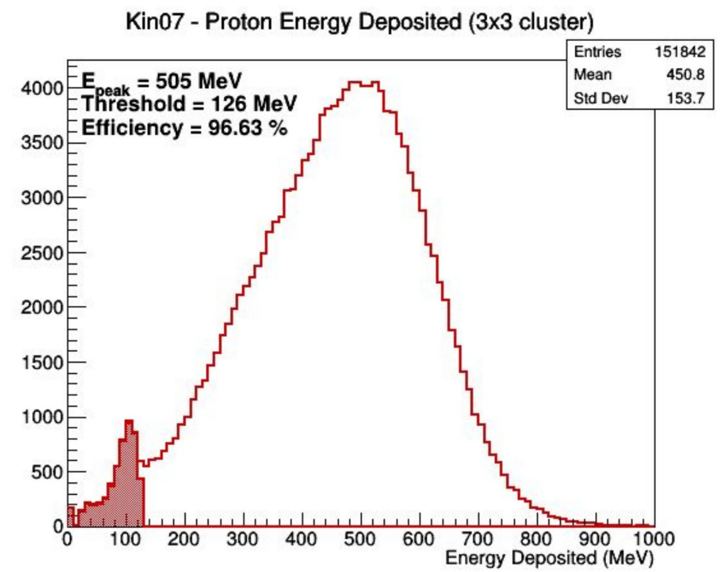
Protons :
E_{peak} = 475 MeV
Eff ~ 96 %
(Thr = 119 MeV)
μ_x = -0.23 cm
σ_x = 3.5 cm

HCal : impact of background in QE nucleons

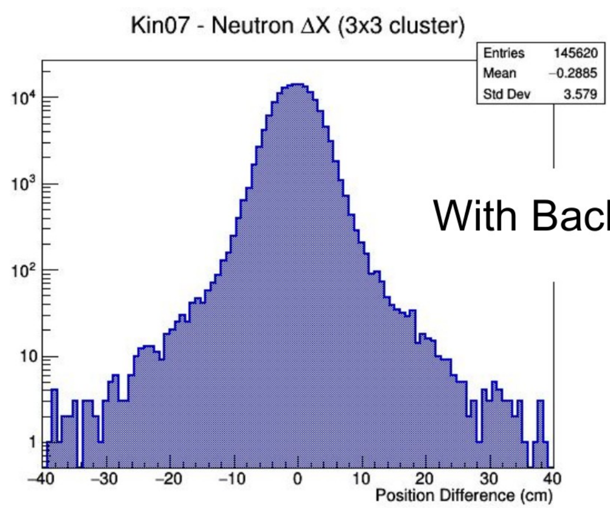
Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter

(credit: Juan Carlos) HCal Efficiency (3” steel front plate) **+** background

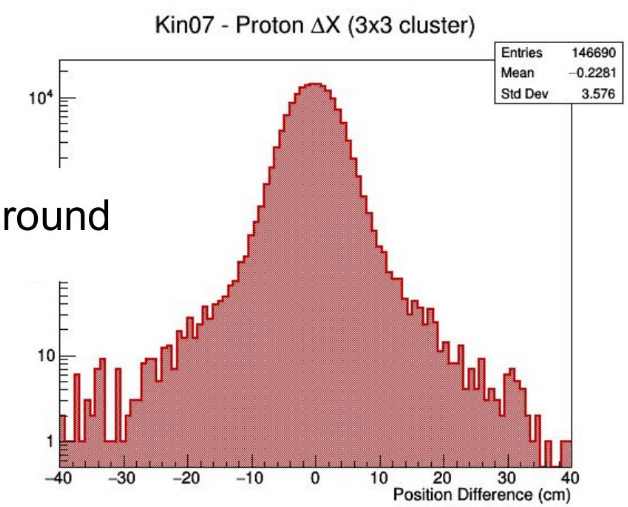




Neutrons :
E_{peak} = 505 MeV
Eff ~ 95 %
(Thr = 126 MeV)
μ_X = -0.29 cm
σ_X = 3.6 cm



With Background

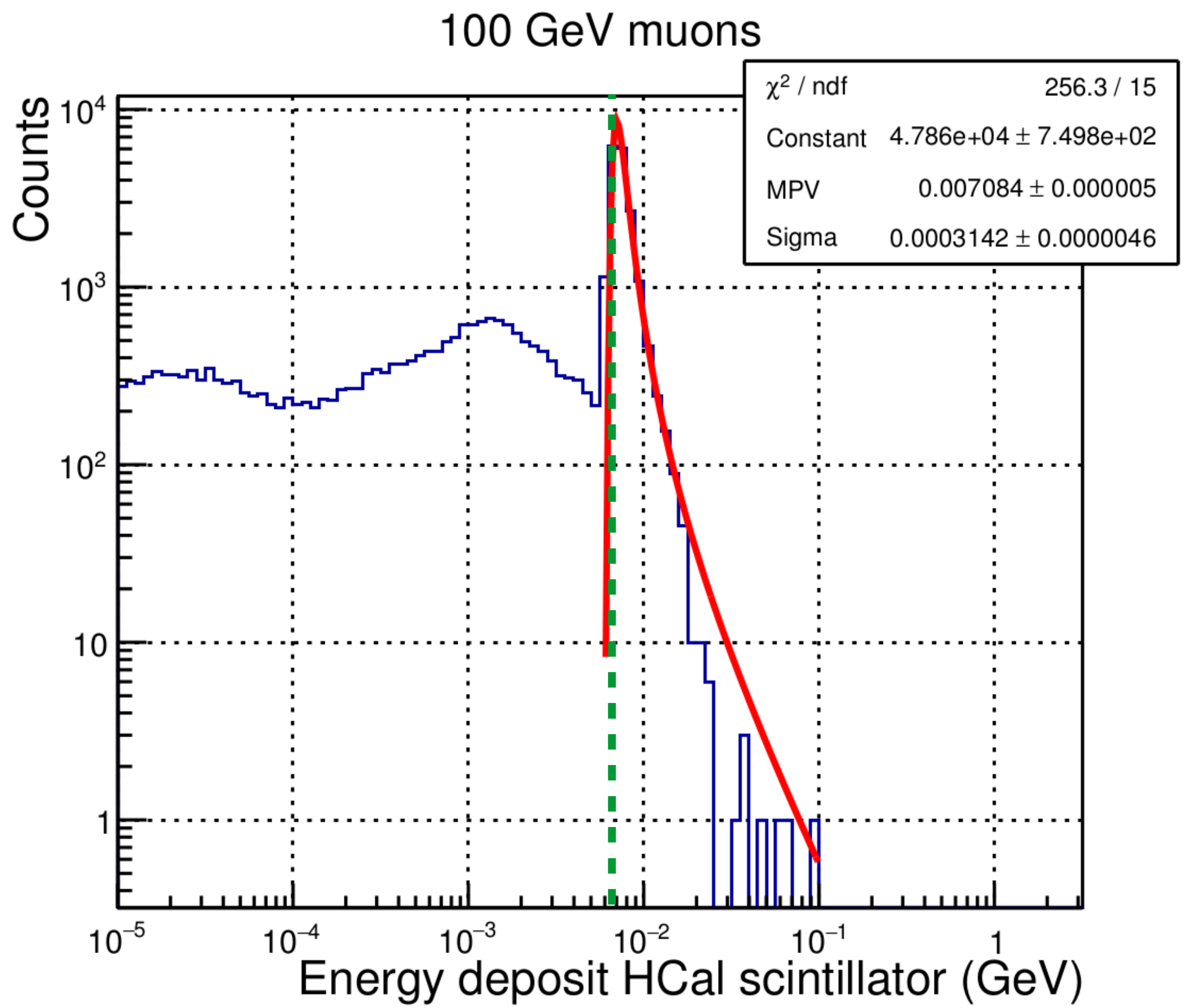


Protons :
E_{peak} = 505 MeV
Eff ~ 97 %
(Thr = 126 MeV)
μ_X = -0.23 cm
σ_X = 3.6 cm

Background has a marginal effect on signal reconstruction

Cdet response to ultrarelativistic muons

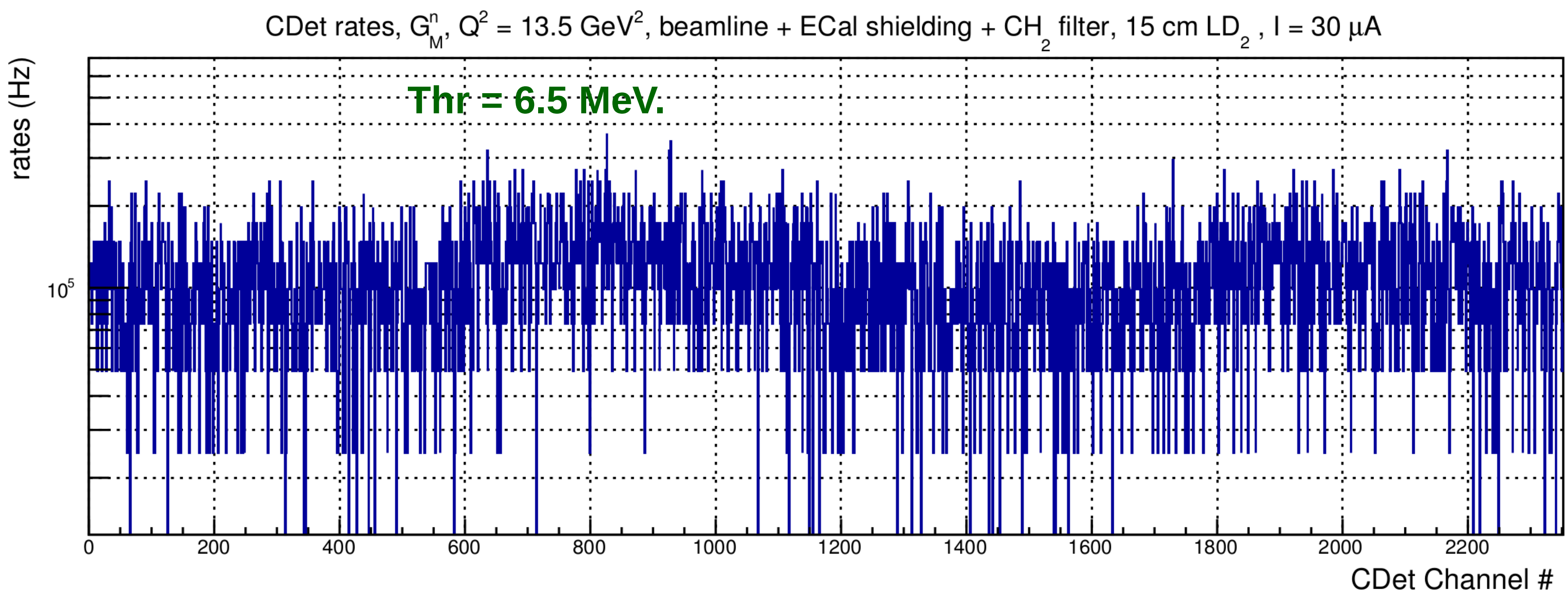
Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map



Energy MPV: **7.1 MeV**
FWHM: **0.3 MeV**
I set threshold at
MPV – 2*FWHM = **6.5 MeV.**

CDet background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter



Rates : 100-300 kHz / channel with CH_2 filter :

Average energy deposit in a CDet slat *per second*: 9.2 10^6 MeV.

=> Signal (MIPS 7.1 MeV) / 15 ns integrated background => ~50

```
Channel numbering conventions for CDet:
channels # 0-587: first plane, far from beam
channels # 588-1175: first plane, close to beam
channels # 1176-1763: second plane, far from beam
channels # 1764-2352: second plane, close to beam
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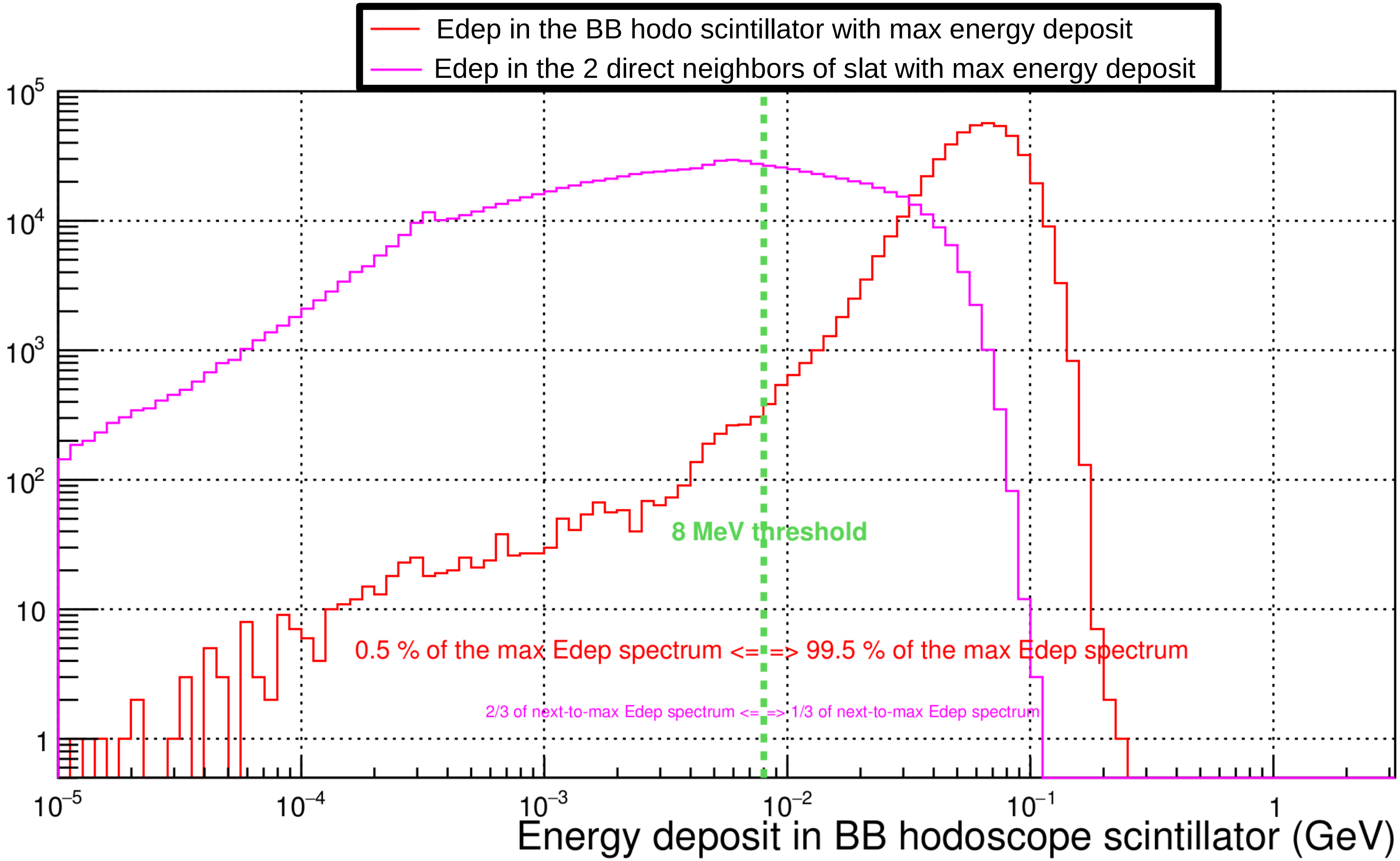
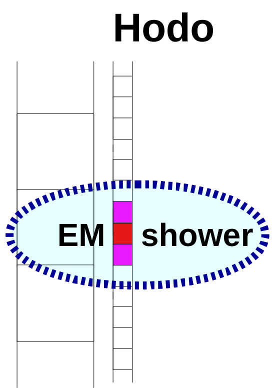
BB hodoscope response to quasi-elastic eletrons

Q^2 = 13.5 GeV^2, I_{beam} = 30 µA, 15 cm LD_2, beamline shielding + CH_2 filter

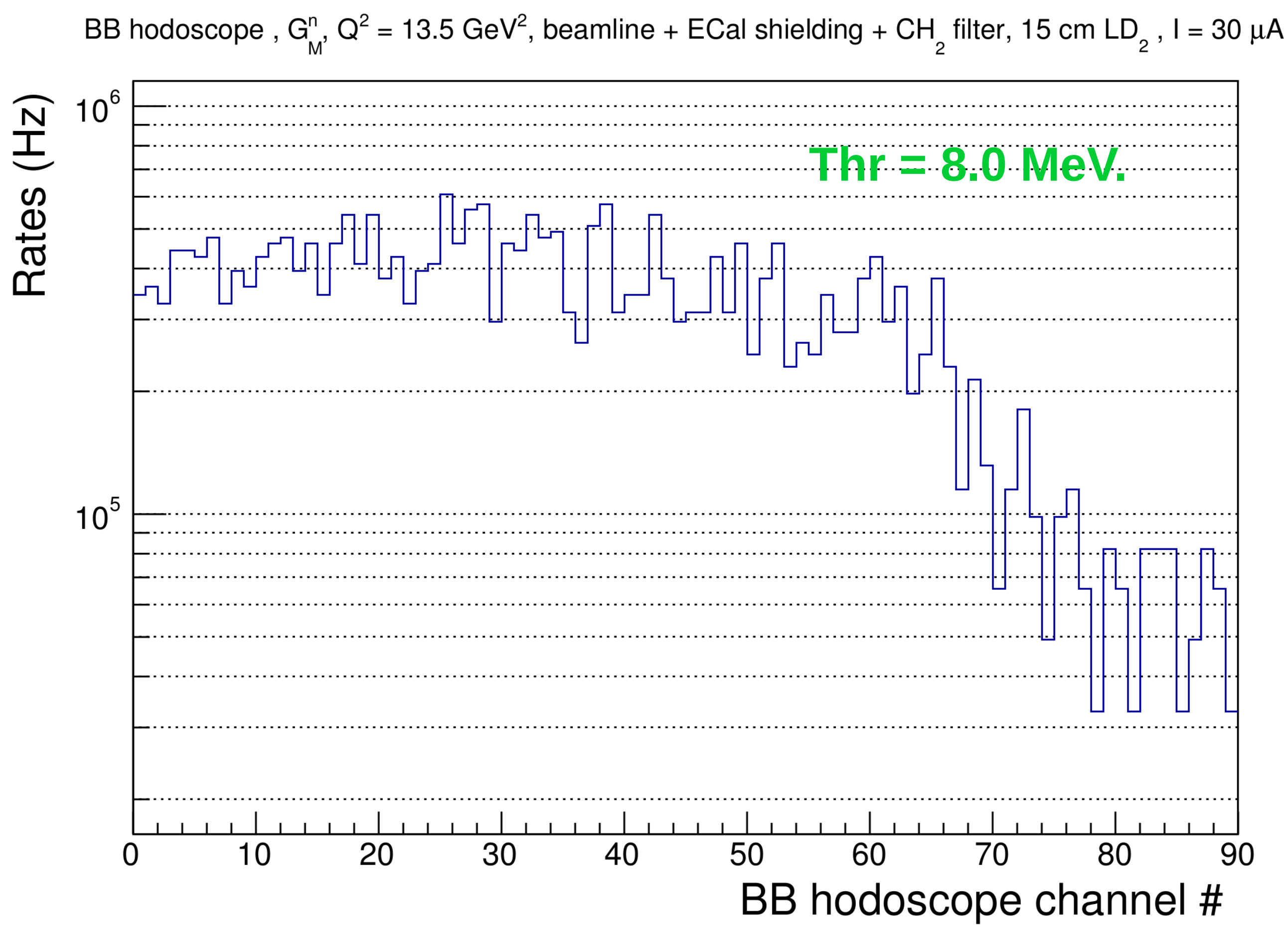




Total energy deposited over BB hodoscope for QE electrons: **110 MeV**
(the BB hodoscope is hit by EM showers, not MIPS)
=> In most cases, **60 MeV** are deposited in **1** element. To record the signal from this scintillator with 99.5% efficiency, threshold needs to be **8 MeV.**

BB hodoscope background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, beamline shielding + CH_2 filter



Rates: 500 kHz Max / Channel
Average energy deposit in a BB hodo slat *per second*: 1.25 10^7 MeV.
=> Signal (QE e^-, 60 MeV) / 15 ns integrated background => ~320

> Channel numbering conventions for BBHodo:
> channel # 0: bottom
> channel # 89: top

GEM electronics dose rate for G_M^n

(credit: Freddy)

G_M^n Electronics Hut

$Q^2(GeV^2)$	$\theta_{BB}(deg)$	$d_{BB}(m)$	$E_{beam}(GeV)$	$I_{beam}(\mu A)$
13.5	33.0	1.55	11.0	44.0

- Ran 15 $\times 10^9$ events with the beam generator
- Silicon sensitive region is 101.6 x 101.6 x 2.54 cm^3
- Density of Silicon used = 2.33 g/cm^3
- Total energy deposited = 910 MeV
- Results:

Dose rate = 0.016 rad/hr

Overview

* G4SBS simulation: addition / update of geometries

* Recent background calculations for G_M^n ERR

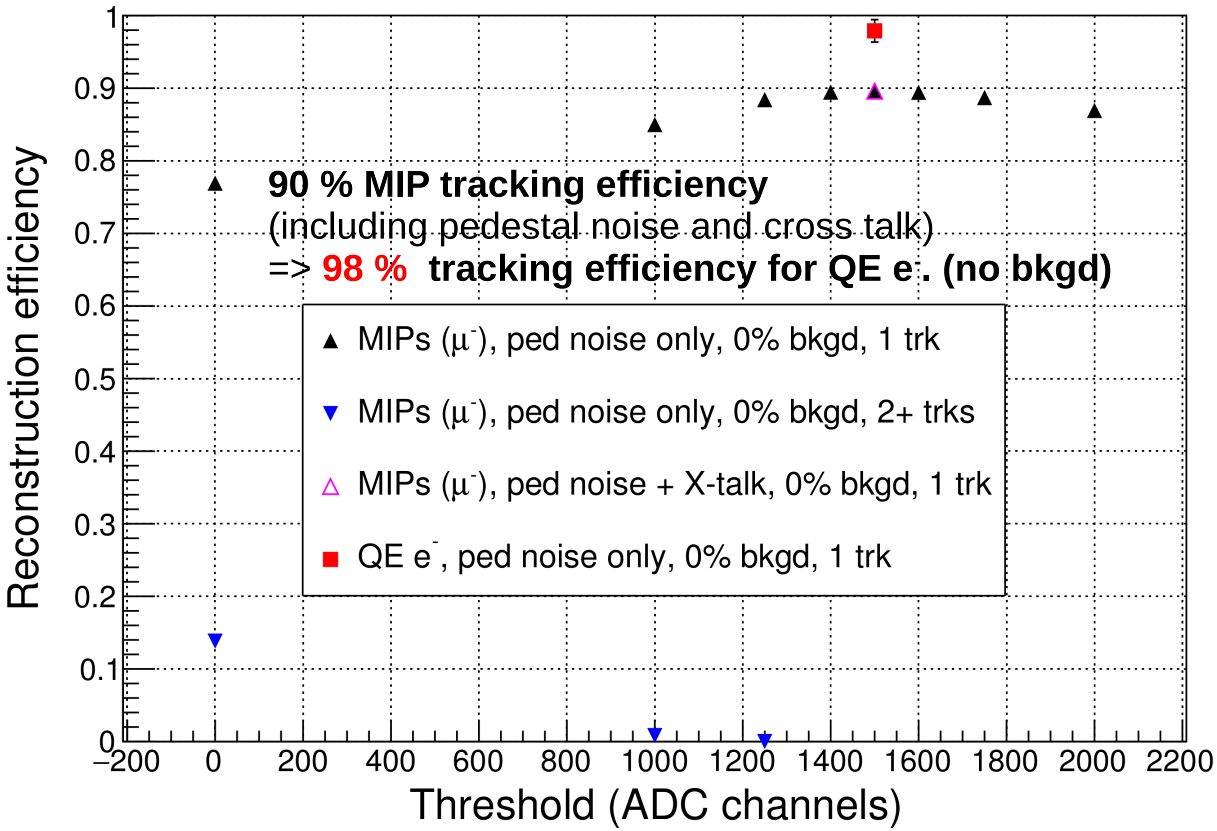
* Tracking

* Summary

GEM tracking software

Currently adapting SoLID tracking software for SBS
→ inclusion of the lastest version of the digitization code developed for SoLID, including more realistic avalanche model, cross talk, pedestal noise (courtesy from W. Xiong).
→ interfaced with TreeSearch, analyzer, etc...
→ Adapted to : **BigBite GEMs**, **FT+FPPs**, SIDIS SBS GEMs

- In ideal conditions (0 % bkg), track fitting works;



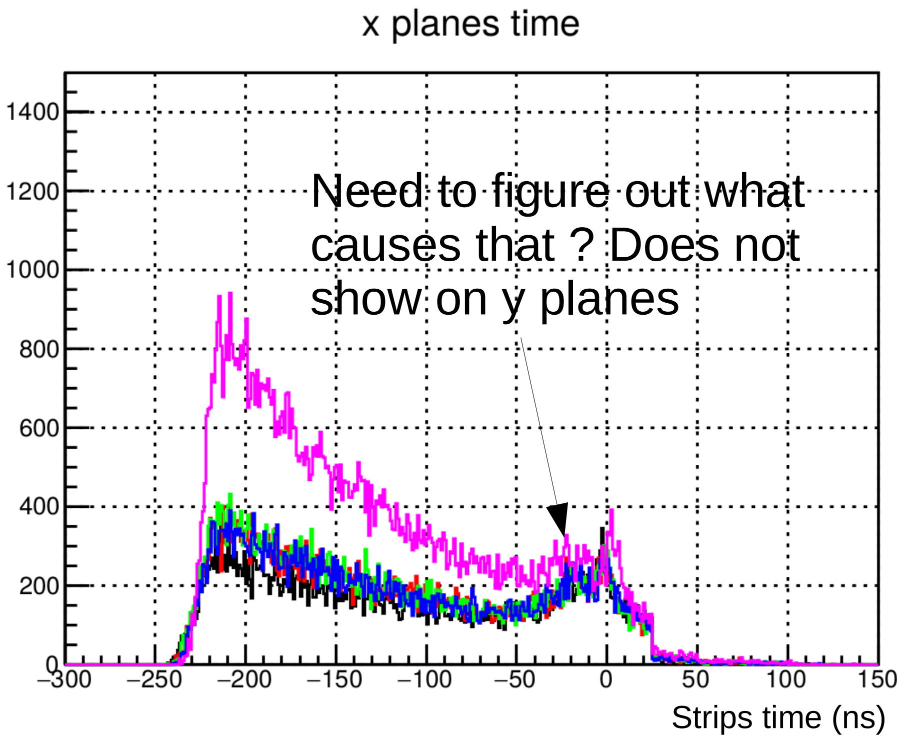
(don't understand the difference of efficiency between MIPs and QE e^-

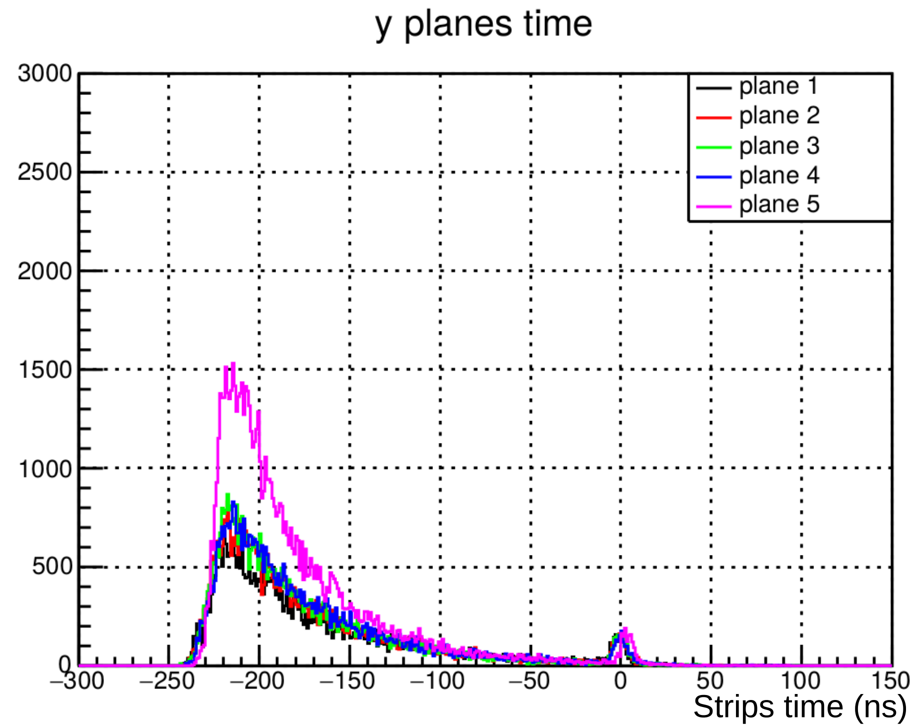
UCONN Jefferson Lab

GEM tracking software

Currently adapting SoLID tracking software for SBS :
→ inclusion of the lastest version of the digitization code developed for SoLID, including more realistic avalanche model, cross talk, pedestal noise (courtesy from W. Xiong).
→ interfaced with TreeSearch, analyzer, etc...

- In ideal conditions (0 % bkg), track fitting works;
- Issues adding background under investigation ;





I have had checked for hypothetical correlations with other variables:
I haven't found yet

Overview

* G4SBS simulation: addition / update of geometries

* Recent background calculations for G_M^n ERR

* Tracking

* Summary

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Summary

*** Good progress on completing/updating g4sbs**
TODOs already listed above

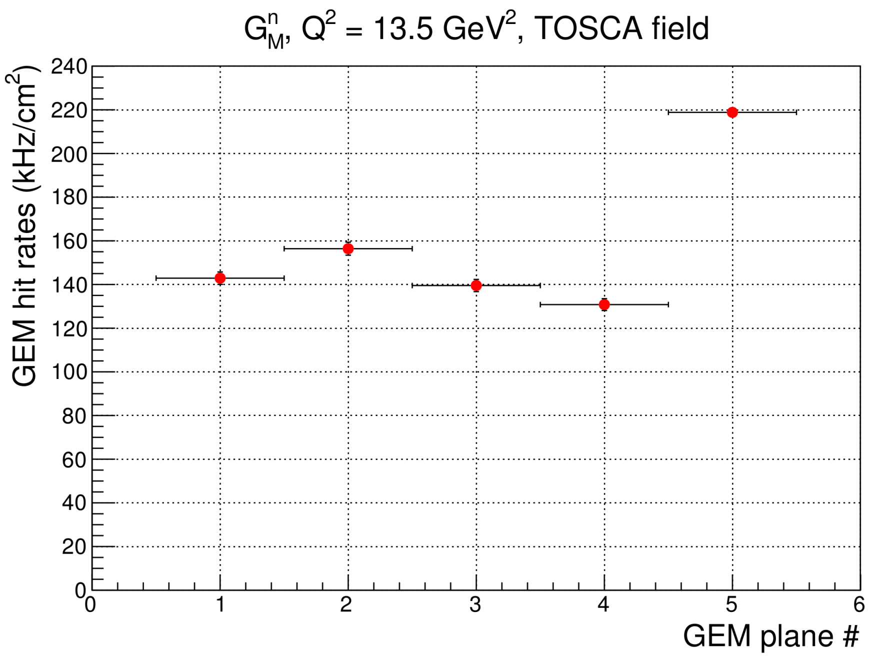
*** Studied extensively backgrounds and signal to background ratios for G_M^n at higher Q^2;**

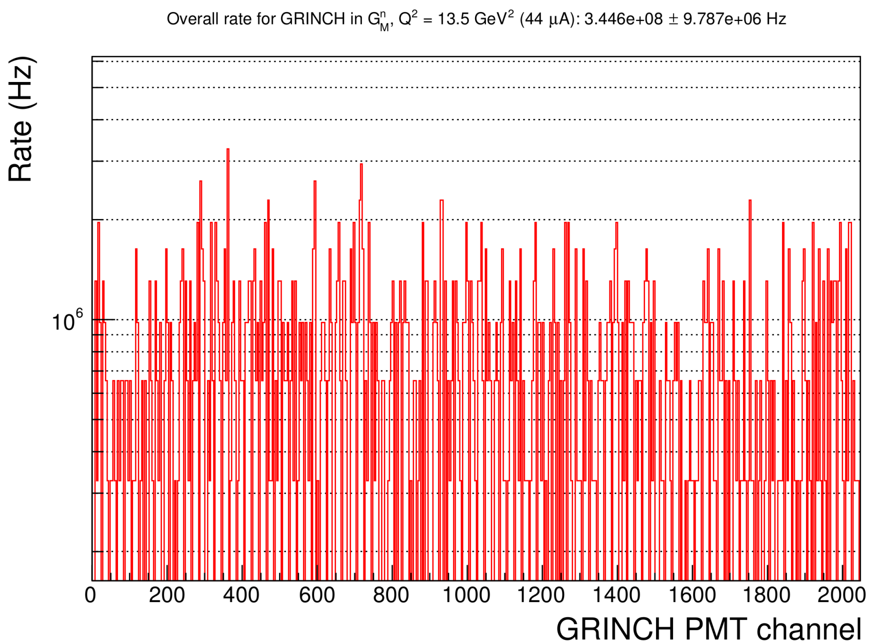
*** Tracking software has made good progress :**
TODO : → solve pending issues, and finish debug the tracking;
→ clean the background by cuts on timing, etc;
→ plug in external constraints (ECal cluster for BB GEMs, HCal cluster for FPPs, kinematic correlations for FT)

Thank you for your attention !

GEM, GRINCH background rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44 μA, 10 cm LD_2, NO SHIELDING





New setup, TOSCA field map:
~140kHz/cm^2 per GEM for INFN GEMs (front),
220kHz/cm^2, for UVA GEM (behind GRINCH)
70% from **target**, 4% from 48D48;
11% from beamline; 5% from scattering chamber;

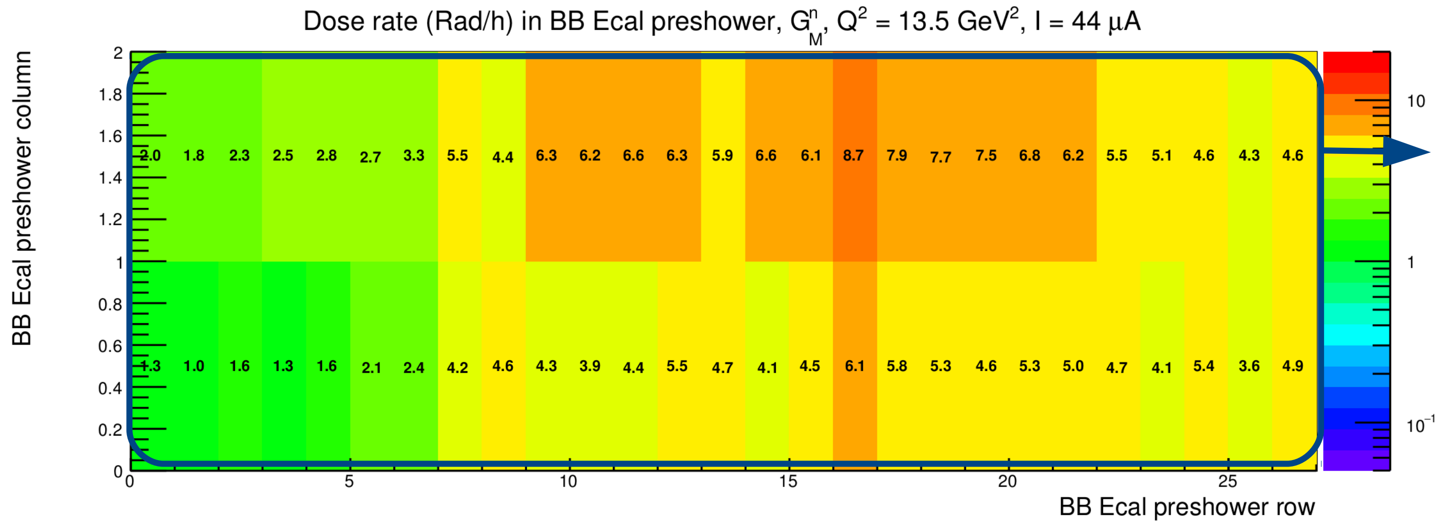
Rates are rather high, but can be handled...

345 MHz over detector => ~680kHz/PMT;
not easy to deal with, but handleable;

=> 410 kHz (60%) from **target**;
55 kHz (8%) from 48D48 magnet;
135 kHz (20%) from beam line;
60 kHz (9%) from scattering chamber;

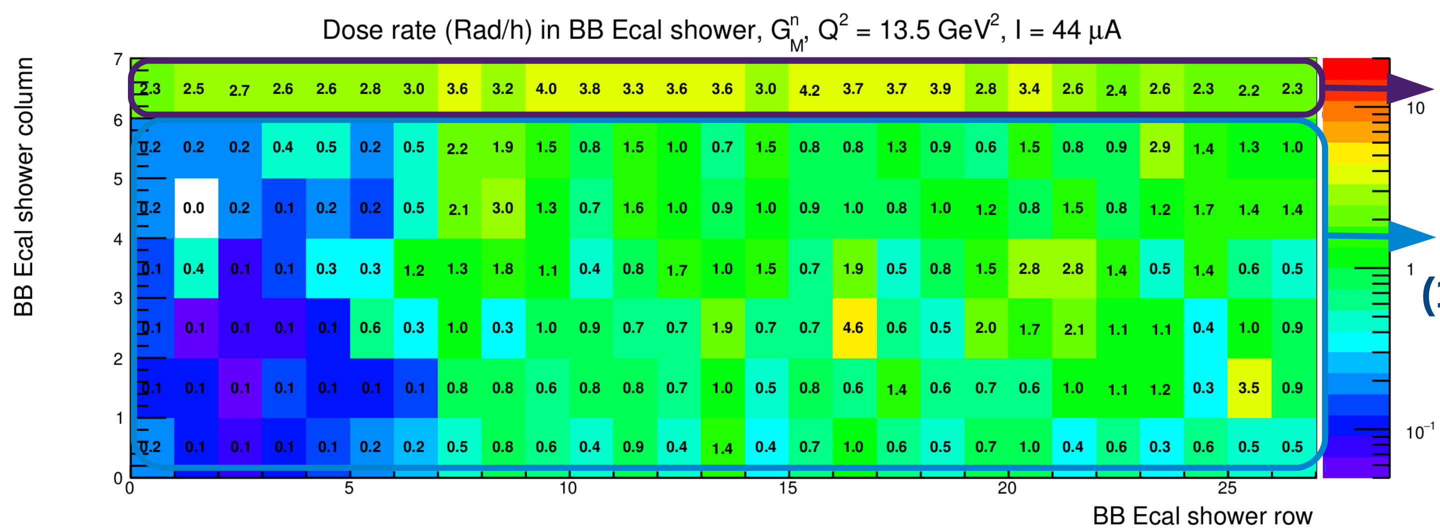
BB Ecal dose rate for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44 μA, 10 cm LD_2, NO SHIELDING



4.6 Rad/h/block avg over PS

x100 h beam time: 460 Rad integrated *for this kinematic*. Max dose for a single block: ~900 Rad.



3.1 Rad/h/block avg

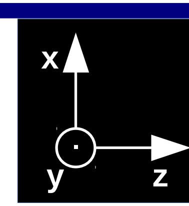
0.9 Rad/h/block avg

(1.2 Rad/h/block avg over SH)

NB : Lead glass performance starts to deteriorate for cumulated radiation dose ≥ 1kRad

UVA GEM, GRINCH rates

Explaination for GRINCH, UVA GEM rates with TOSCA field map

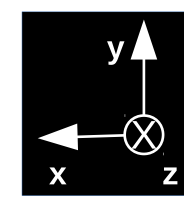


(bounce 0)

looks like Moeller electrons

100 charged geantinos
$9<\theta<11.0$ deg, 30MeV<p<50MeV
/g4sbs/invertfield true

Could low angle/low energy Moeller electrons be deflected by the magnetic field beam line ? => YES



We might be able to shield that...

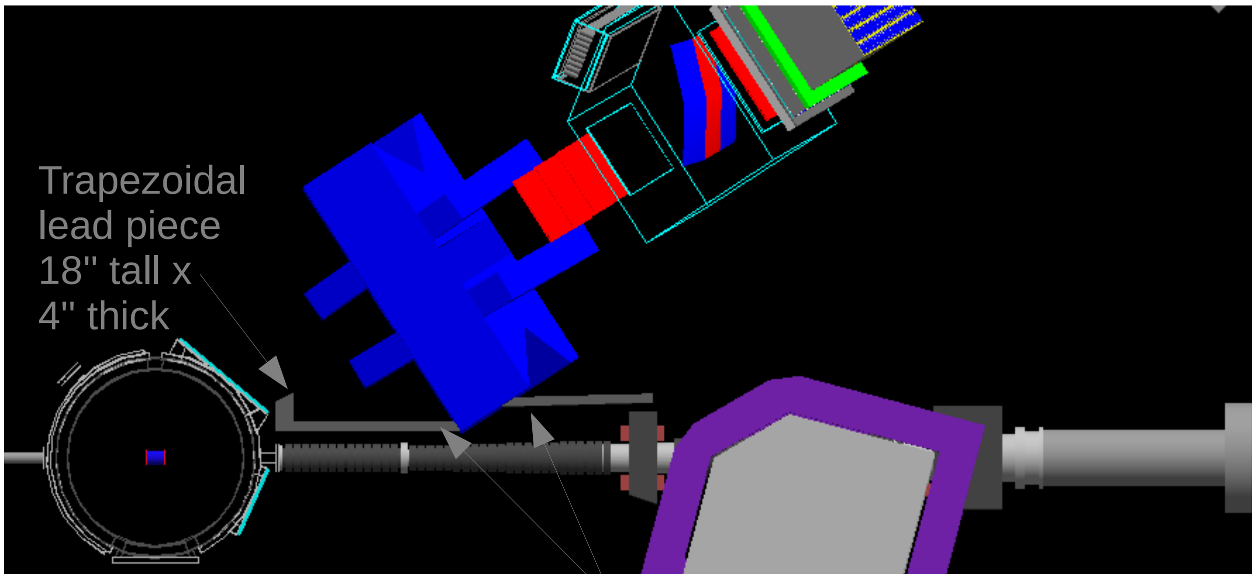
$\theta_{particle}$ (deg)

Beamline shielding for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map

Preliminary design:

ITERATION 2"



~~Trapezoidal "wood" shielding~~
~~(NB I used polyethylene…)~~
~~50 cm thick (min) x 4m tall x 3m long~~

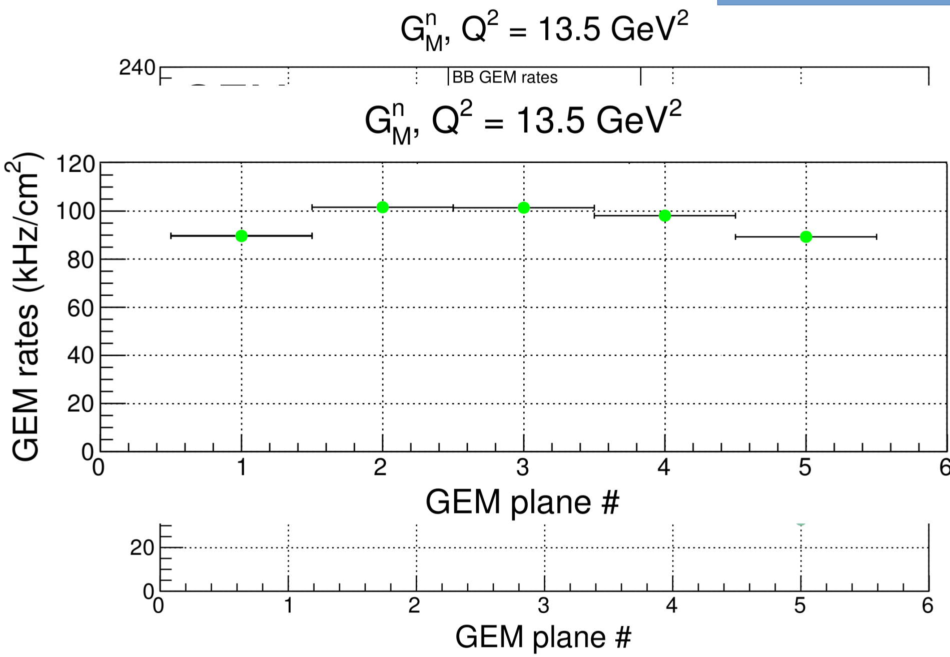
~~1cm thickness lead~~

All detector rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map

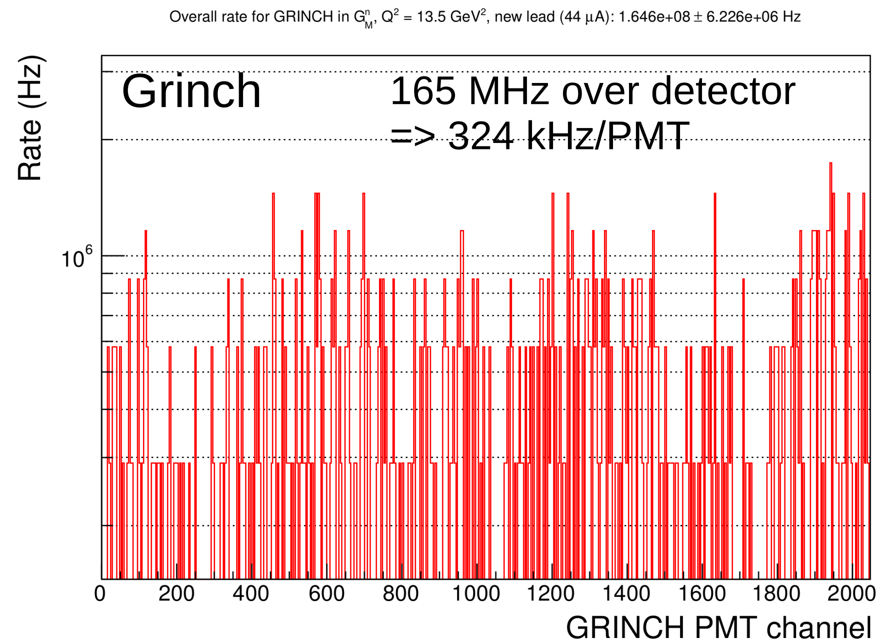
Beamline shielding + ECal shielding (1 cm steel + 5cm Al)

ITERATION 2''



64% from **target**,
6% from 48D48,
14% from BL,
6% from SC;

Rest (10%) ?



146 kHz/PMT (45%) from **target**,
62 kHz/PMT (19%) from 48D48,
84 kHz/PMT (26%) from BL,
32 kHz/PMT (10%) from SC.

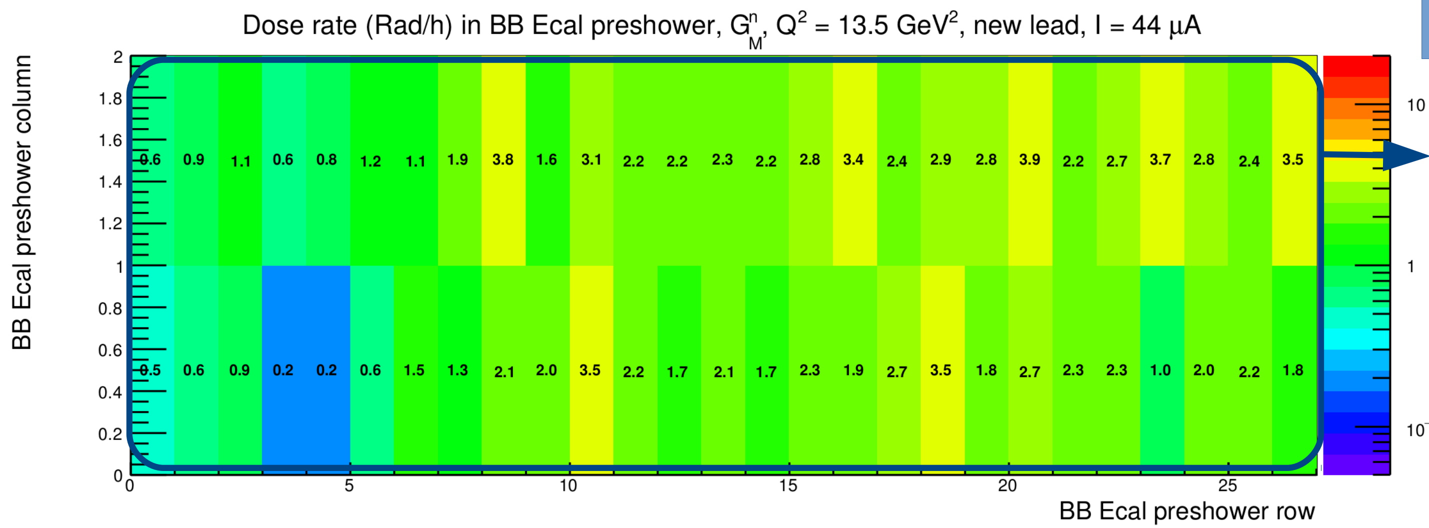
(* wrt no lead shielding)

BB Ecal dose rate for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map

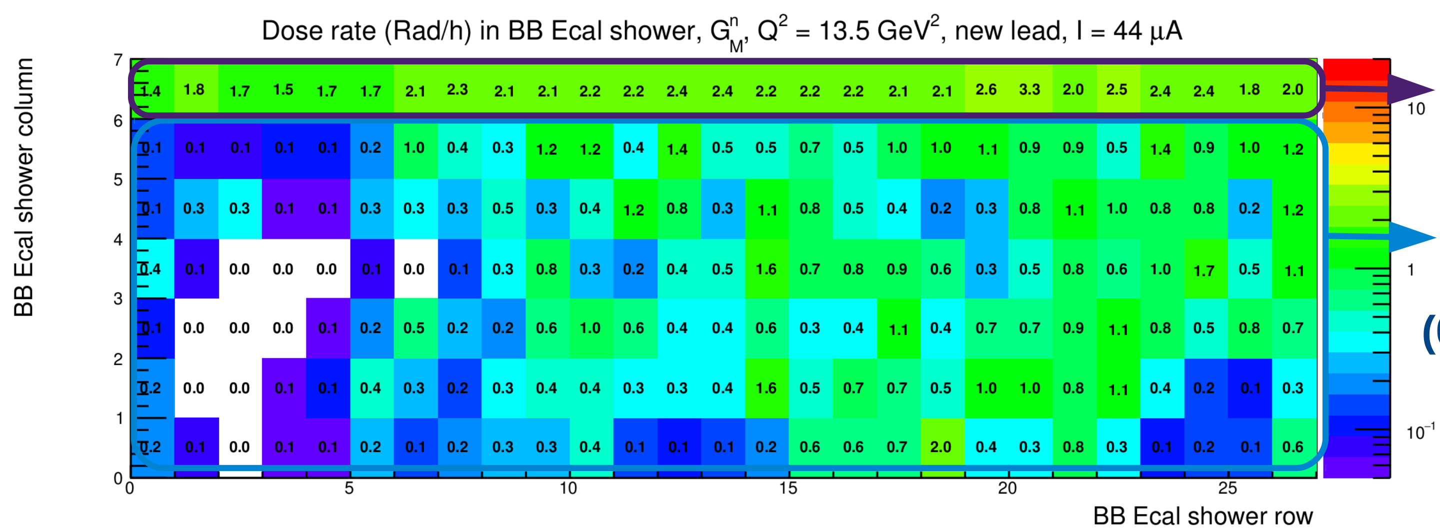
Beamline shielding + ECal shielding (1 cm steel + 5cm Al)

ITERATION 2"



2.01 Rad/h/block avg over PS

x100 h beam time: <200 Rad integrated *for this kinematic*. Max dose for a single block: ~300 Rad.



2.13 Rad/h/block avg

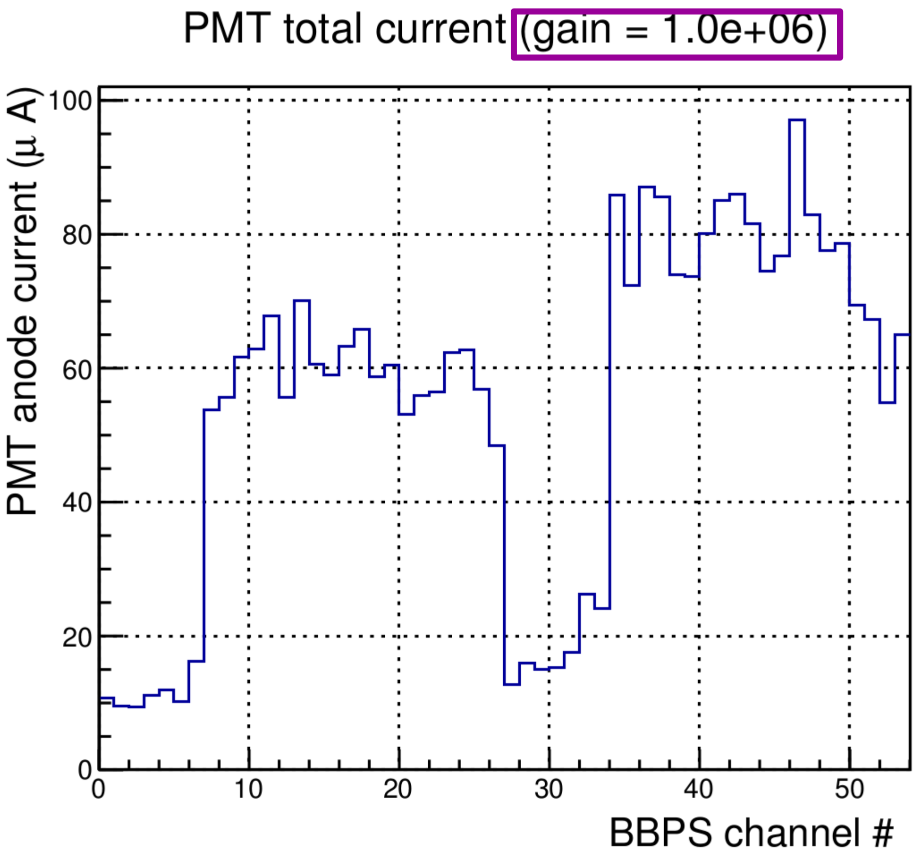
0.51 Rad/h/block avg

(0.74 Rad/h/block avg over SH)

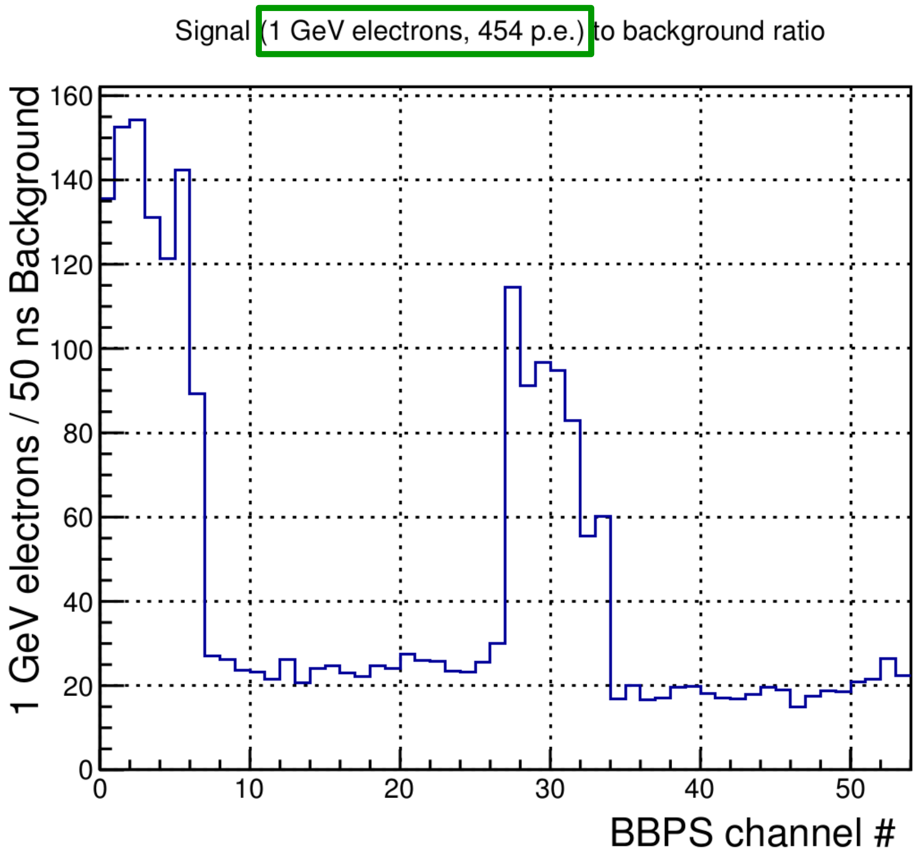
BB PS Anode current + Signal over background ratio

(Channel per channel)

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map



PMT anode current (reliable ?)



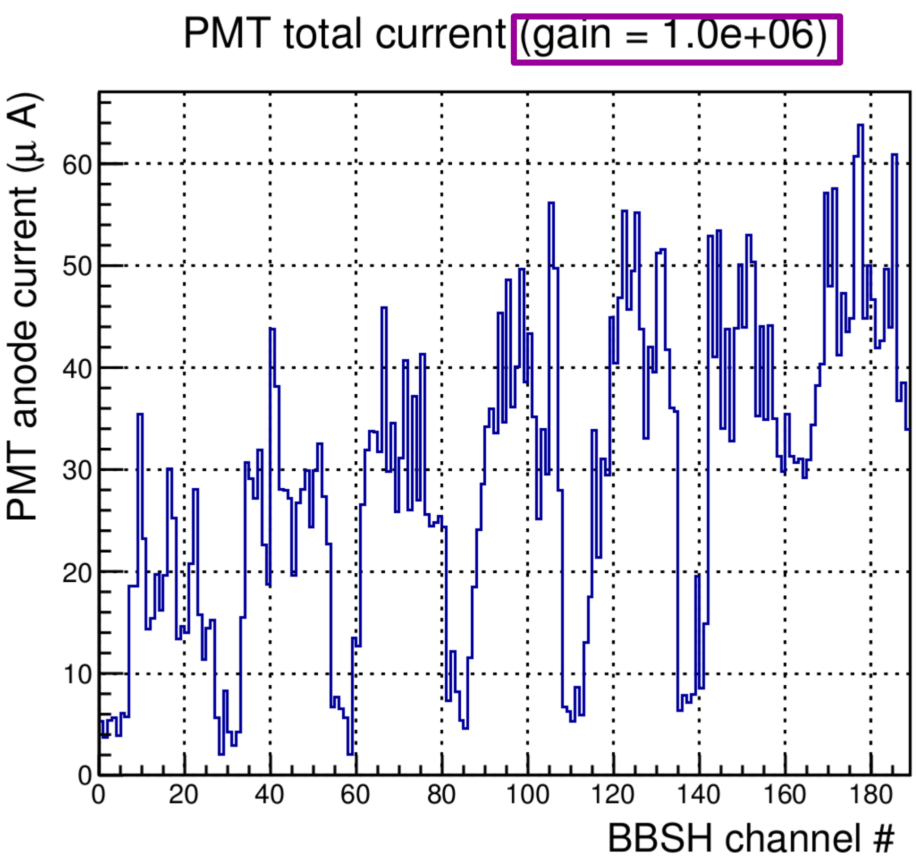
Δt(background): 50 ns

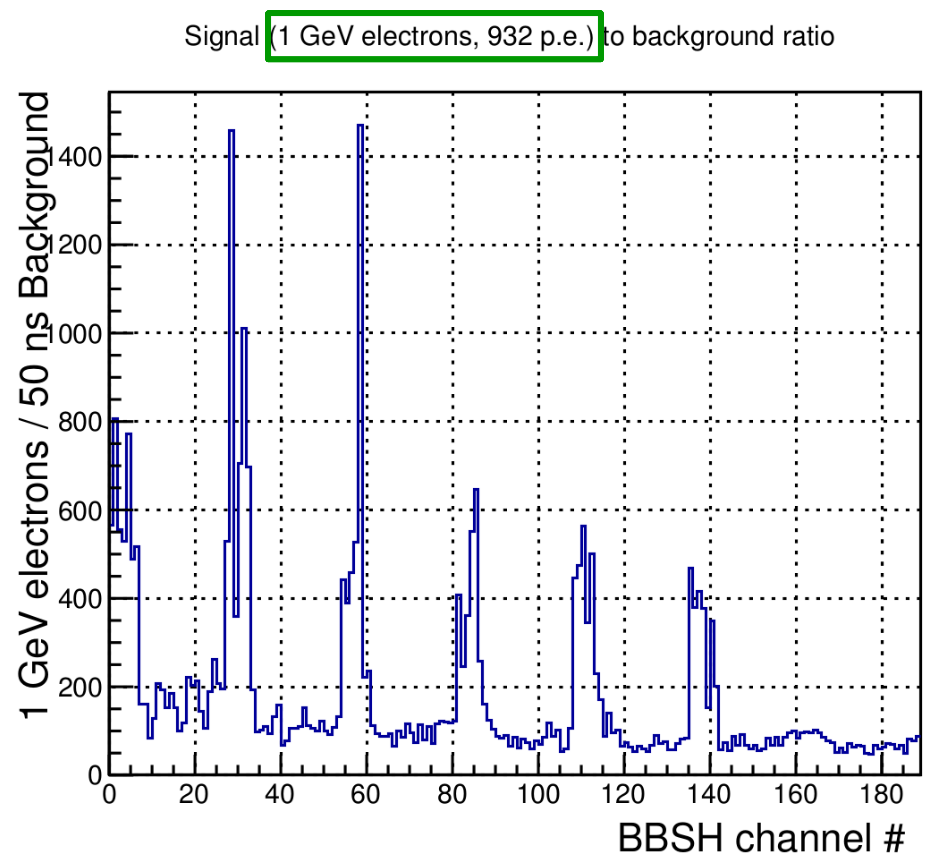
S/B ratio ≥ 20

BB SH Anode current + Signal over background ratio

(Channel per channel)

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map





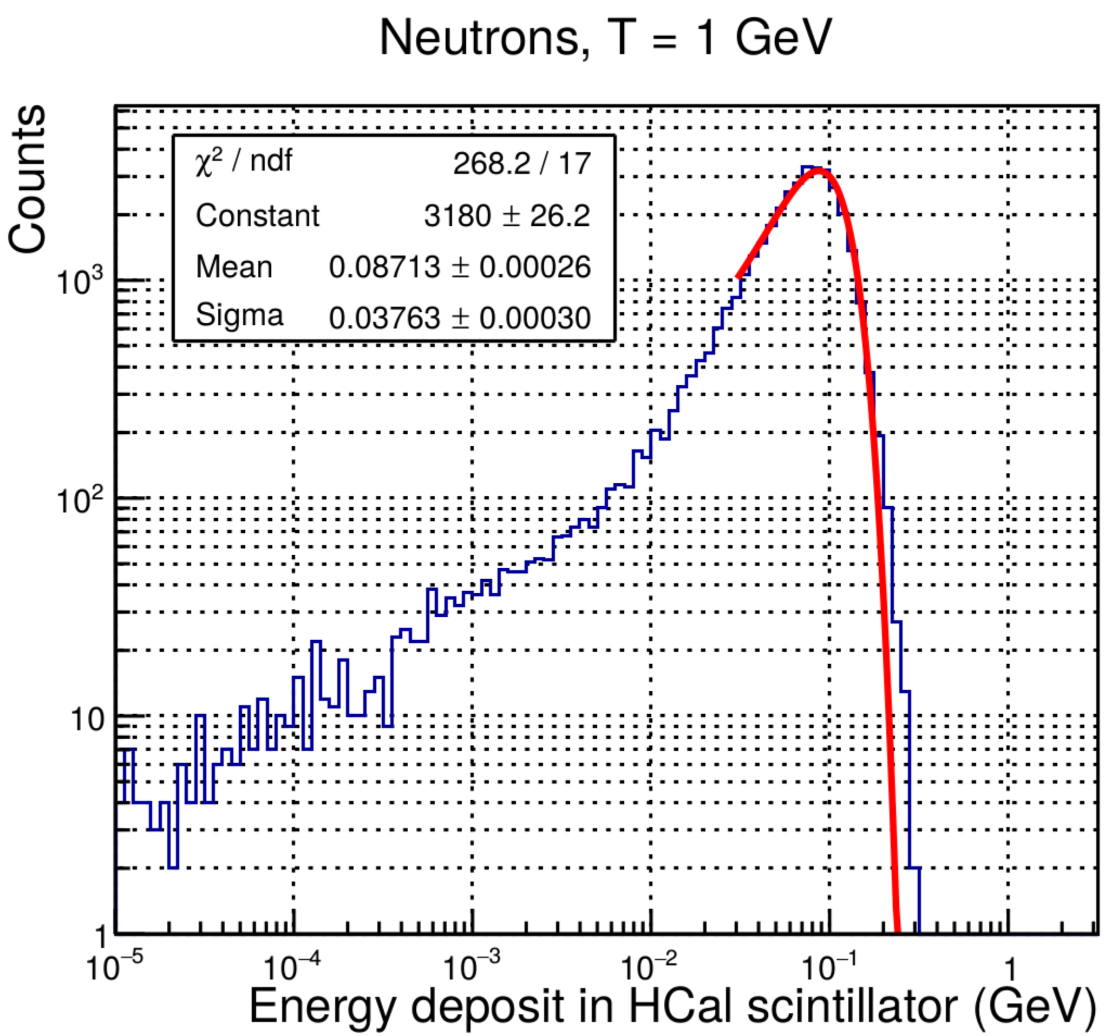
PMT anode current (reliable ?)

Δt(background): 50 ns

S/B ratio ≥ 100

HCal response to 1 GeV neutrons

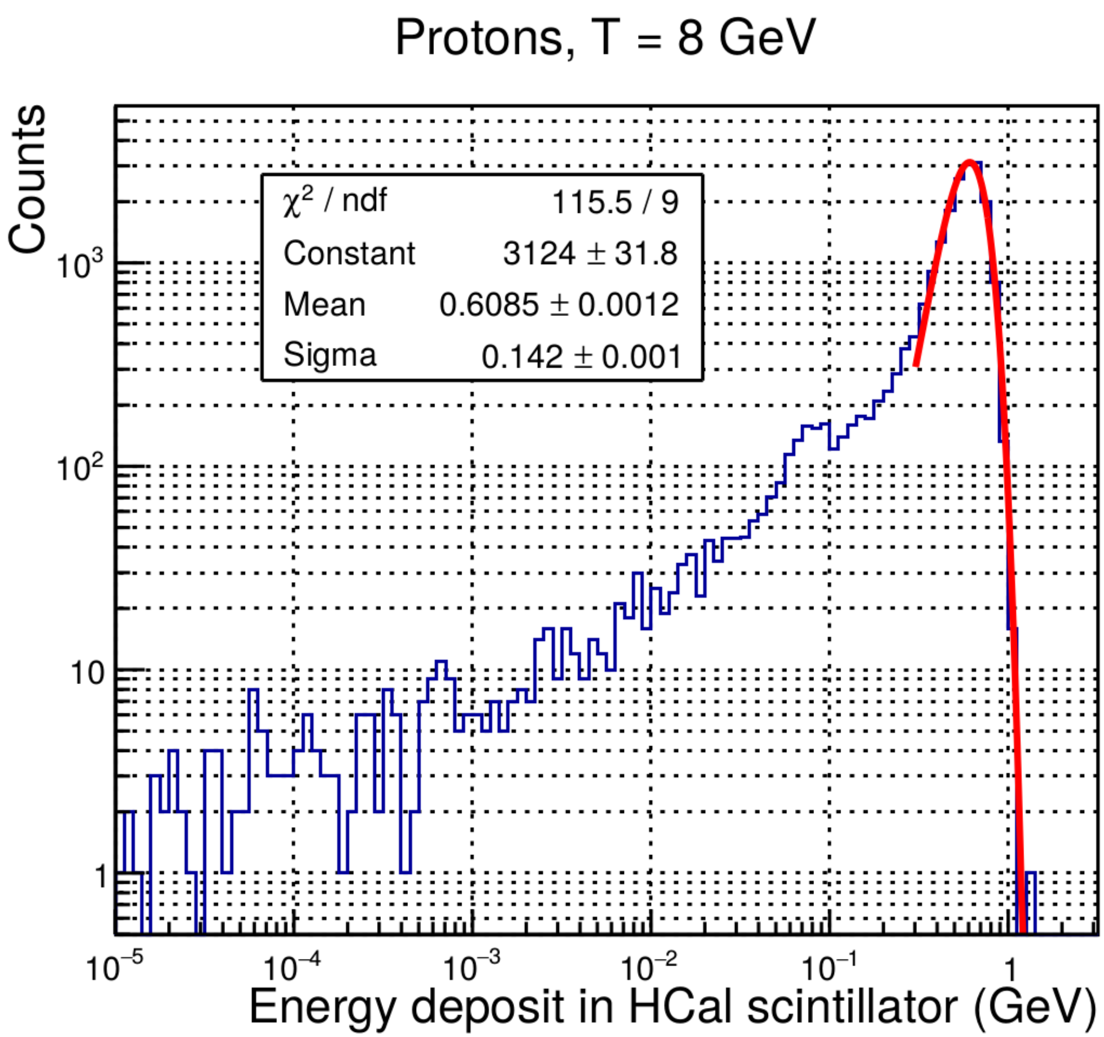
Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map



Energy MPV: **87 MeV**
σ: **38 MeV**
(sampling fraction ~1/11: similar to 8 GeV protons)

HCal response to 8 GeV protons

Q^2 = 13.5 GeV^2, I_{beam} = 30 μA, 15 cm LD_2, new setup, Tosca field map

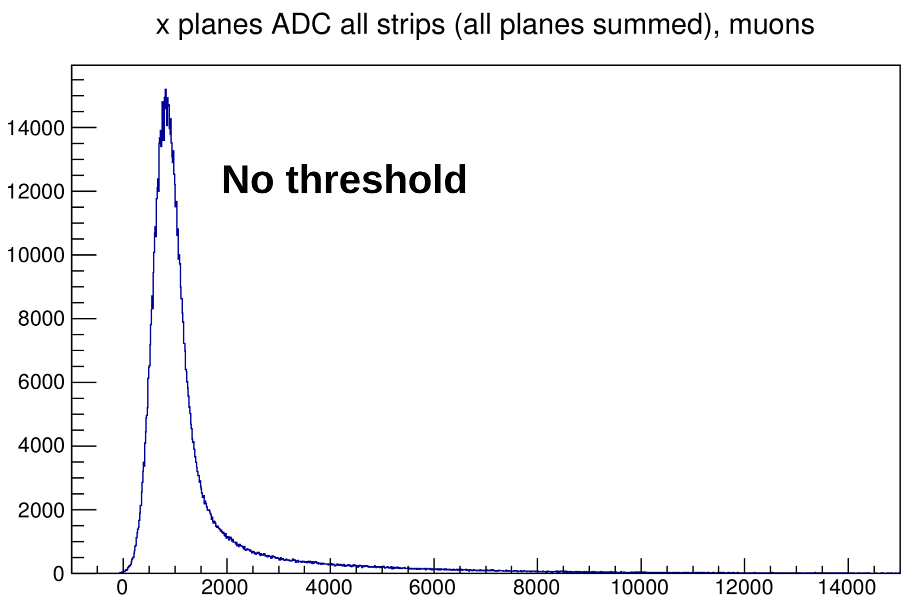


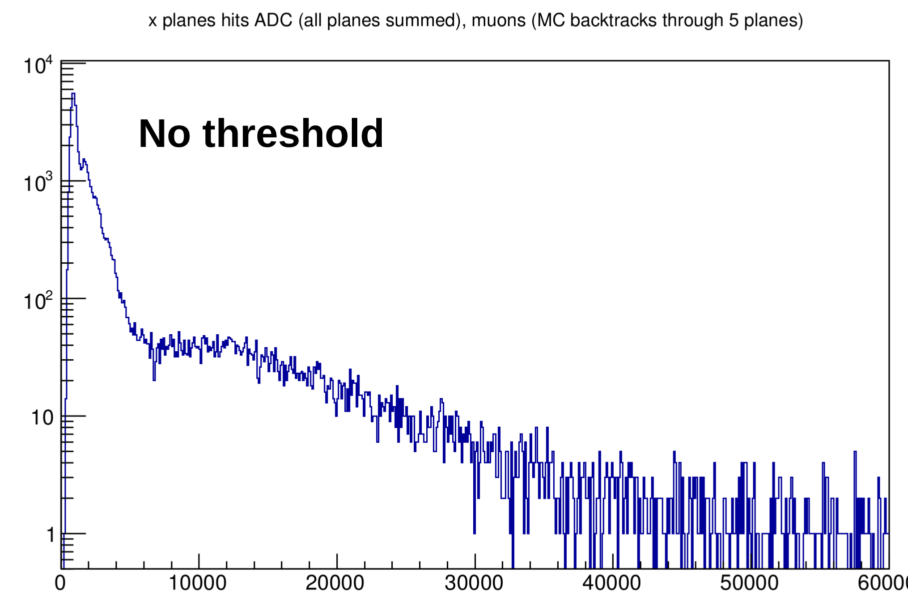
Energy MPV: **609 MeV**

σ: **142 MeV**

(sampling fraction ~1/13: similar to 1 GeV neutrons)

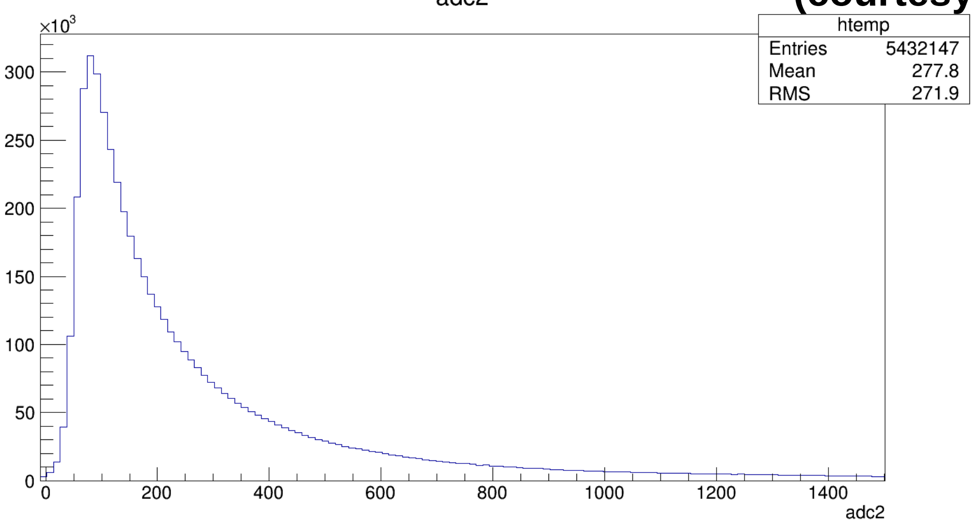
Tracking: ADC spectra
Simulation vs cosmics data

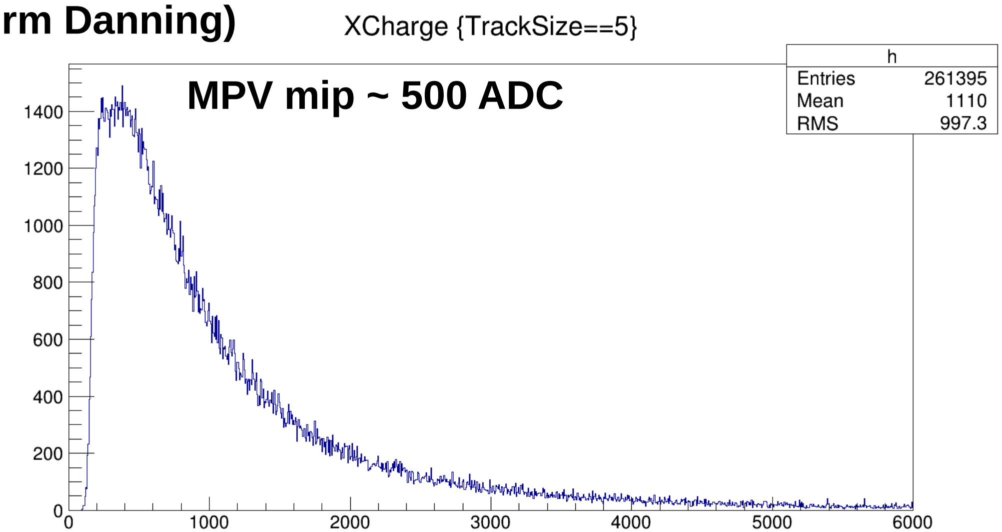




Cosmics data
(courtesy form Danning)

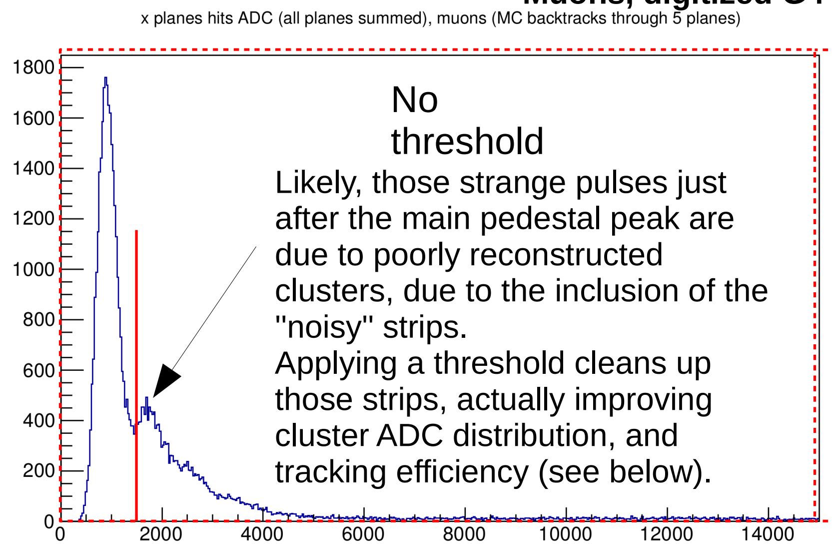
adc2

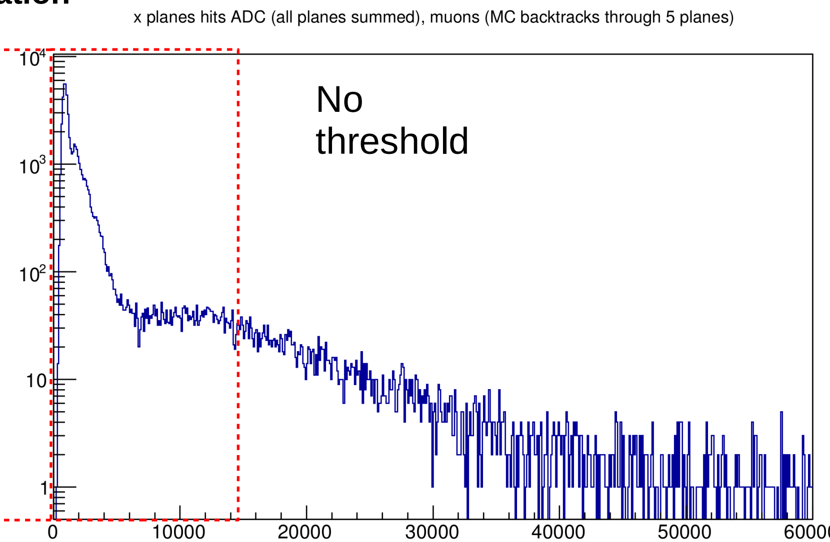


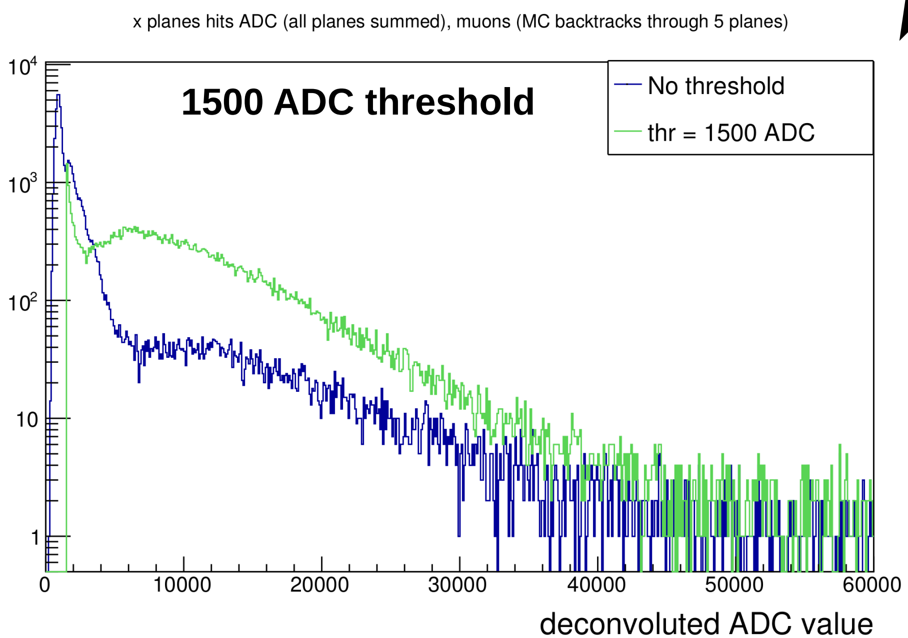


Tracking: Threshold study

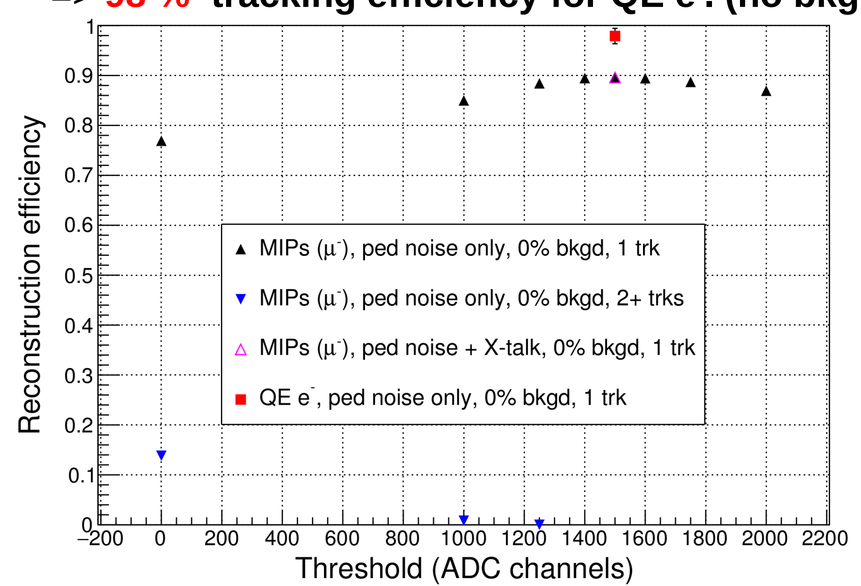
Muons, digitized G4 simulation



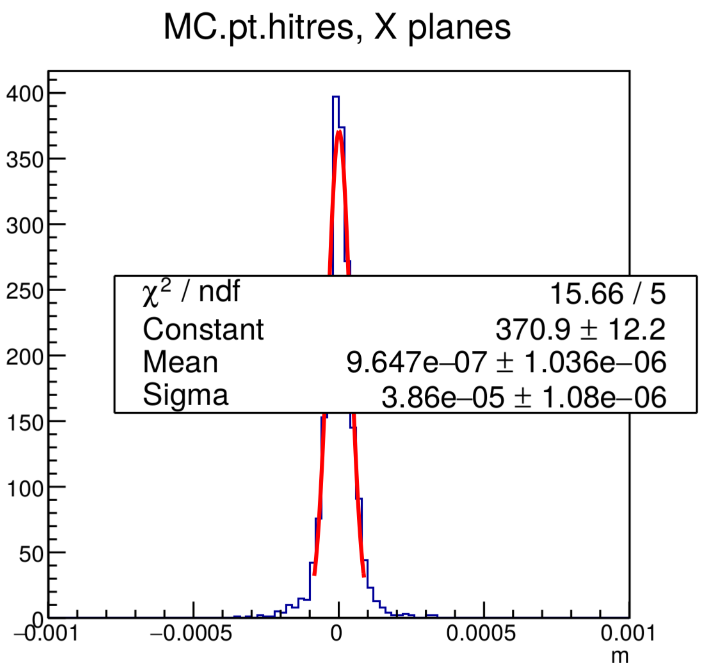


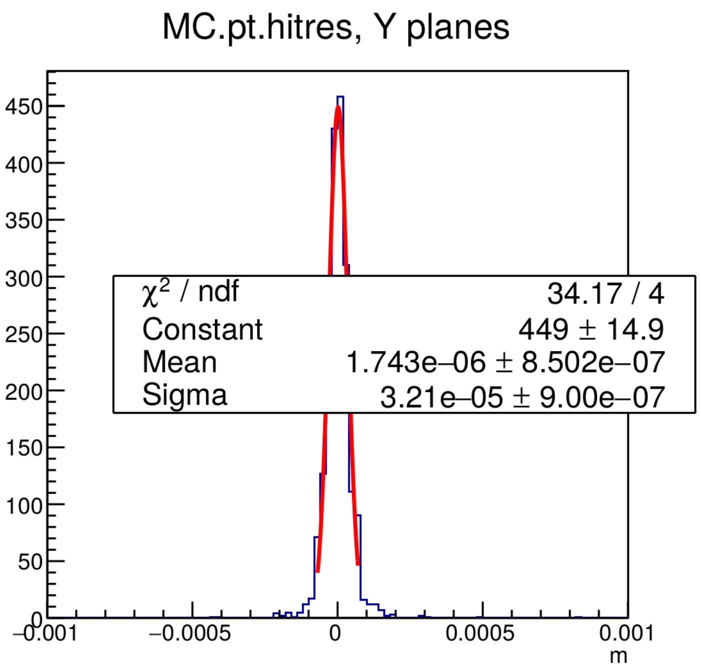


90 % MIP tracking efficiency
(including pedestal noise and cross talk)
=> 98 % tracking efficiency for QE e-. (no bkgd)



Tracking: hit resolution





0 % background