Simulations and software development

Ho San KO

Laboratoire de Physique des 2 Infinis Irène Joliot-Curie d'Orsay (IJCLab)

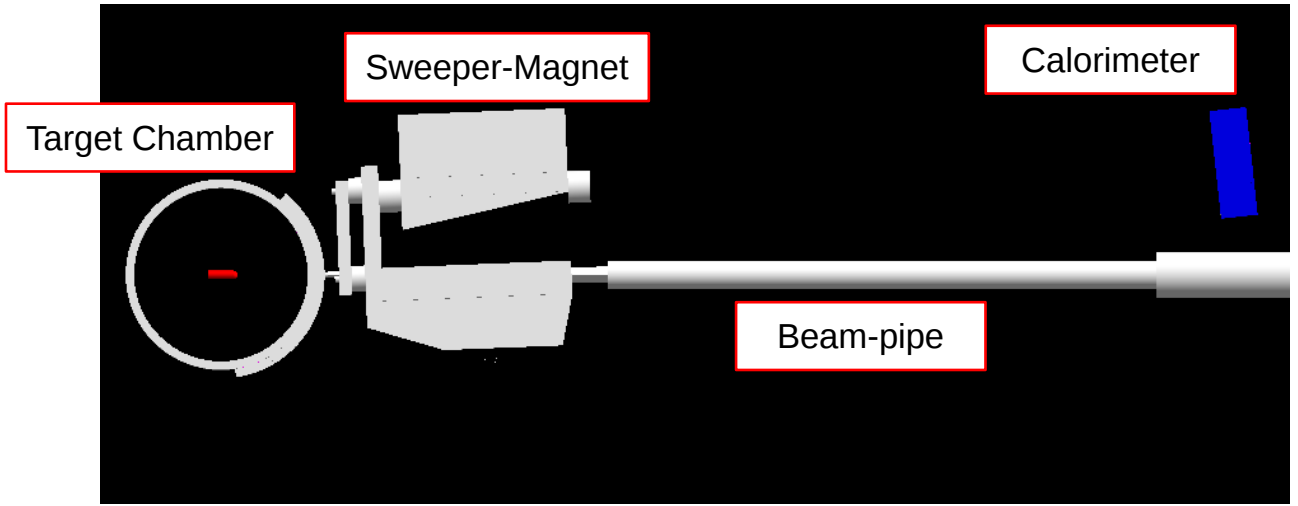
NPS Collaboration Meeting 2020

Outline

- Calorimeter simulations
  - Background source by particle ID
  - Beam-pipe and calorimeter magnetic field shieldings
  - Requirements on the magnetic field strength

- Calorimeter software
  - Photon reconstruction
  - Position and angular resolution

Background simulation geometry

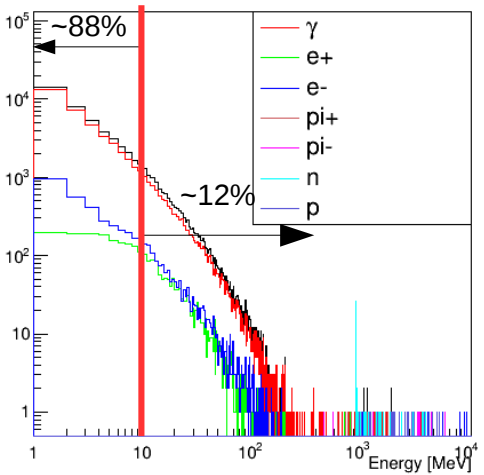


Low-xB setting : xB = 0.2, Q^2 = 3.0 GeV^2. Beam-time : 1 day with 11uA
Calorimeter : 6 m from the target, 6.3 deg from the beam-line axis
Sweeper-Magnet Center : 1.6 m (SHMS-right), 2.3 deg from the beam-line

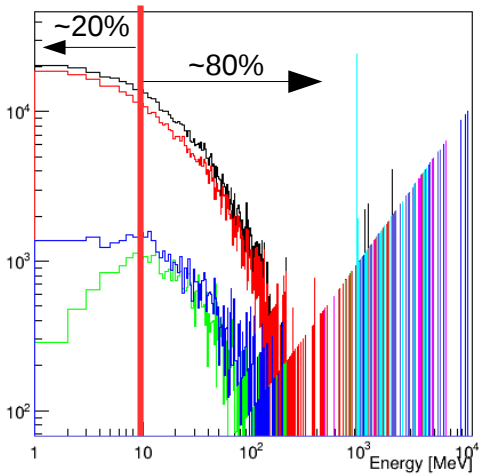
Background energy and dose distribution

Magnetic field ON

Energy distribution of background in NPS.



Dose distribution



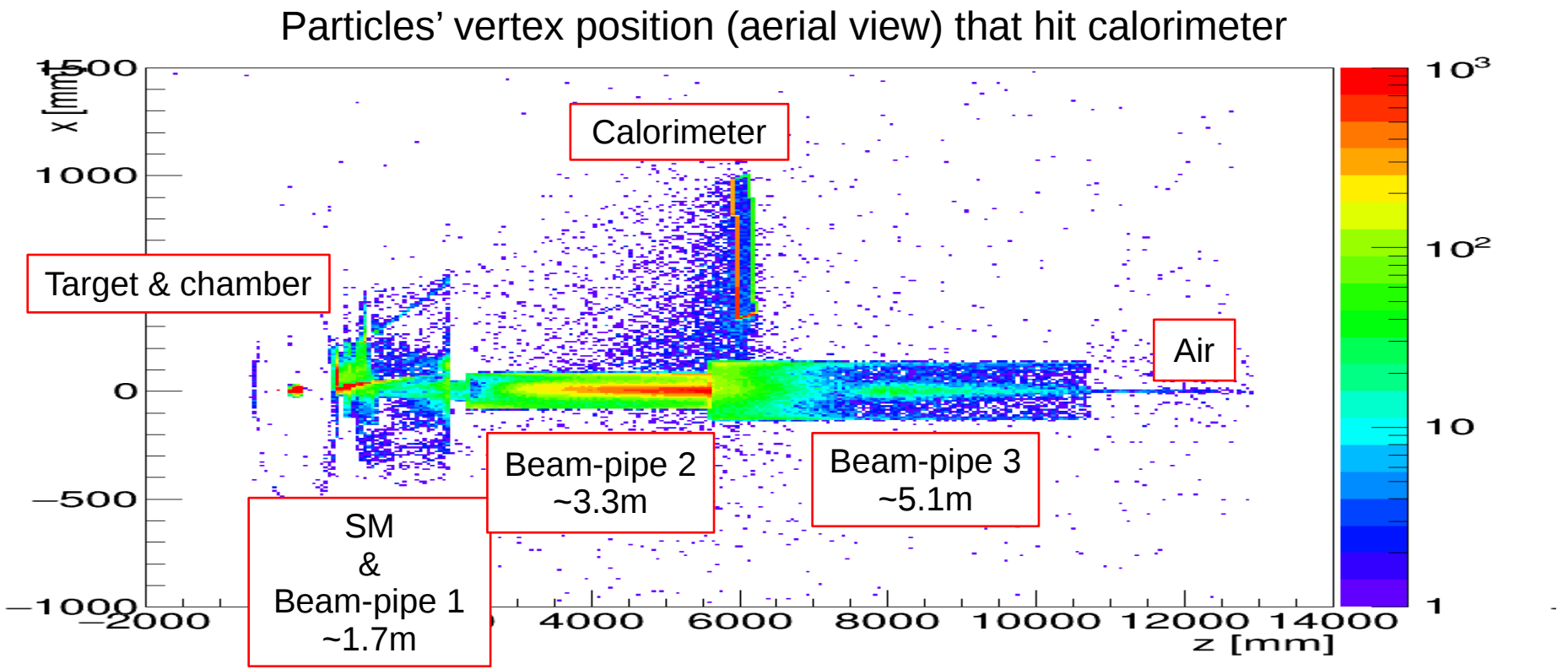
Right plot was obtained by weighting each particle by its energy.

The numbers (~88%, ~20%, etc.) were calculated by integrating the ranges of interests ([0 MeV, 10 MeV] or [10 MeV, 11 GeV]) of the plots above.

~88% of background is from particles with E < 10 MeV.
However, the total energy from particles with E < 10 MeV is ~20% of the total energy deposited in the detector

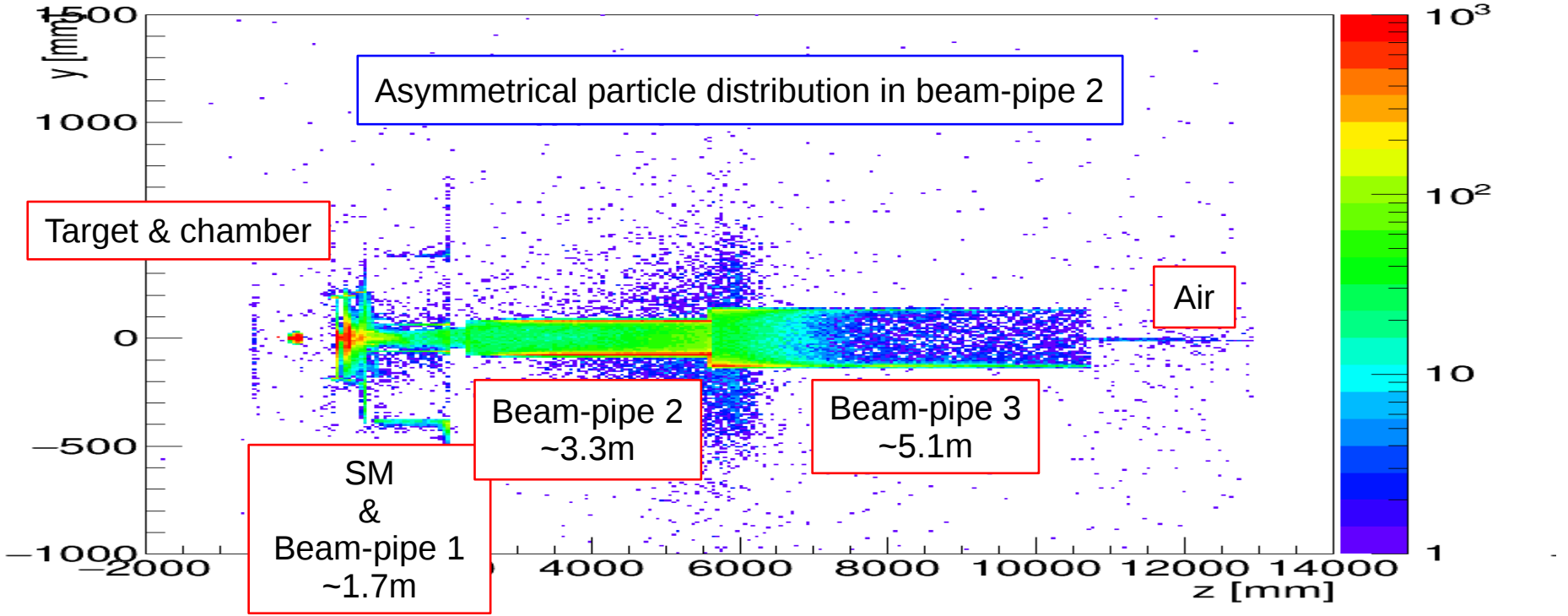
- Dose is mostly coming from E > 10 MeV particles.
- Dose is dominated by gamma and e-/e+

Background source tracking



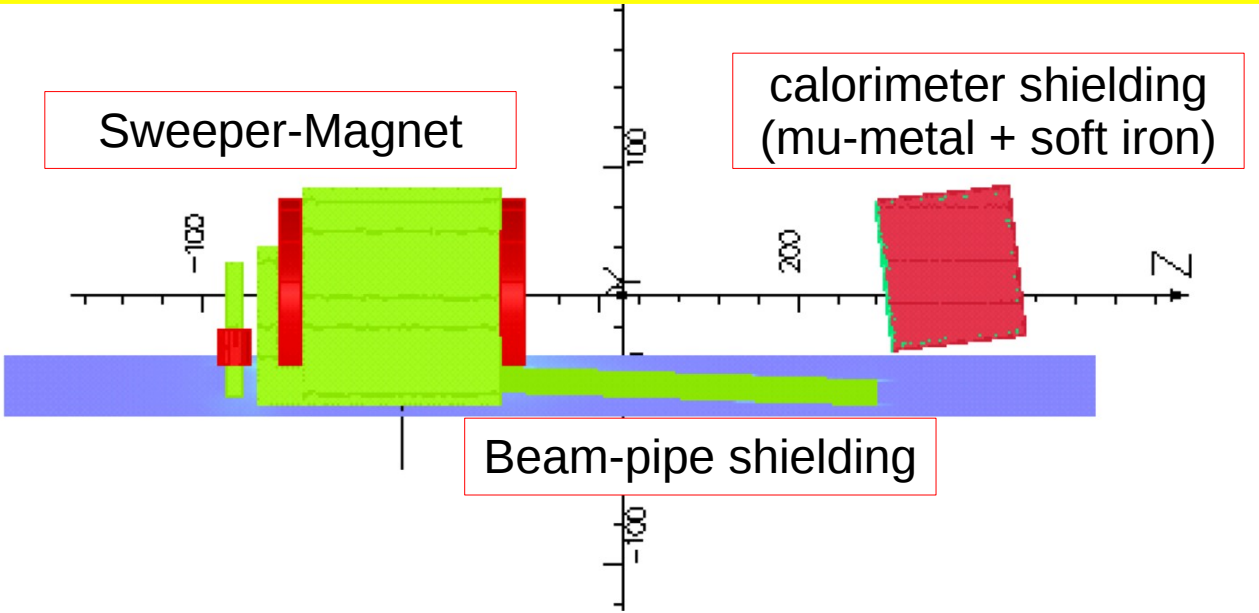
Background source tracking

Particles' vertex position (side view) that hit calorimeter



Magnetic field shielding should be considered

Beam-pipe magnetic field shieldings

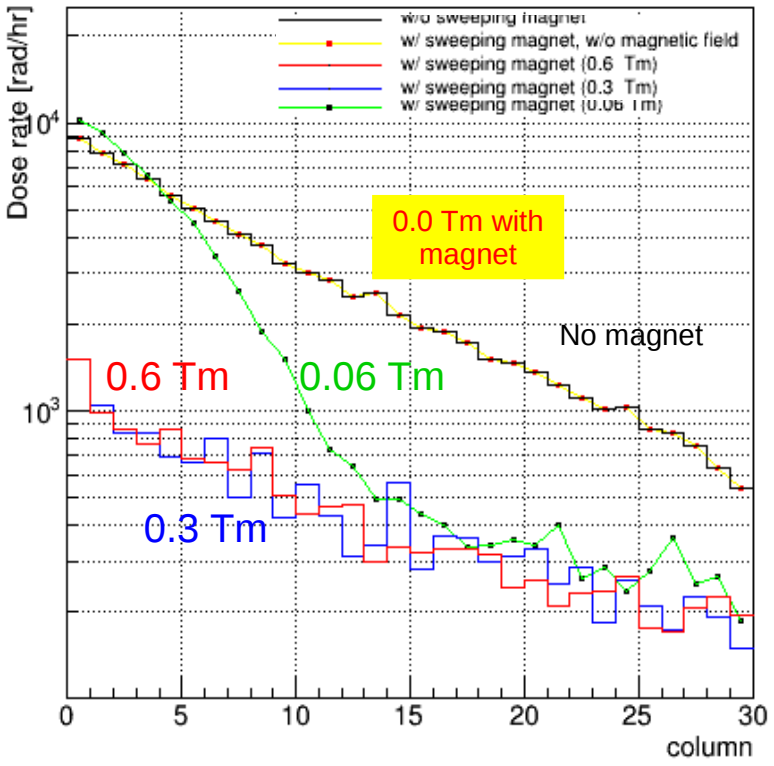


Calorimeter : 4 m from the target, 8.5 deg from the beam-line axis
Sweeper-Magnet Center : 1.6 m (SHMS-right), 2.3 deg from the beam-line

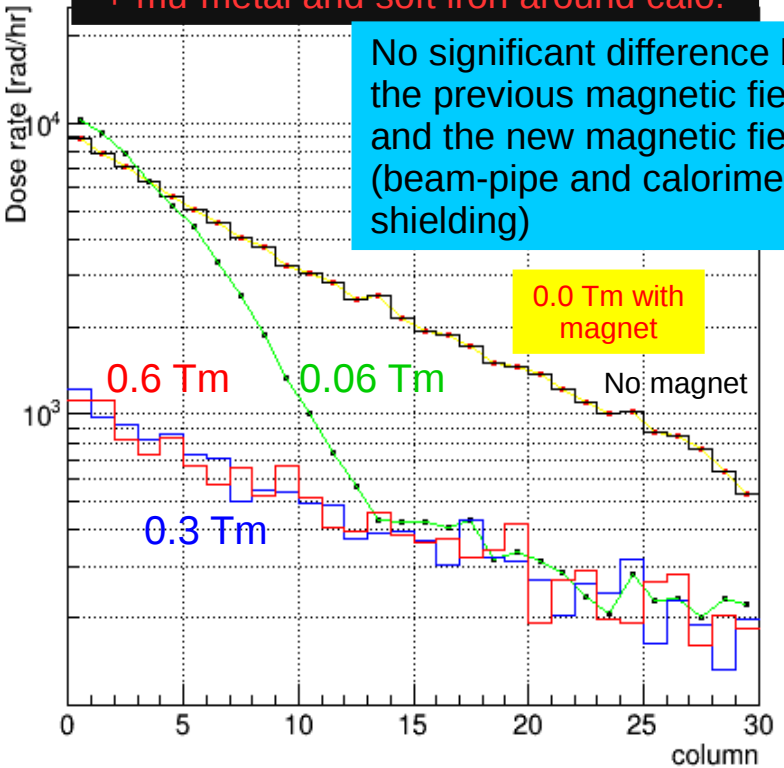
- Results may differ in other settings (eg. calorimeter 3 m @ 8.5 deg or 4 m @ 6 deg)

Background dose with magnetic field shieldings

No beam-pipe magnetic field shielding



Beam-pipe magnetic field shielding
+ mu-metal and soft iron around calo.

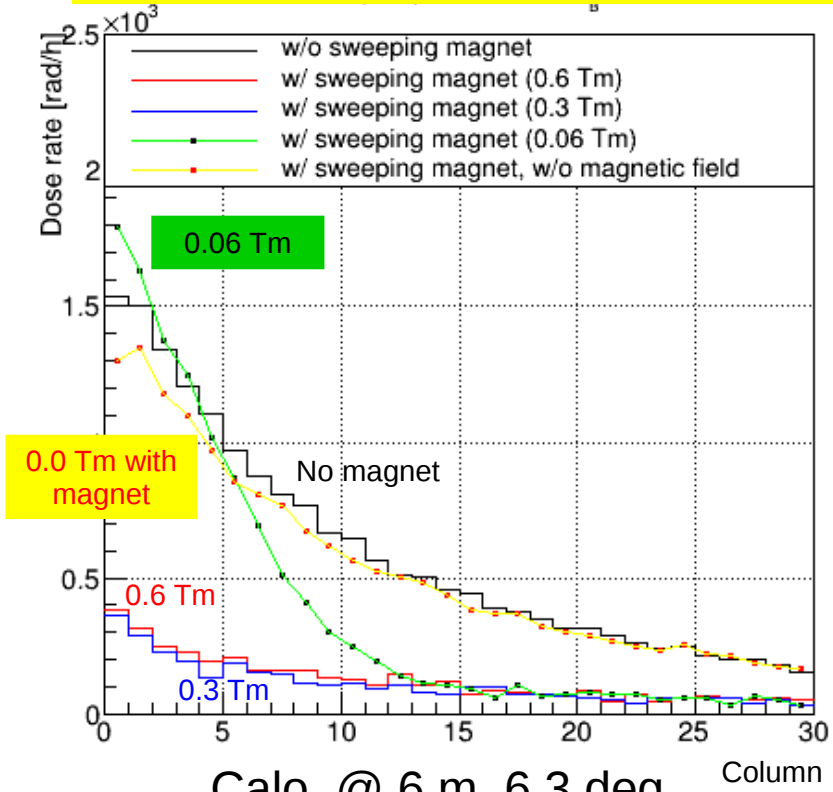


No significant difference between
the previous magnetic field map (no shieldings)
and the new magnetic field map
(beam-pipe and calorimeter magnetic field shielding)

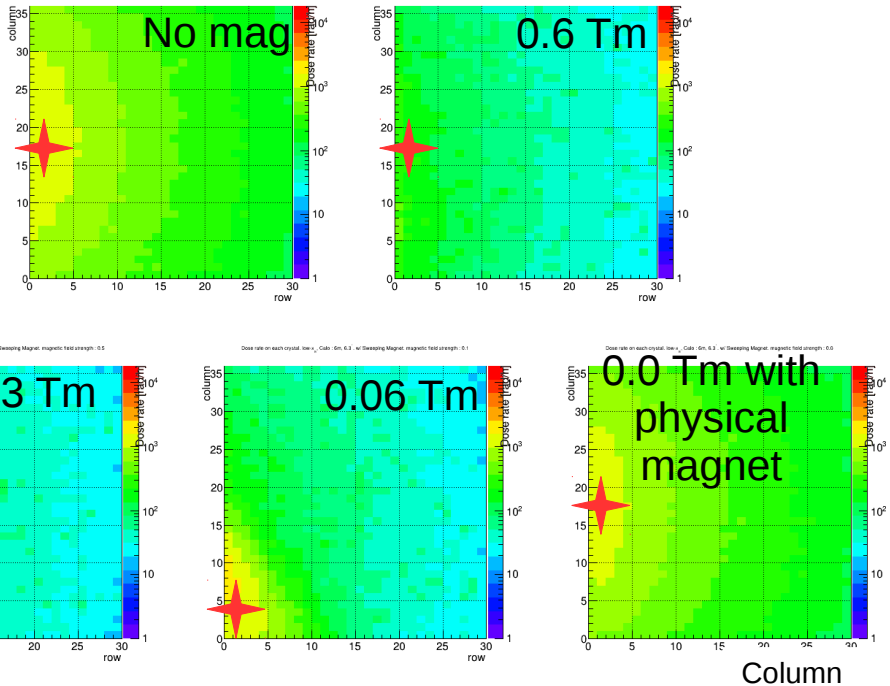
Results may differ
in other settings

Magnetic field strength required

w/o magnetic field shielding



Calo. @ 6 m, 6.3 deg
(low-xB 11uA)



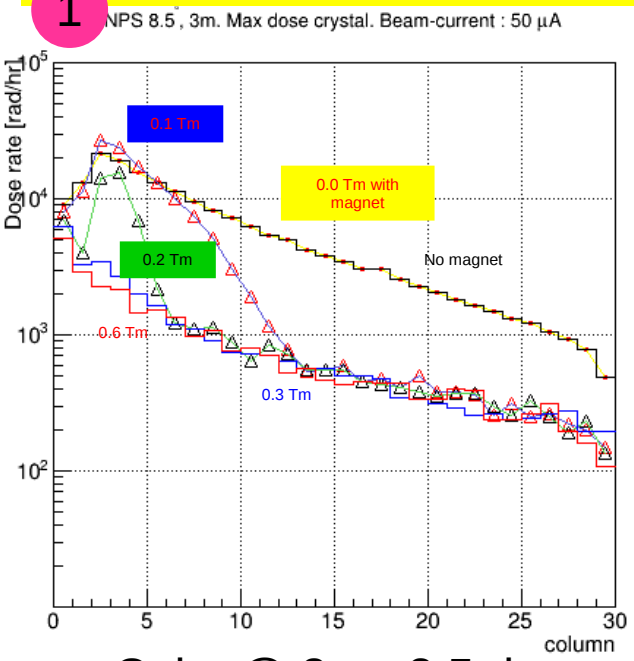
Maximum dose in each column of crystals.
Not necessarily comparing the same crystals.(stars)

Sweeping magnet's magnetic field ~ 0.3 Tm is sufficient to reduce background

Magnetic field strength required

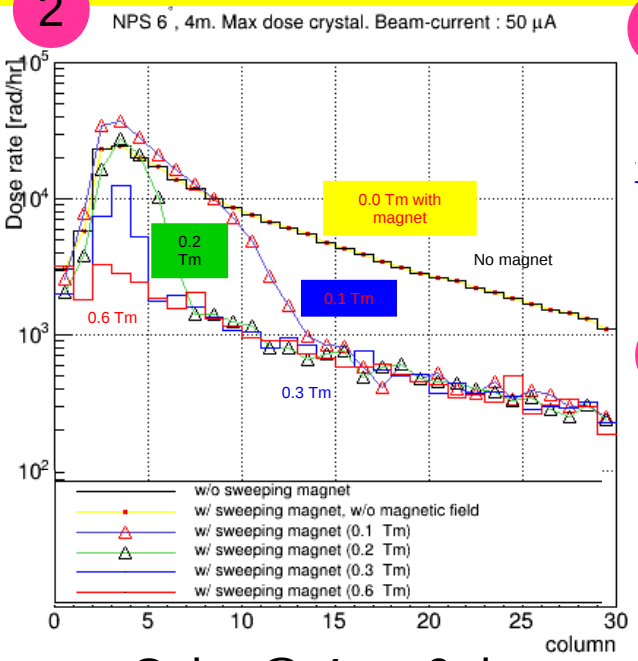
w/o magnetic field shielding

1



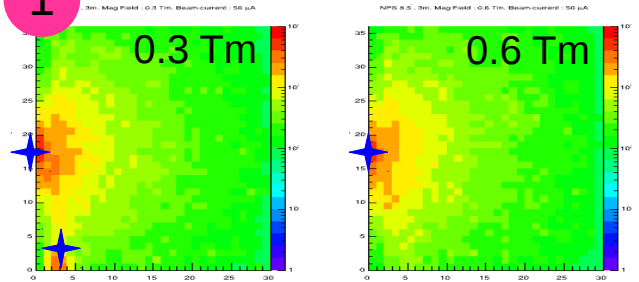
Calo. @ 3 m, 8.5 deg
(50 uA)

2

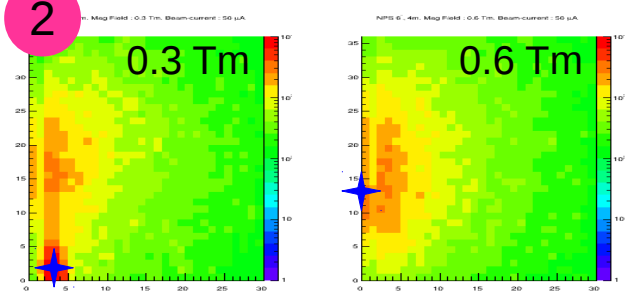


Calo. @ 4 m, 6 deg
(50 uA)

1



2



Sweeping magnet's magnetic field ~ 0.3 Tm is insufficient to reduce background

Calorimeter simulations summary

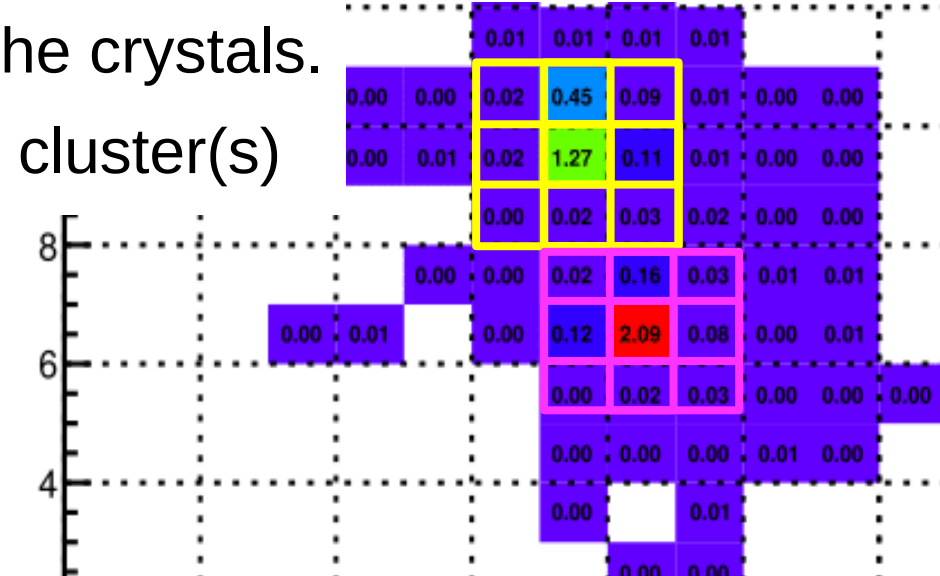
- The total energy from particles with E < 10 MeV is ~20% of the total energy deposited in the detector.
  - Most of the background is gamma.
- Magnetic field shieldings on beam-pipe and calorimeter does not decrease the background dose on the calorimeter significantly.
- Magnetic field strength of 0.3 Tm is probably enough for the “approved” kinematic settings.

Photon reconstruction software

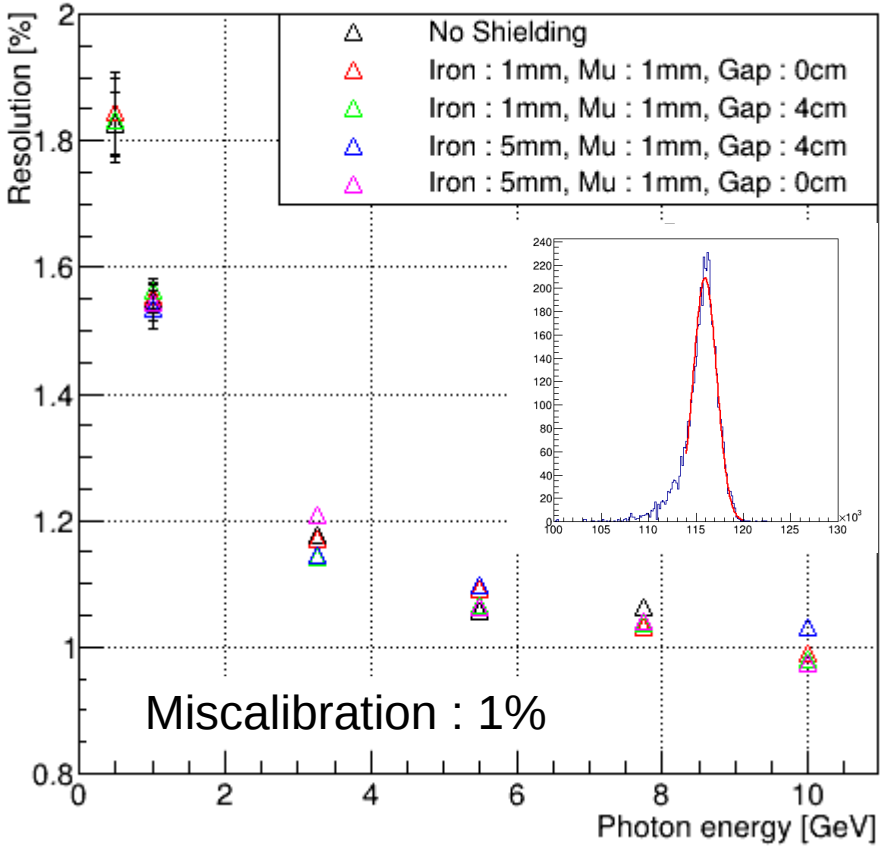
- Adapted Hall A DVCS software to NPS geometry

1. Check if the energy deposited to the crystals (2X2) is above a given threshold. (clustering threshold)
    1. If above, keep those 2X2 crystals. If below, discard them for the next step.
2. Make clusters(i.e. photons) out of the crystals.
3. Get position and momentum of the cluster(s)

Clustering threshold : 1.10 GeV

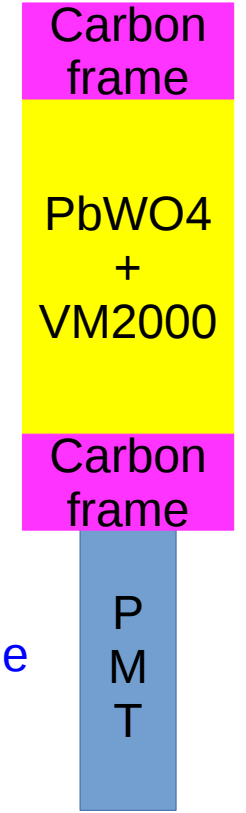


Energy resolution of the calorimeter



0.5 mm thick, 2cm long

Updated calorimeter's design

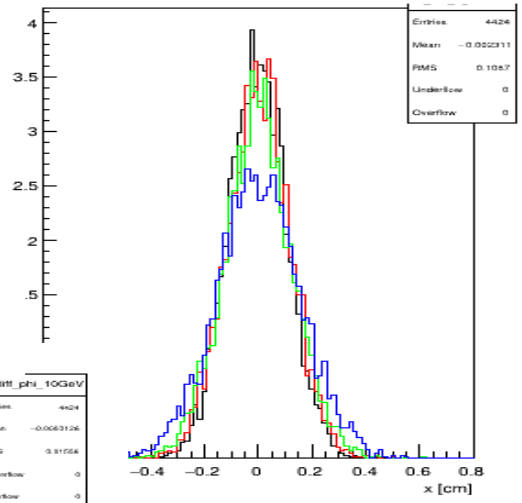


➔ Iron and mu-metal shielding have little effect on energy resolution

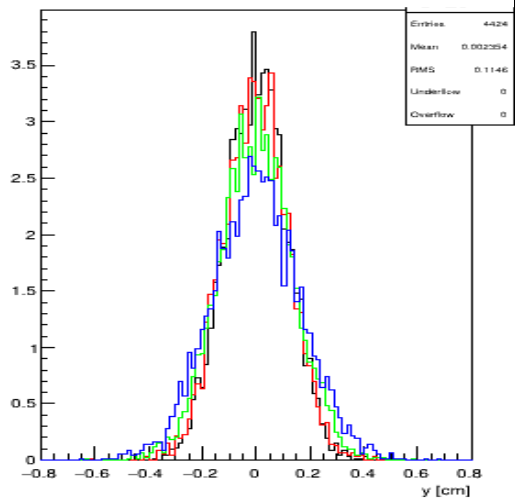
Position and angular resolution

Clustering threshold : 1.10 GeV

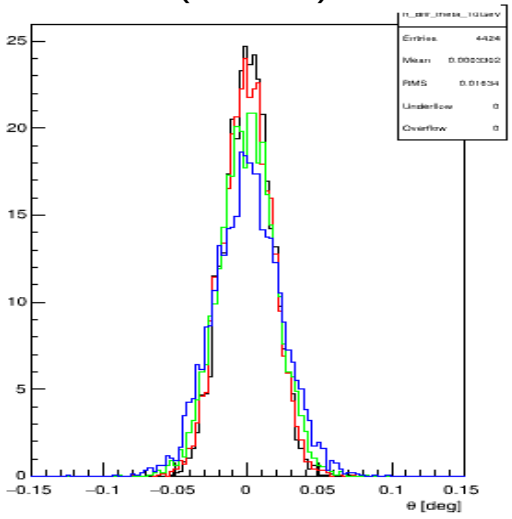
Reconstructed x – generated x



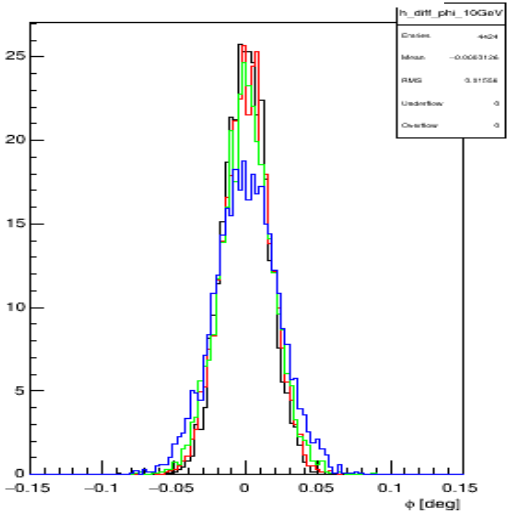
Reconstructed y – generated y



Reconstructed angle – generated angle (vertical)



Reconstructed angle – generated angle (horizontal)



Photon beam energy

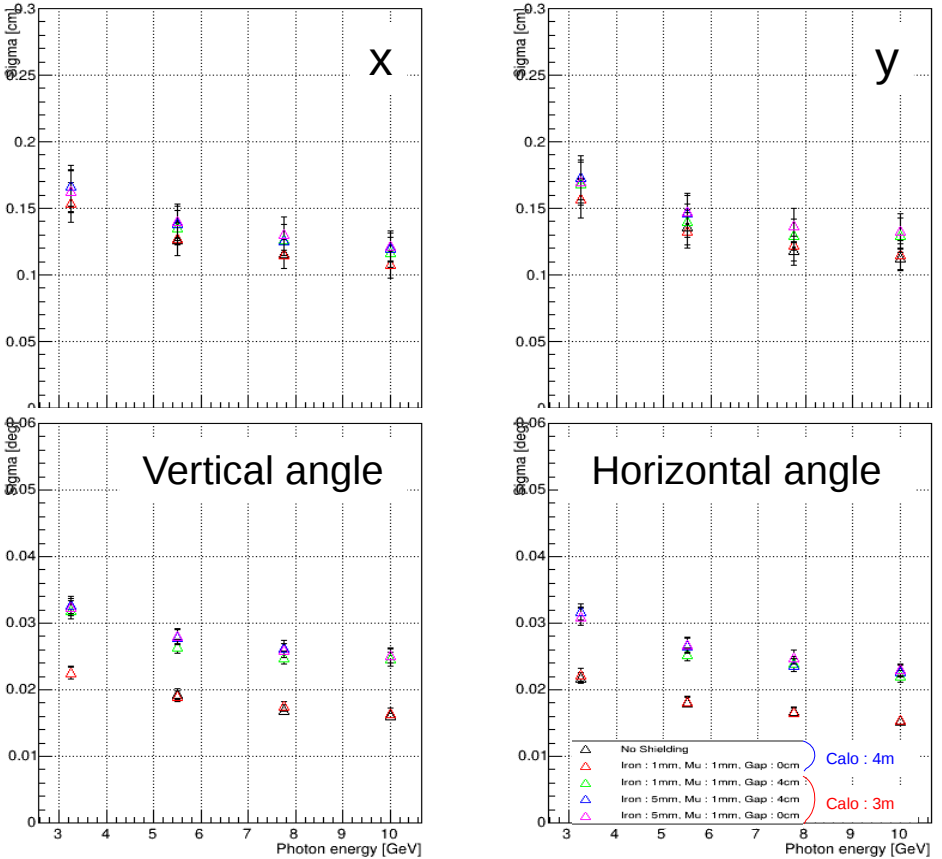
10 GeV

7.75 GeV

5.5 GeV

3.25 GeV

Position and angular resolution calculation results and summary



Clustering threshold : 1.10 GeV
Miscalibration : 1%

- Position resolution : ~ 1.5 mm
- Angular resolution : < 0.03 deg

➔ Iron and mu-metal shielding has also a small impact on position resolution

Photon reconstruction software is ready for off-line analysis.

Conclusion

- Most of the background on the calorimeter is gamma.
- Beam-pipe and calorimeter's magnetic field shielding have no significant effect on the background dose.
- For "approved" kinematic settings, magnetic field strength can probably be reduced to 0.3 Tm.
  - Some extreme configurations (calo. 3 m @ 8.5 deg & 4 m @ 6 deg) may need the full 0.6 Tm.

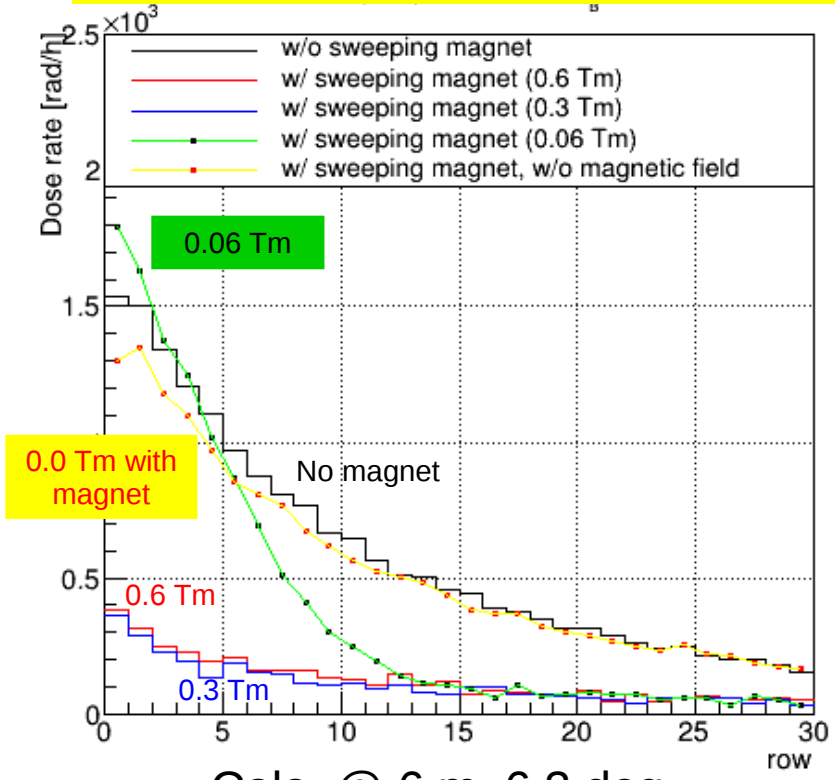
- Photon reconstruction software for off-line analysis is ready.
  - Energy resolution of the calorimeter is < 1.2 % at ~ 7 GeV.
  - Position resolution of the calorimeter is ~ 1.5 mm at ~ 7 GeV.

Backups

	Energy Dependence at fixed (Q^2, x_B)											Low-x_B				High-Q^2		
x_B	0.36					0.50		0.60				0.2				0.36	0.50	0.60
Q^2 (GeV)^2	3.0			4.0		3.4	4.8	5.1			6.0	2.0			3.0	5.5	8.1	10
k (GeV)	6.6*	8.8	11	8.8*	11	8.8	11	11	6.6	8.8*	11	11	6.6	8.8	11	11	11	11
k' (GeV)	2.2	4.4	6.6	2.9	5.1	5.2	7.4	5.9	2.1	4.3	6.5	5.7	1.3	3.5	5.7	3.0	2.9	2.4	2.1
θ_{Calo} (deg)	11.7	14.7	16.2	10.3	12.4	20.2	21.7	16.6	13.8	17.8	19.8	17.2	6.3	9.2	10.6	6.3	7.9	8.0	8.0
D_{Calo} (m)	3	3	3	4	3	3	3	3	3	3	3	3	6	4	4	6	4	4	4
I_{beam} (μA)	28	28	28	50	28	28	28	28	28	28	28	28	11	5	50	11	50	50	50
N_{evt} (10^5)	1.5	8.8	8.2	2.1	7.9	7.3	11	5.1	0.2	0.2	2.7	2.6	3.5	3.6	64	3.4	6.1	0.8	0.4
$\sigma_{M_X^2}$ (GeV^2)	0.13	0.13	0.12	0.15	0.15	0.09	0.09	0.11	0.09	0.09	0.09	0.09	0.17	0.17	0.17	0.22	0.19	0.15	0.13
Days	1	2	1	1	3	3	2	5	5	1	5	10	1	1	1	1	5	5	12

Magnetic field strength required

w/o magnetic field shielding



Calo. @ 6 m, 6.3 deg
(low-xB 11uA)

Max dose ~ 400 rad/hr → ~ 0.25 GeV/50ns
→ ~ 400 p.e./50ns (15p.e./MeV)

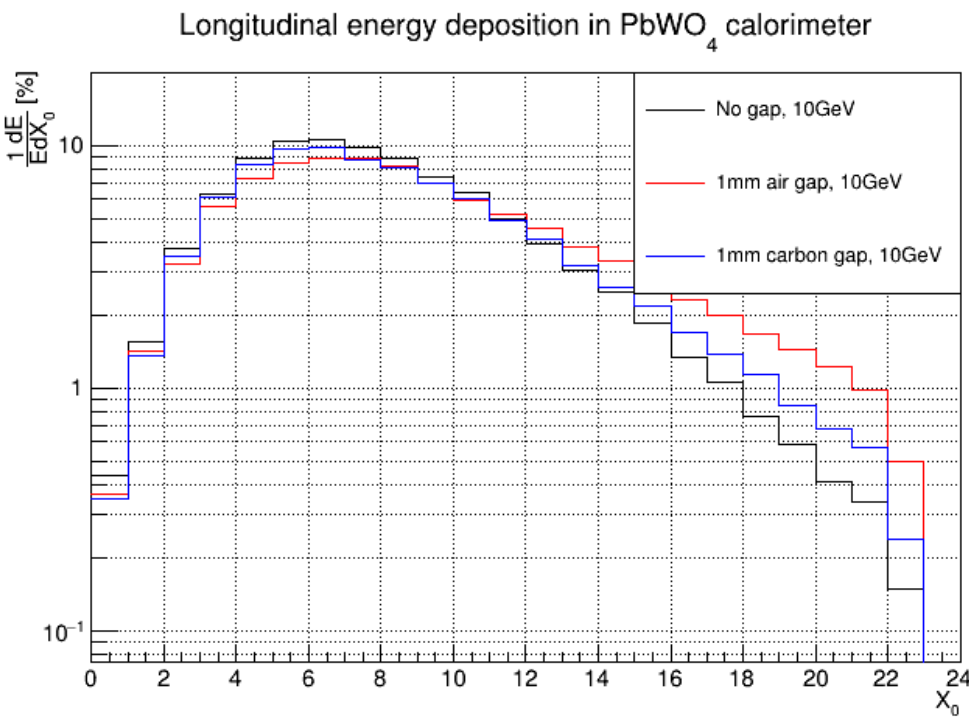
PMT gain : 10^6

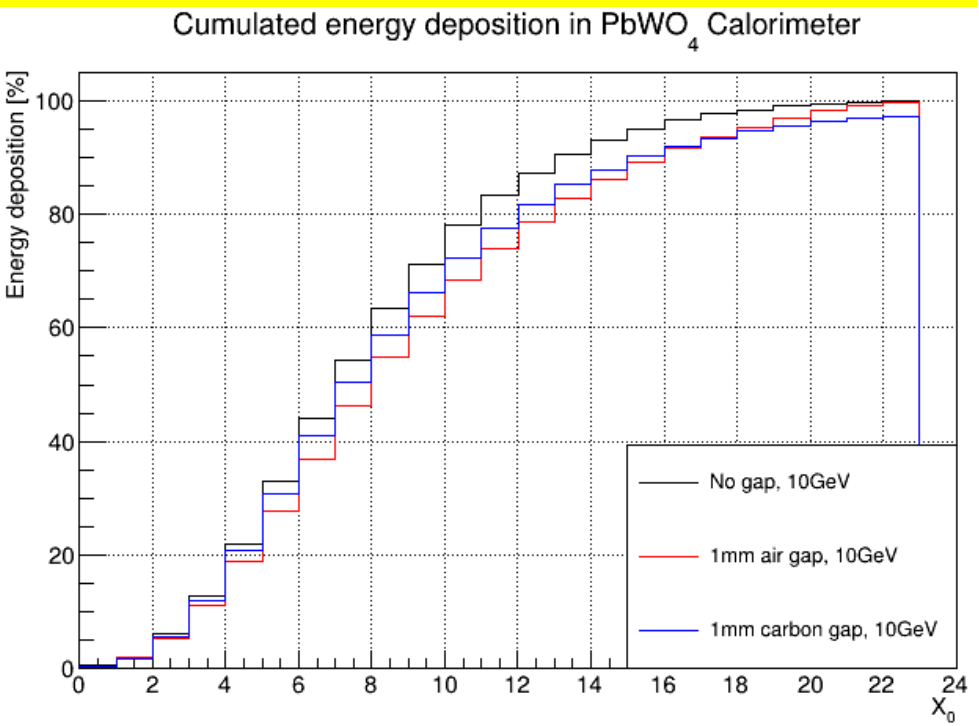
→ ~ 4X10^8 p.e./50ns → ~ 6.4X10^-11 C/50ns
→ ~ 1.3mA anode current.

High Q^2 setting's max dose : ~ 2500 rad/hr

Sweeping magnet's magnetic field ~ 0.3 Tm is sufficient to reduce background

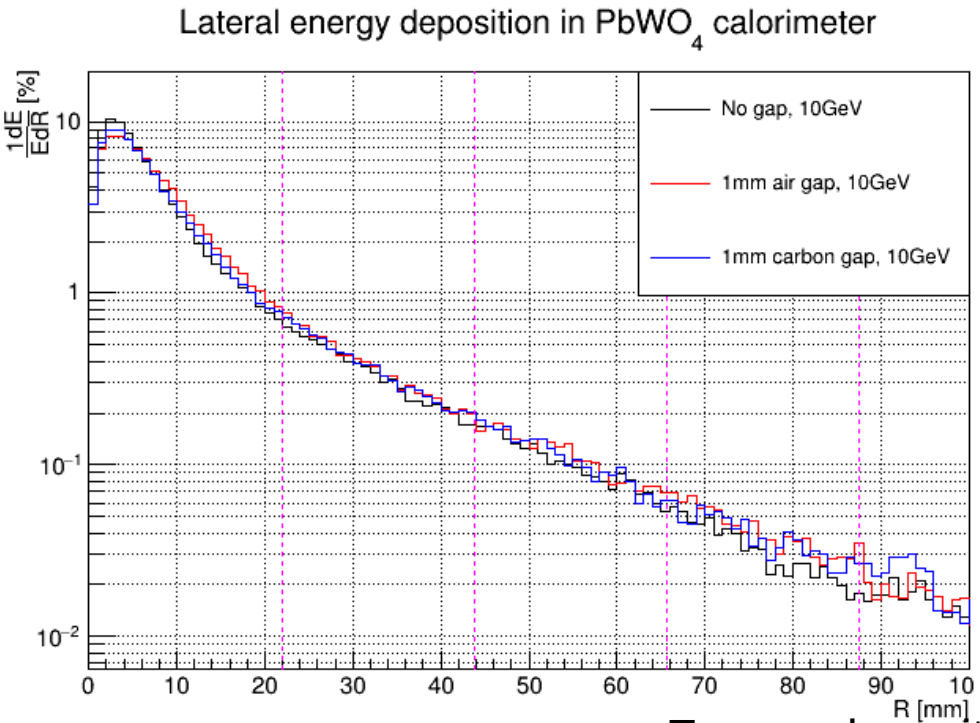
Longitudinal energy deposition on the calorimeter

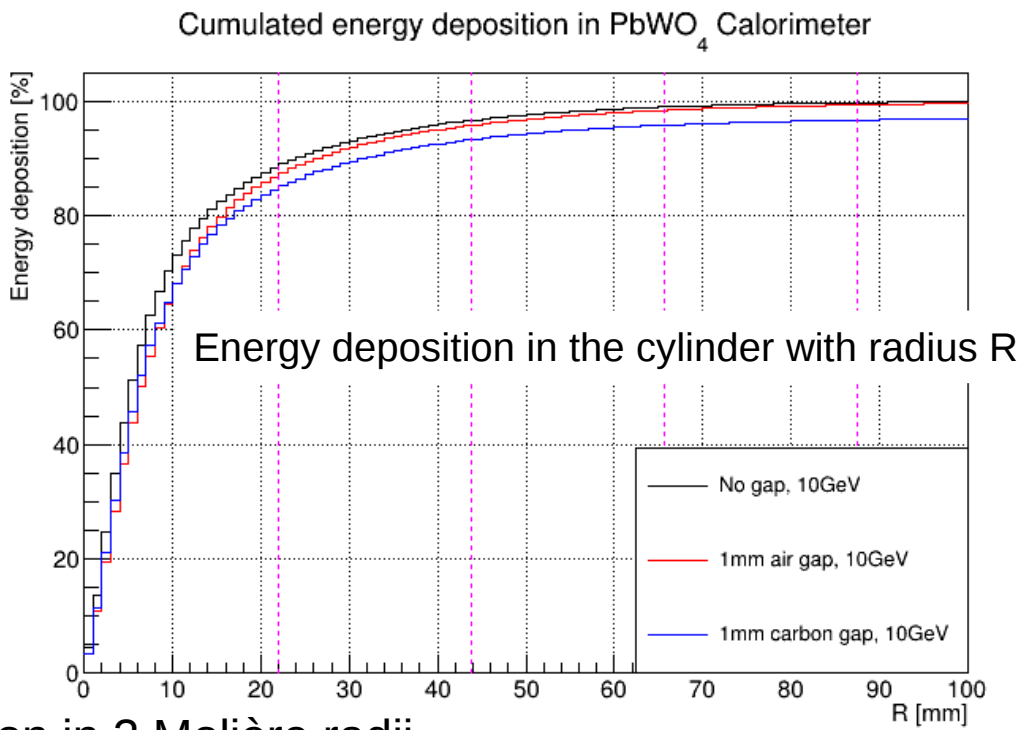




1mm air gap : ~100% energy deposition
1mm carbon gap : >95% energy deposition

Lateral energy deposition on the calorimeter





Energy deposition in the cylinder with radius R

Energy deposition in 2 Molière radii

1mm air gap : >95% energy deposition

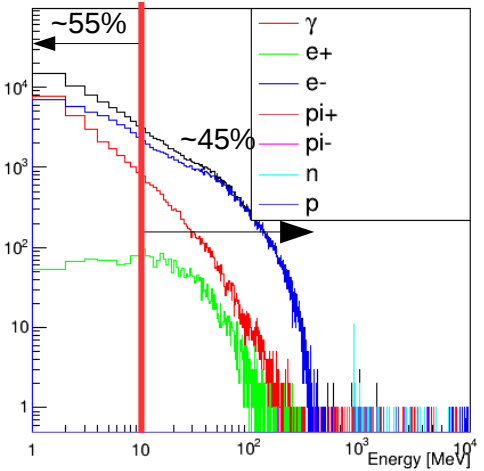
1mm carbon gap : ~93% energy deposition

Background energy and dose distribution

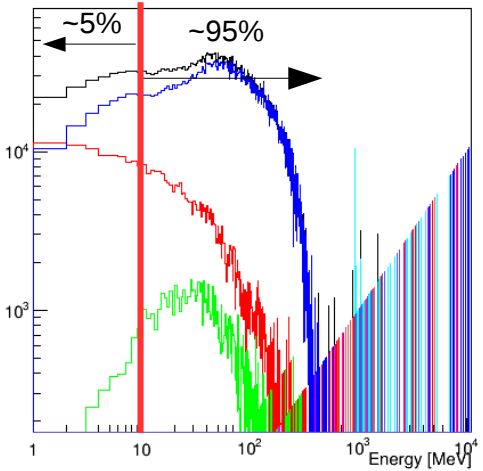
Low-xB setting : Calorimeter 6m from the target, 6.3 deg from the beam-line axis

Magnetic field OFF

Energy distribution of background in NPS.



Dose distribution



Right plot was obtained by weighting each particle by its energy.

The numbers (~55%, ~5%, etc.) were calculated by integrating the ranges of interests ([0 MeV, 10 MeV] or [10 MeV, 11 GeV]) of the plots above.

~55% of background is from particles with E < 10 MeV.

However, the total energy from particles with E < 10 MeV is ~5% of the total energy deposited in the detector