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Beta backscattering measurements

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Motivation

First results: error budget (November 2018)

	Source	Uncertainty	$\Delta\tilde{a}_{\beta\nu}(10^{-3})$
background	false coinc.	8%	< 1
proton	detector calibration	0.2%	2
	detector position	1 mm	< 1
	source position	3 mm	3
	source radius	3 mm	1
	B field homogeneity	1%	< 1
	silicon dead layer	0.3 μm	5
	mylar thickness	0.15 μm	3
positron	backscattering	10%	15
	threshold	12 keV	8
total			19

OBJECTIVE:

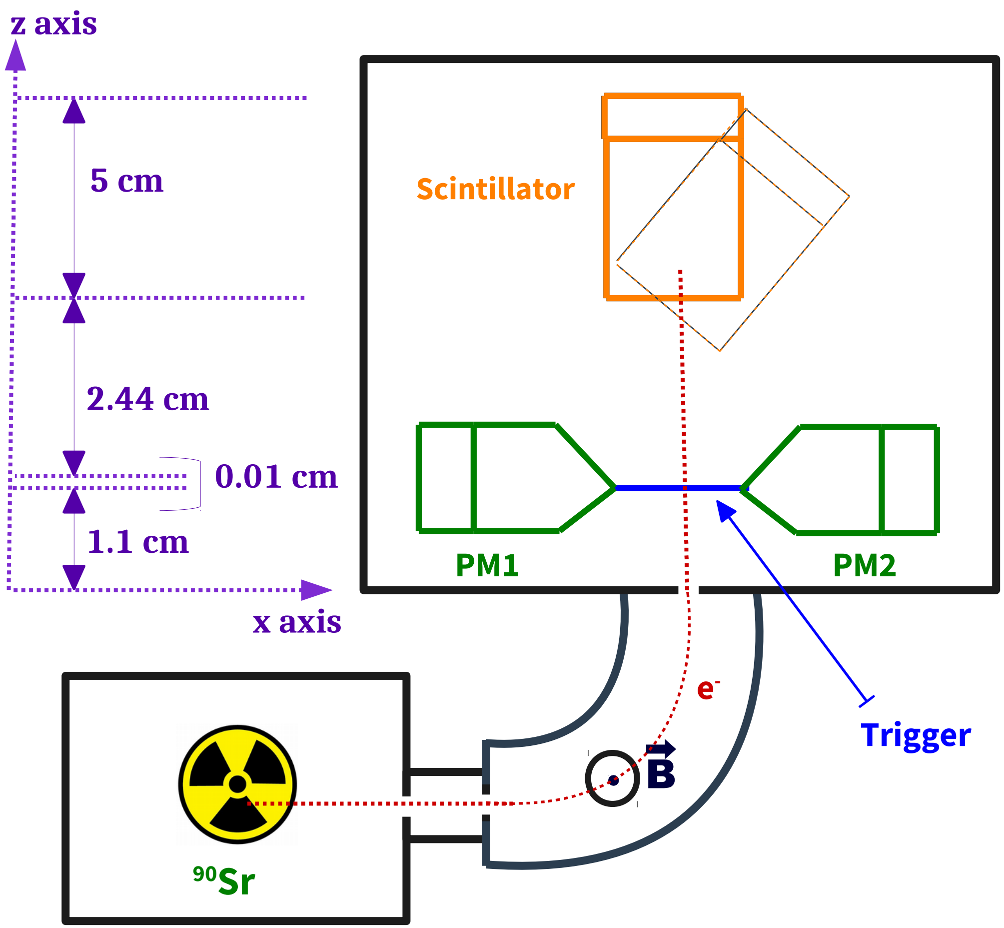
characterization of backscattering of β's

- Detection threshold as a function of E_e and θ_{inc}
- Validation and constraints for GEANT4 simulations

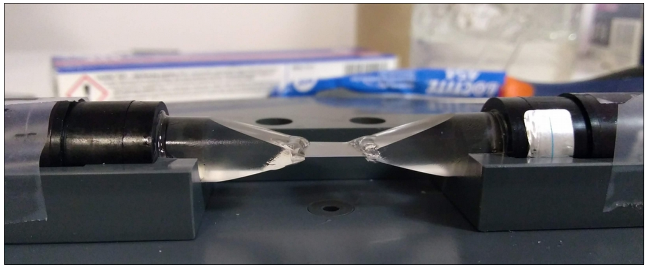
HOW TO ACHIEVE IT:

- Reproduction of the experimental set-up and measuring conditions with GEANT4
  - runs taken with different E_e and θ_{inc}
  - varying models for backscattering computation
- Convolution of simulations with the response function of the detector
- Comparison of the continuum of β spectrum

Experimental set-up – 2019

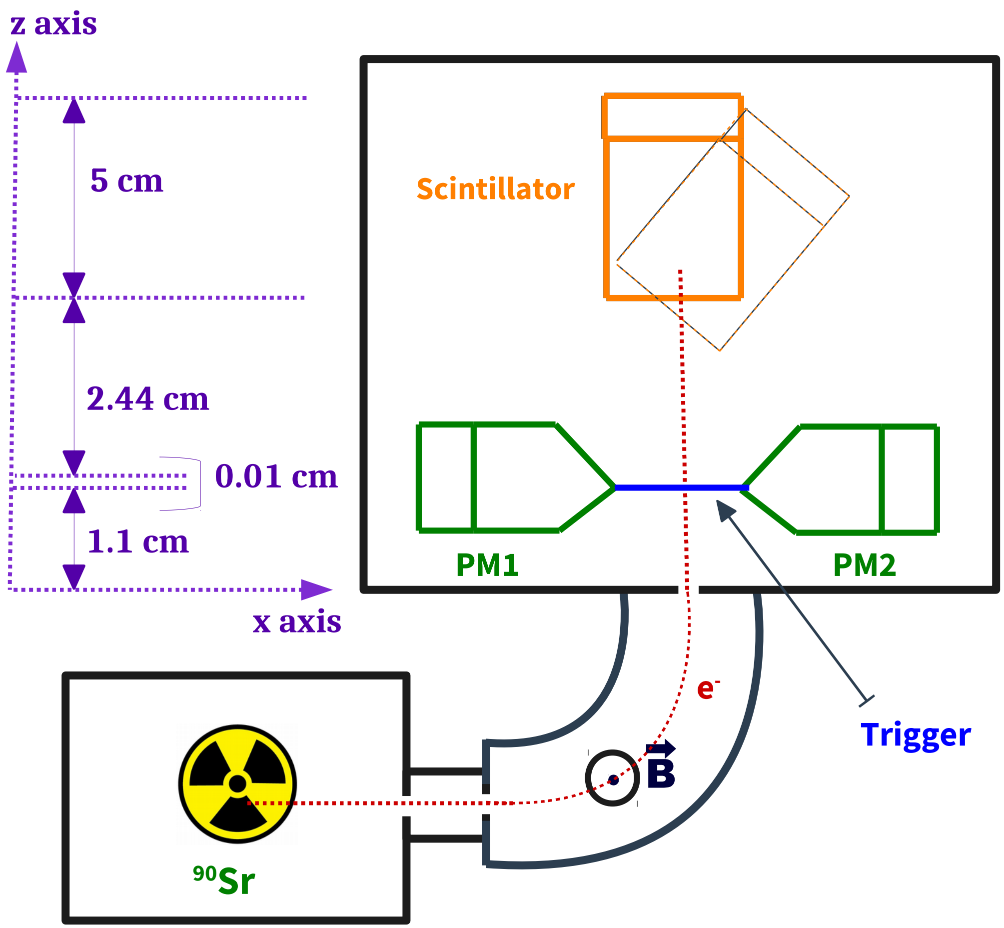


- <u>Source ^{90}Sr:</u>
  - $Q_\beta = 0.546$ MeV
  - Monoenergetic electrons via B field
  - Collimator (radius = 0.2 cm)
  - E_{e-} = 0.7 – 1.8 MeV
- <u>Cavity:</u>
  - Air (no vacuum)
  - Trigger on e-
    - plastic scintillator
    - 100 µm thickness
- + 2 optical guides coupled with PMs



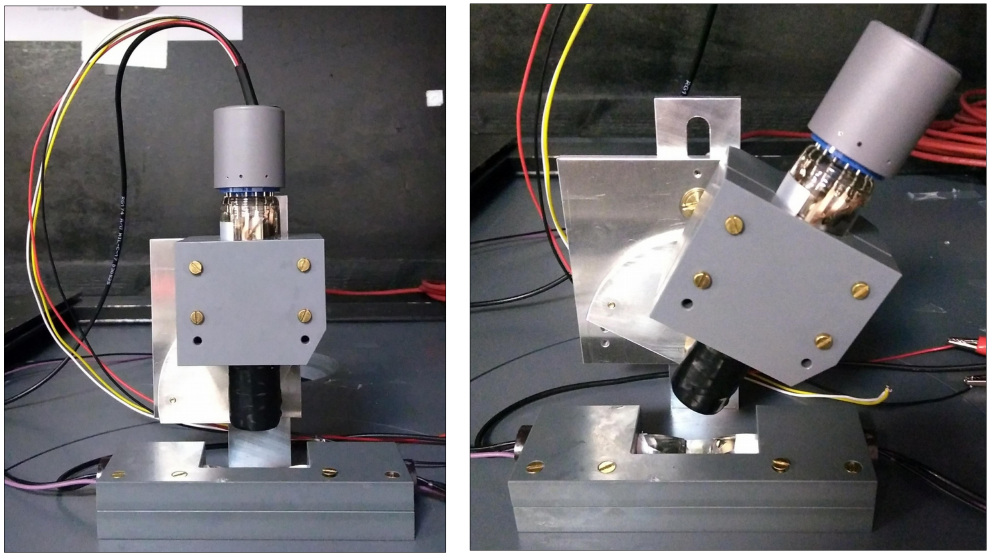
Electron trigger with optical guides and PMs

Experimental set-up – 2019



- <u>Cavity:</u>
  - Plastic scintillator (rotatable)
    - radius = 1 cm
    - length = 5 cm

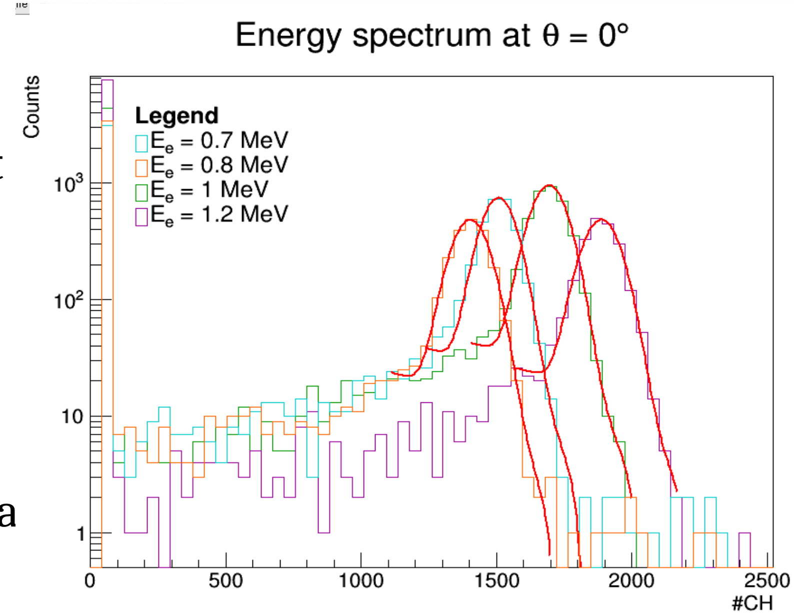
→ collecting data with different electron incident angles

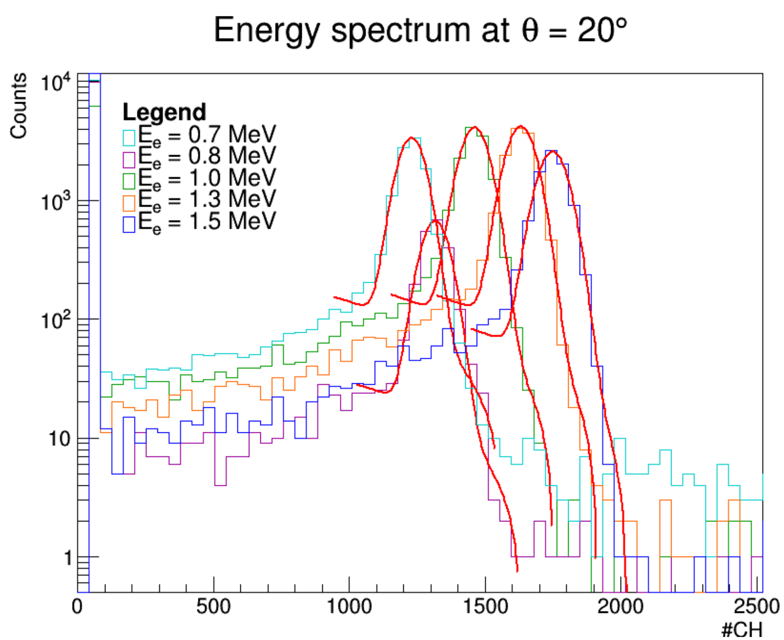


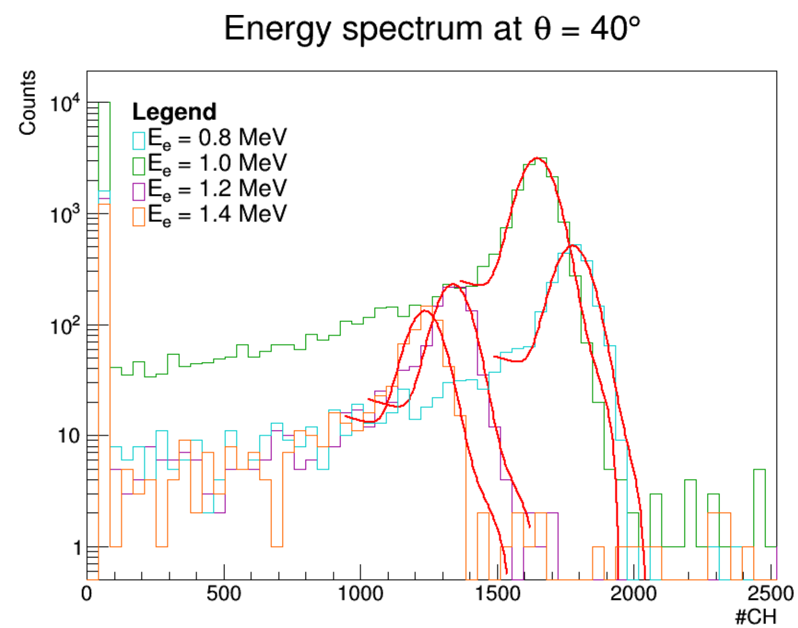
Plastic scintillator fixed on a rotatable support

Data acquisition – energy spectra

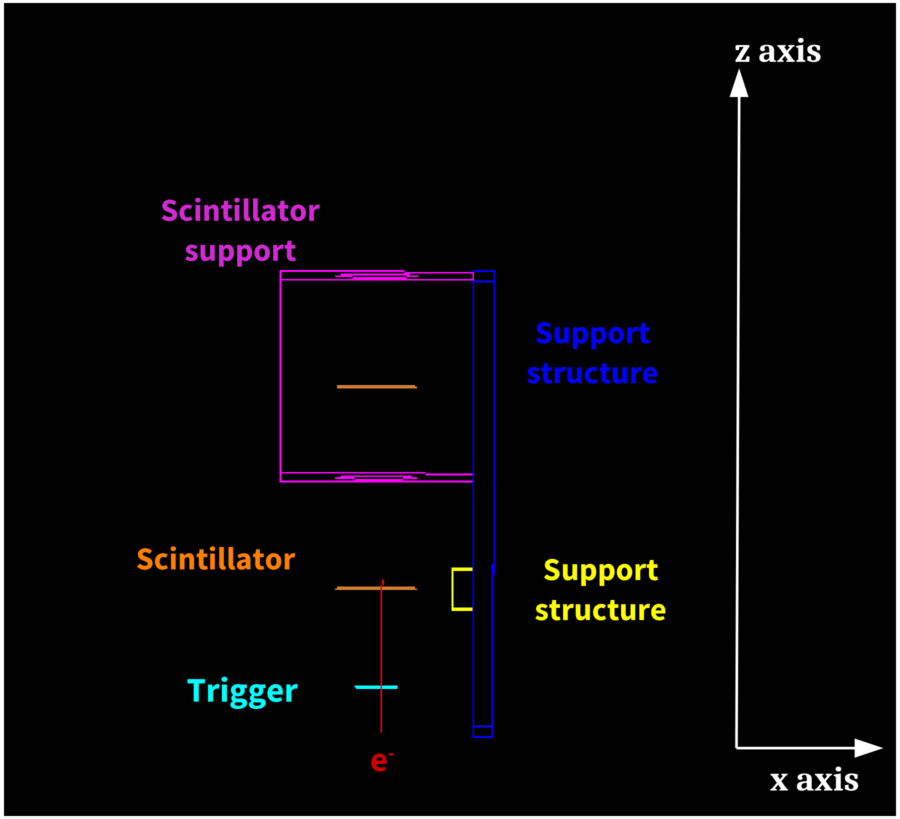
- 13 runs varying 0.7 MeV < E_e < 1.8 MeV at different incident angles with respect to the scintillator (0°,20°,40°)
- Reconstruction of the QDC spectra
- Gaussian+pol1 fits in good agreement with the data







Geant4 – experimental set-up



Source ^{90}Sr:

- Circular source of radius = 0.2 cm in x-y plane (reproducing collimator)
- Monoenergetic e^-
- e^- emission along z axis

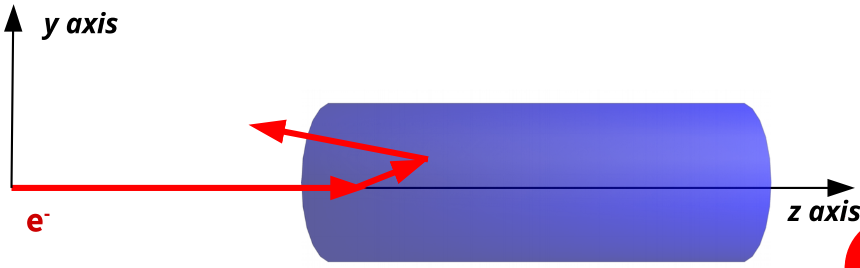
} 10^6 events generated

Set-up geometry:

- Simulations performed in air
- Possibility to rotate the scintillator to study the effects of the different e^- incident angles

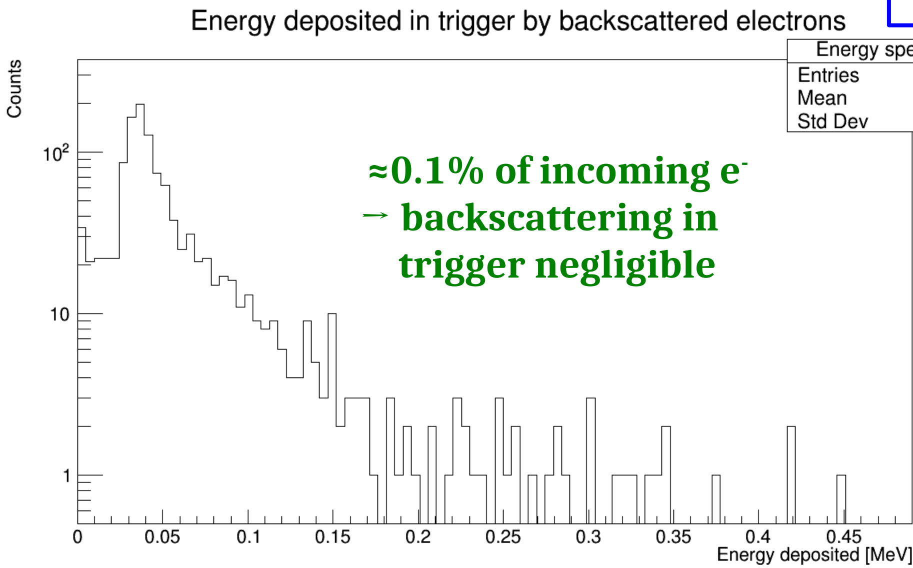
Backscattering angles are defined with respect to the positive z axis in the zy plane

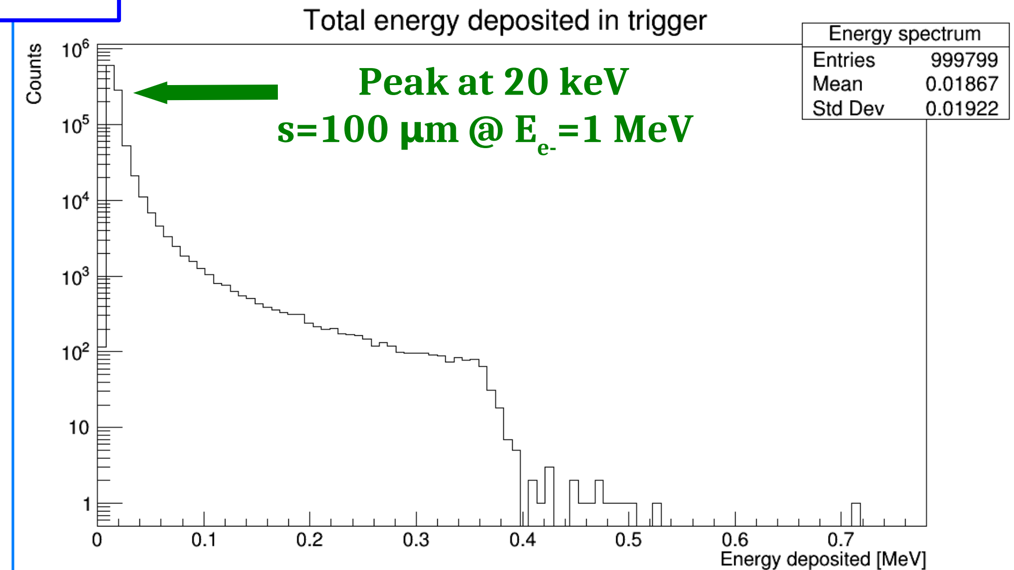
Backscattered e^- → backscattering angles > 90°
→ $p_z < 0$



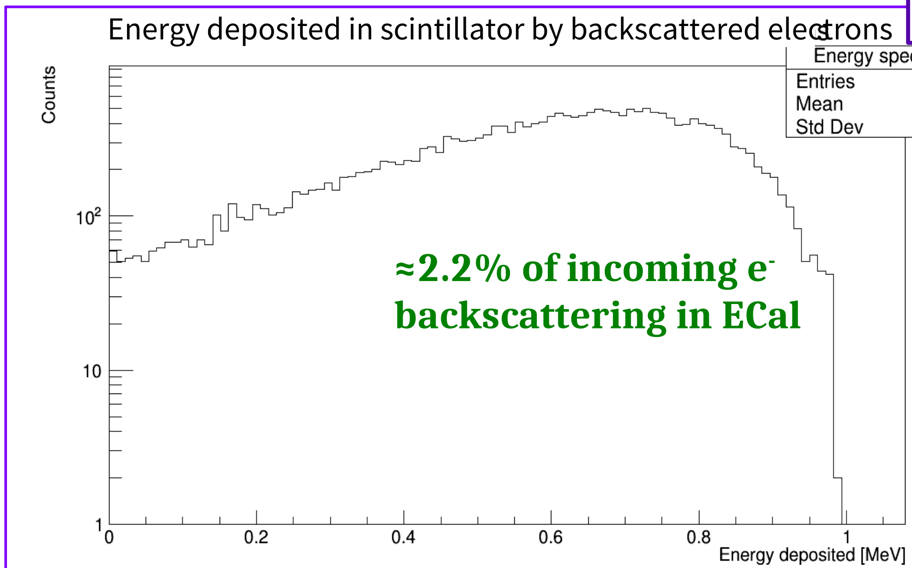
Geant4 simulation – $E_e = 1$ MeV, $\theta = 0°$

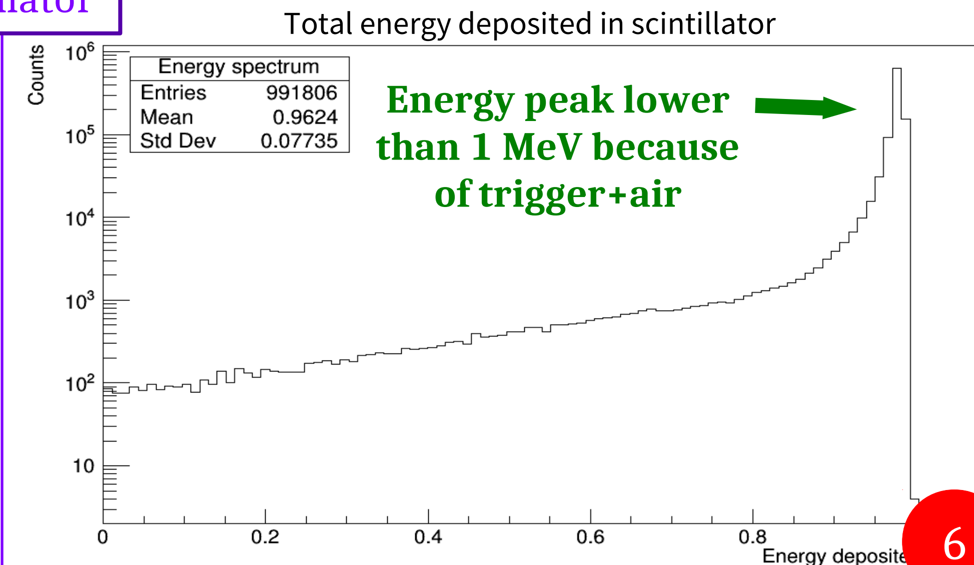
TRIGGER





Scintillator





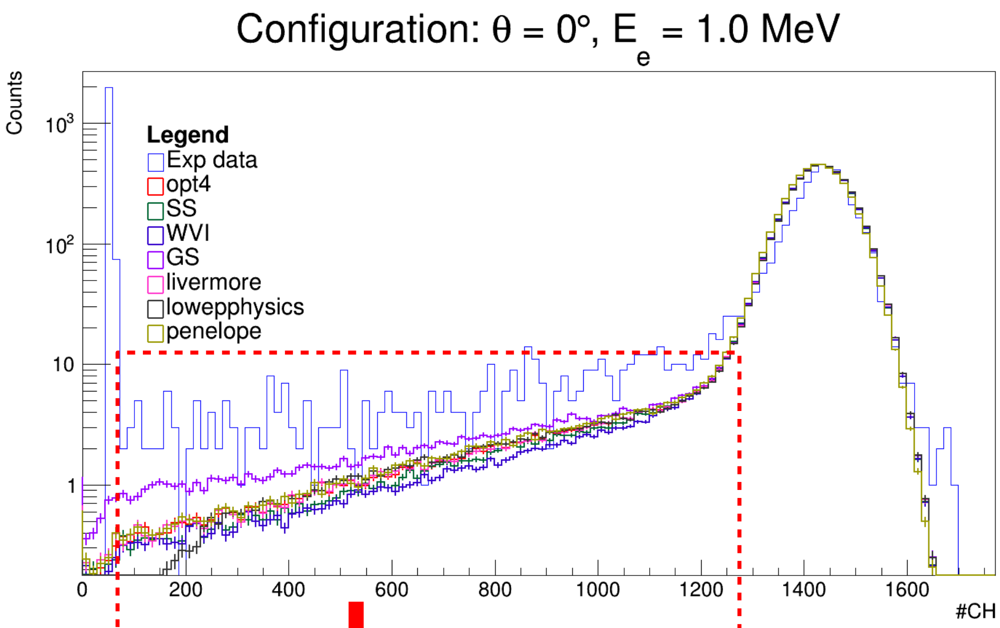
Convolution exp. data - simulation

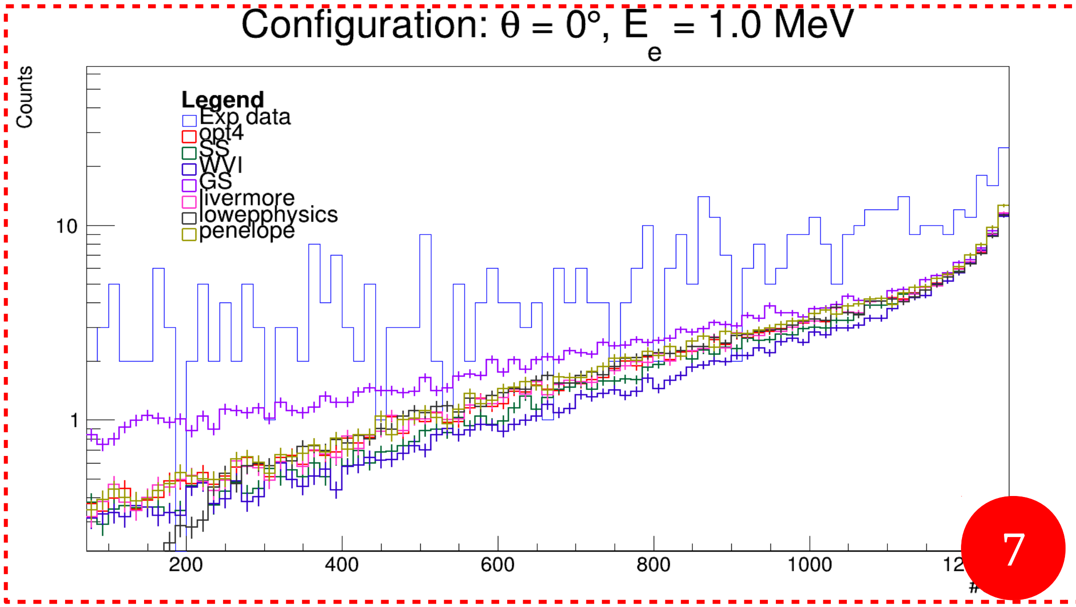
- Simulation performed by varying the algorithm used for backscattering computation *(EM_opt4, Single Scattering, Wentzel-VI, Goudsmit-Sounderson…)*
- Convolution of the simulated spectra with the detector response function
- Superposition of experimental and simulated spectra

GS MSC model reproduces data better

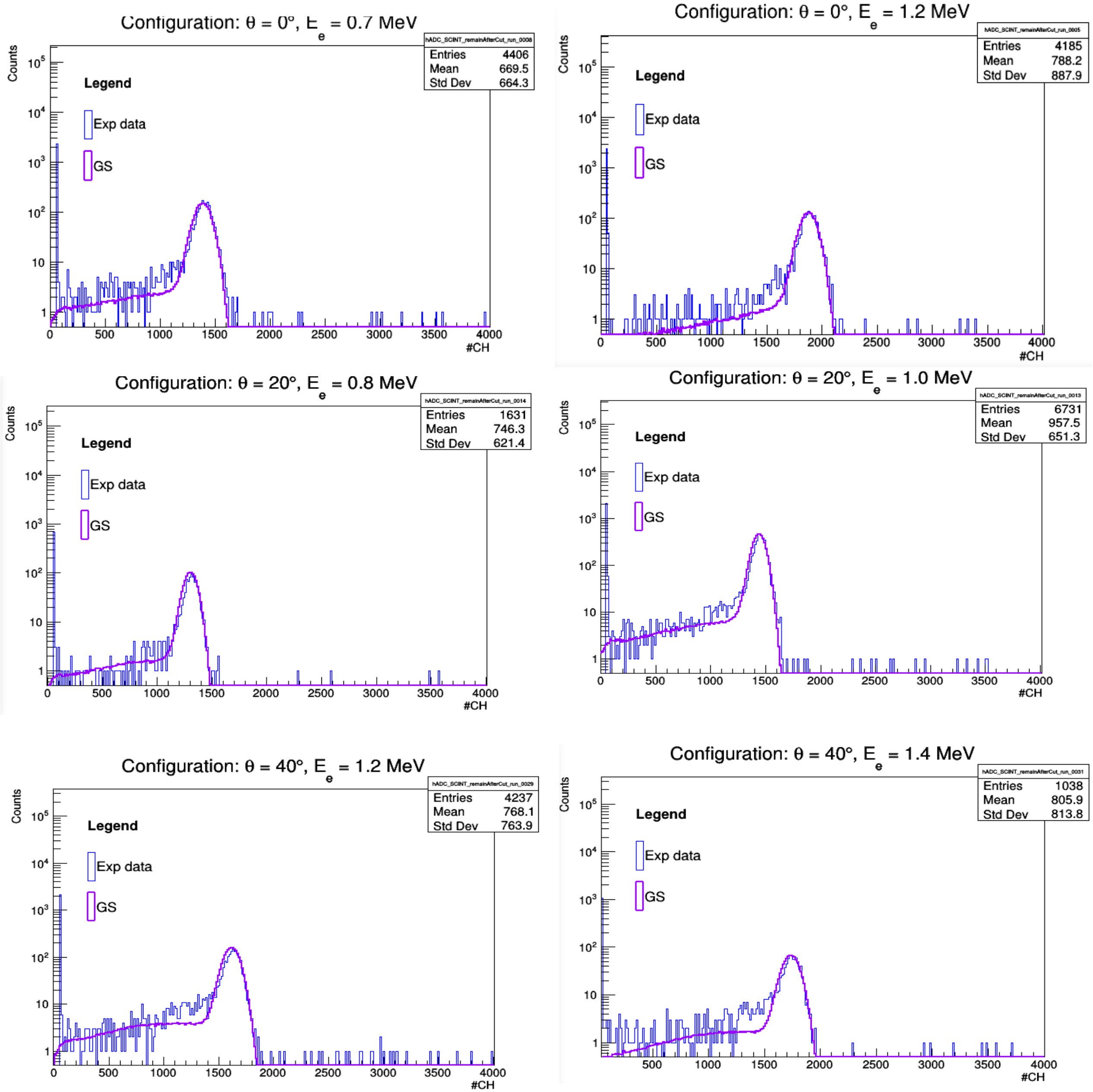
Simulations performed for all θ and E_e

Simulation curves systematically underestimate the continuum background





Convolution exp. data - simulation



CONDITIONS

- Two examples for each θ (0°, 20°, 40°) reported
- All simulations performed with MSC Goudsmith-Sounderson model

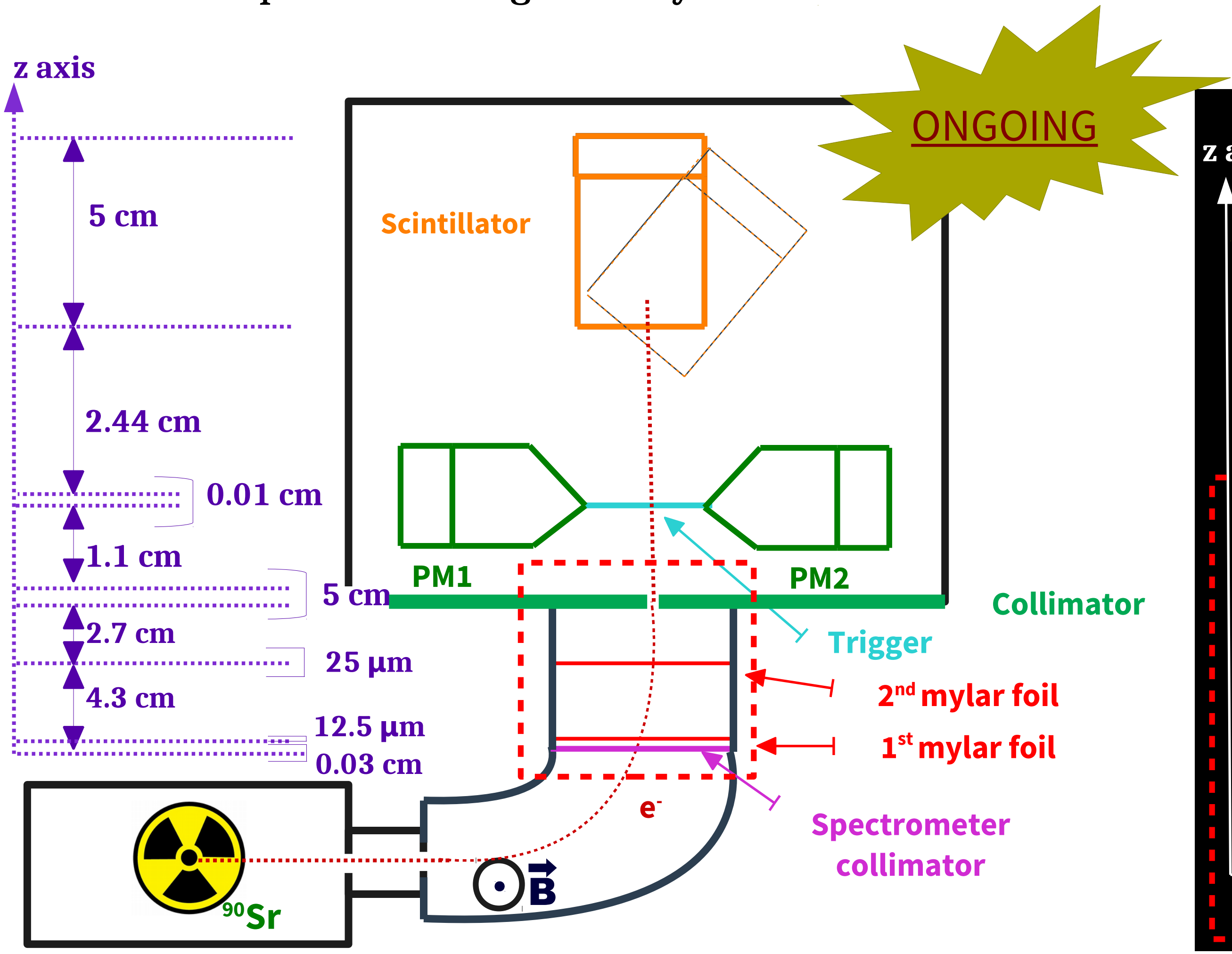
RESULTS

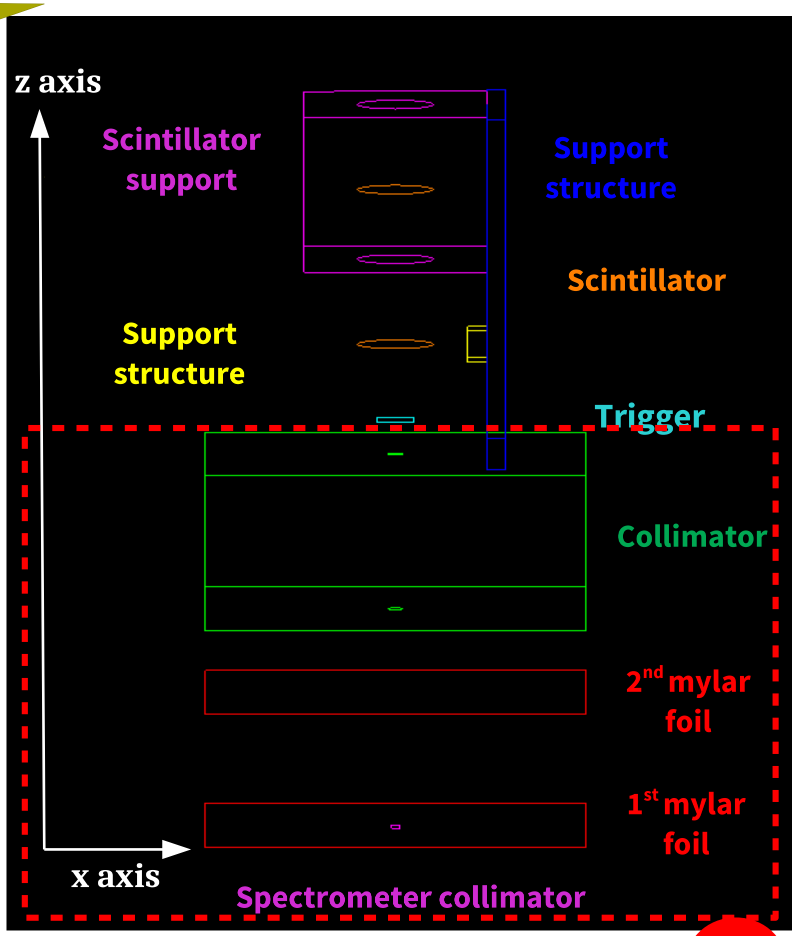
- No significant differences between higher and lower energies
- Seems to be a better reproduction with lower angles (at a given energy)
- Systematic discrepancy just before the energy peak
  → geometry reproduction?

Convolution exp. data - simulation

All simulations re performed by considering the spectrometer geometry

- Point source → e^- emitted in a cone with $\theta_{spread} = 16.7°$
- Mylar foils and spectrometer collimator reproduced

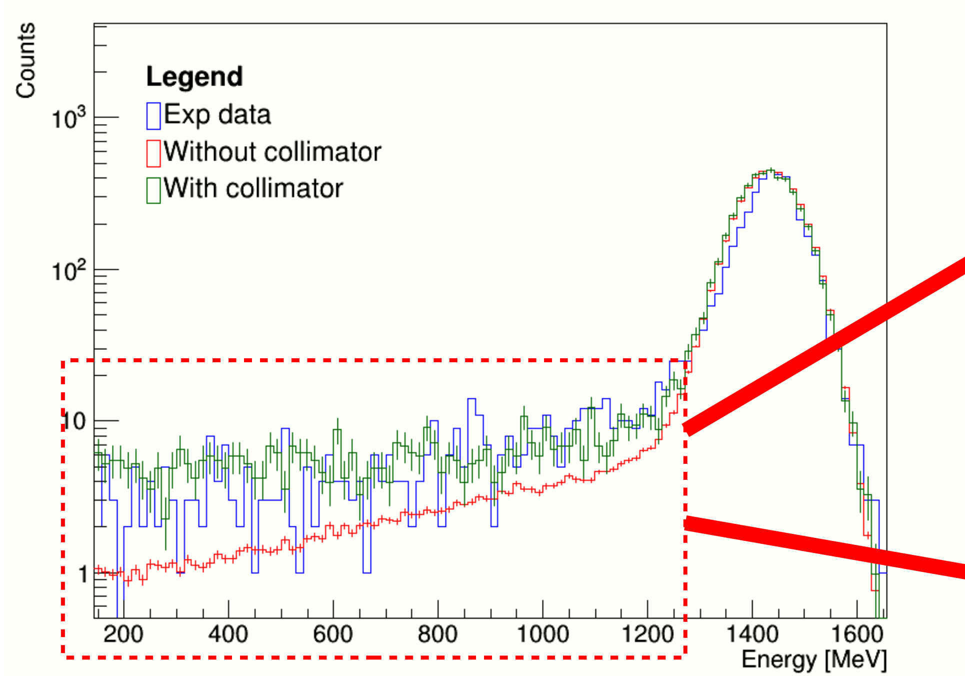




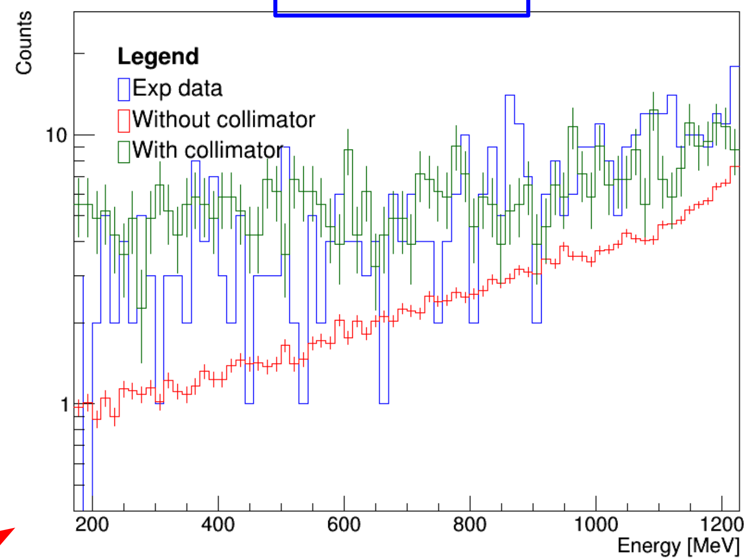
Convolution exp. data - simulation

Example:

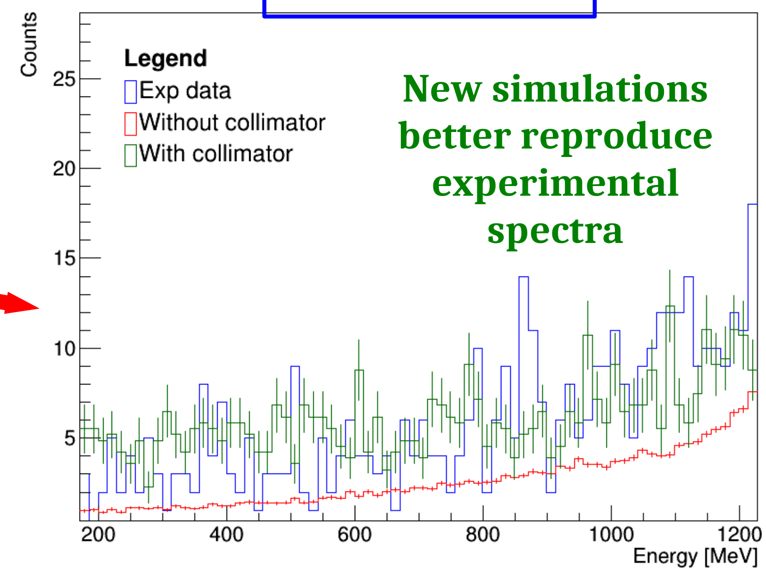
- E_e = 1 MeV, θ=0°
- 10^6 events generated
- GS MSC model implemented



LOG SCALE



LINEAR SCALE

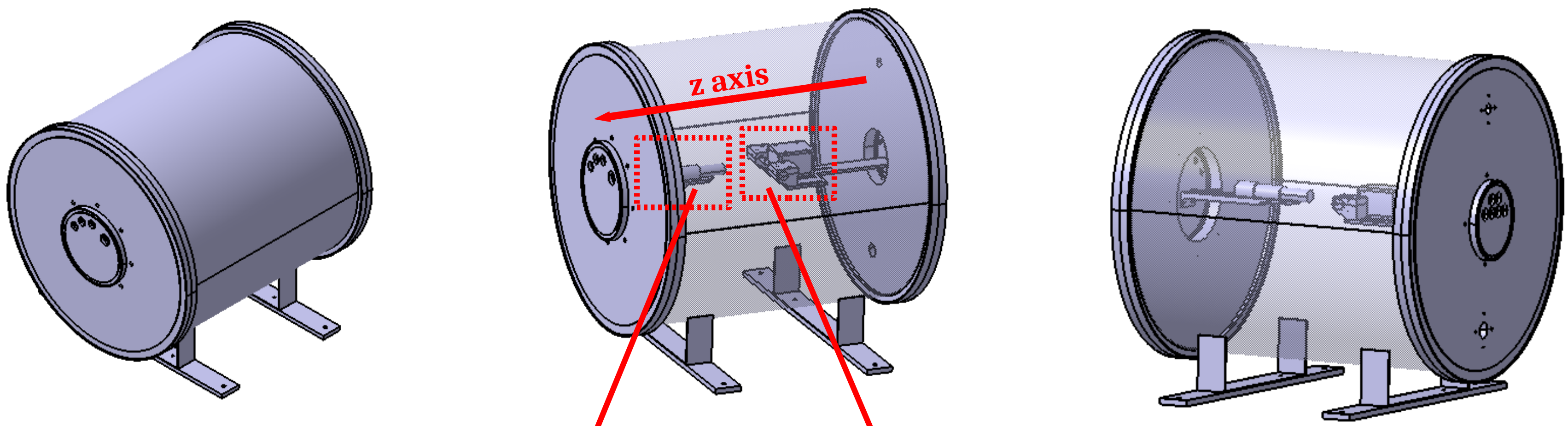


New simulations better reproduce experimental spectra

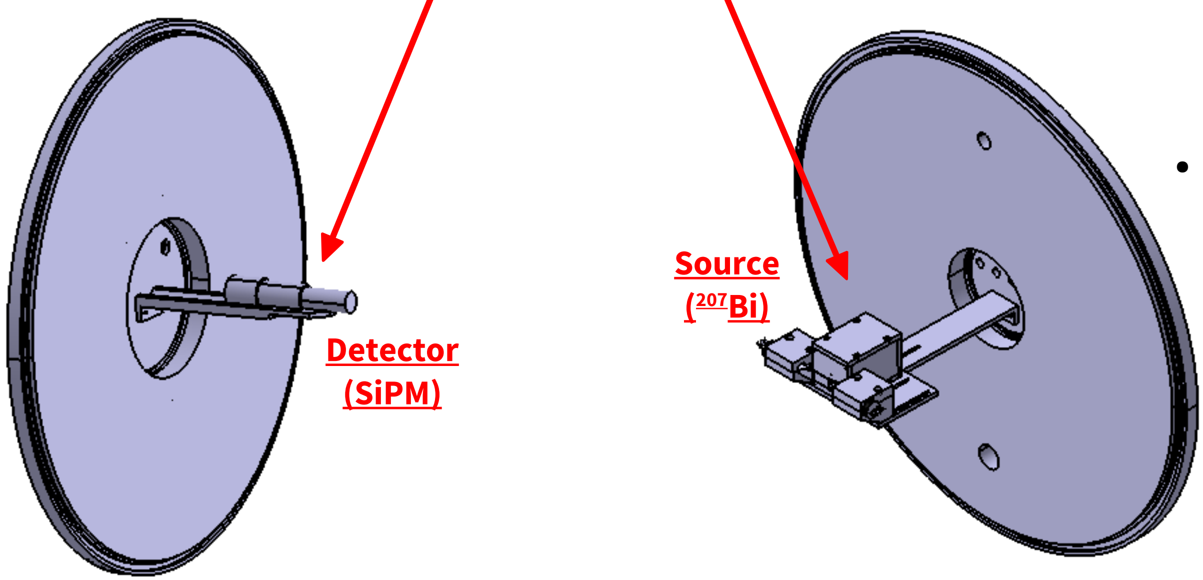
New tests to be performed - ongoing

New tests on e- backscattering

New tests on e- backscattering will be performed at CENBG
Experimental set-up and DAQ system → mounted and available for data taking



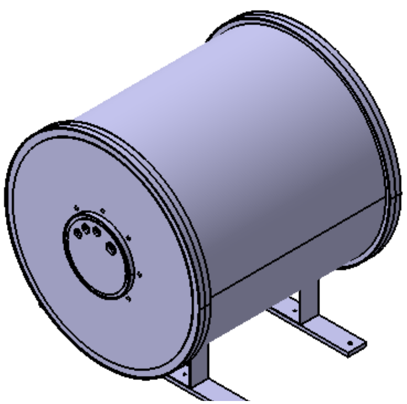
Detector collinear with the z axis for the time being (expected upgrade: rotation)

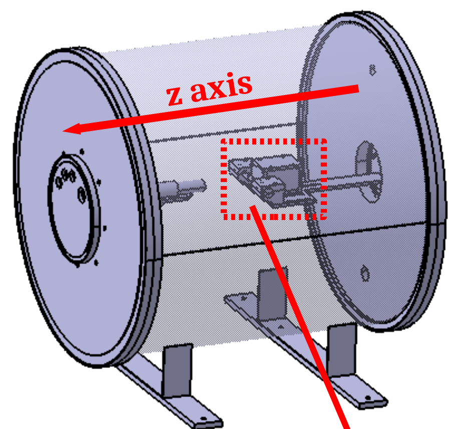


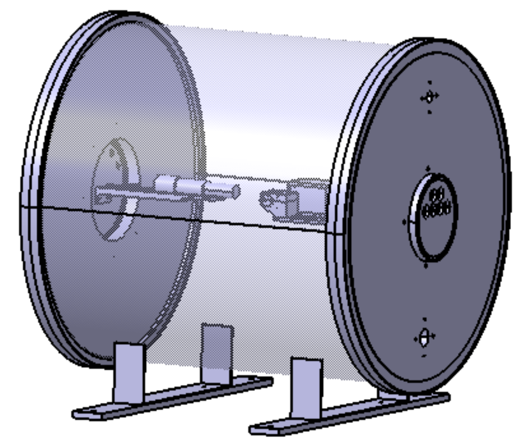
- Box of Al 5x5x5 mm
- Source may be placed at the different z positions
- Collimator r=1 mm
- **Trigger 200 um**
- **Vacuum**

New tests on e$^-$ backscattering

New tests on e- backscattering will be performed at CENBG
Experimental set-up and DAQ system → mounted and available for data taking

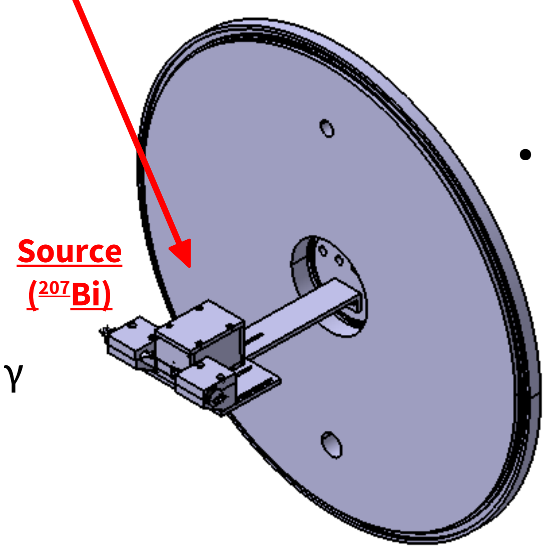






Decay Mode: EC, β^+		Half-Life: (11523 ± 1) d			
Radiation Type		Energy (keV)		Intensity (%)	
Auger-L		5.2 - 15.7		53.8	14
Auger-K		56.0 - 88.0		2.8	3
ec-K-1		481.7		1.52	2
ec-L-1		553.8 - 557.7		0.440	6
ec-M-1		565.8 - 567.2		0.15	2
ec-K-2		809.8		0.003	1
ec-K-3		975.7		7.03	13
ec-L-3		1047 - 1051		1.84	5
ec-M-3		1059 - 1061		0.54	7
ec-K-4		1682		0.02	1
β+max		806.5		0.012	2
β+av		383.4			
X-ray L	Σ	9.18 - 15.8		33.2	14
X-ray Kα	Σ	74.2		58.19	24
X-ray Kβ	Σ	84.4 - 87.6		16.22	25
γ		328.11		0.00076	8
γ	Annih	511.0		0.0024	4
γ		569.70		97.76	3
γ		897.8		0.131	6
γ		1063.7		74.58	49
γ		1442.2		0.131	2
γ		1770.2		6.87	3

Both e- and γ emitted



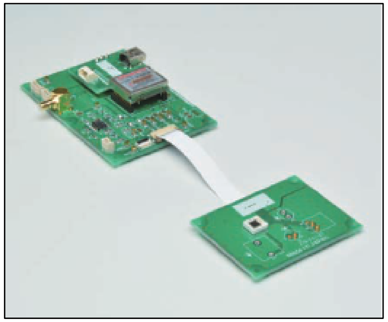
- Box of Al 5x5x5 mm
- Source may be placed at the different z positions
- Collimator r=1 mm
- **Trigger 200 um**
- **Vacuum**

Results tests SiPM S13360– 13/02/2020

Experimental set-up

The apparatus to be tested is composed of two separate parts to be assembled:

- Hamamatsu module C12332-01 (driver circuit)
- Hamamatsu MPPC (SiPM) S13360-60CS
  - → 50 um pitch
  - → 6.0x6.0 mm effective photosensitive area
  - → 14400 pixels



Module C12332-01

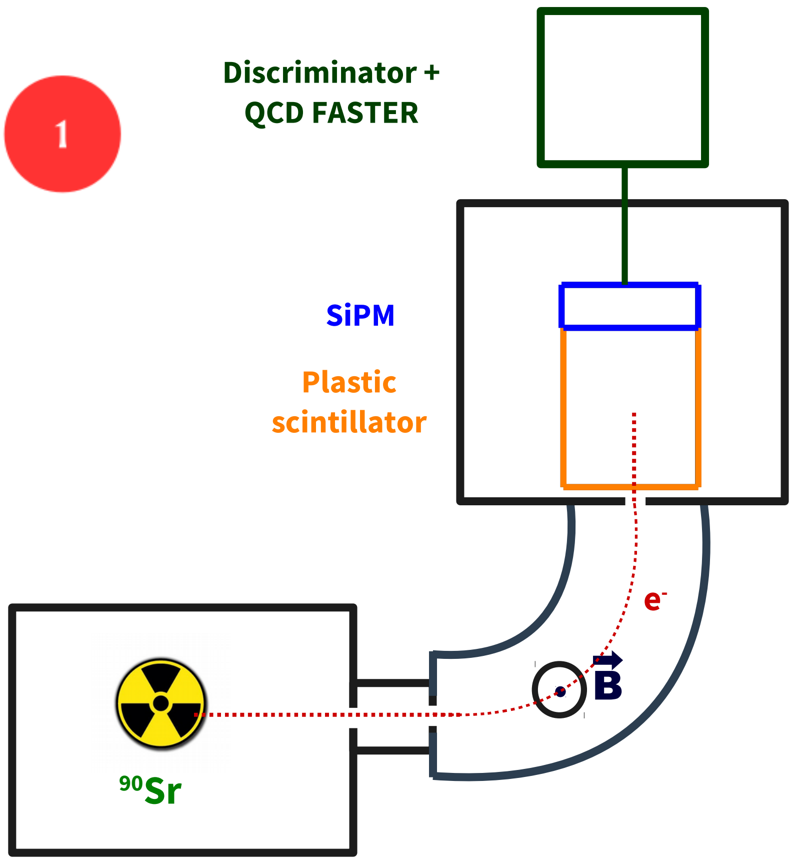
SiPM 13360-6050CS

The tests have been performed by means of two different experimental set-up:

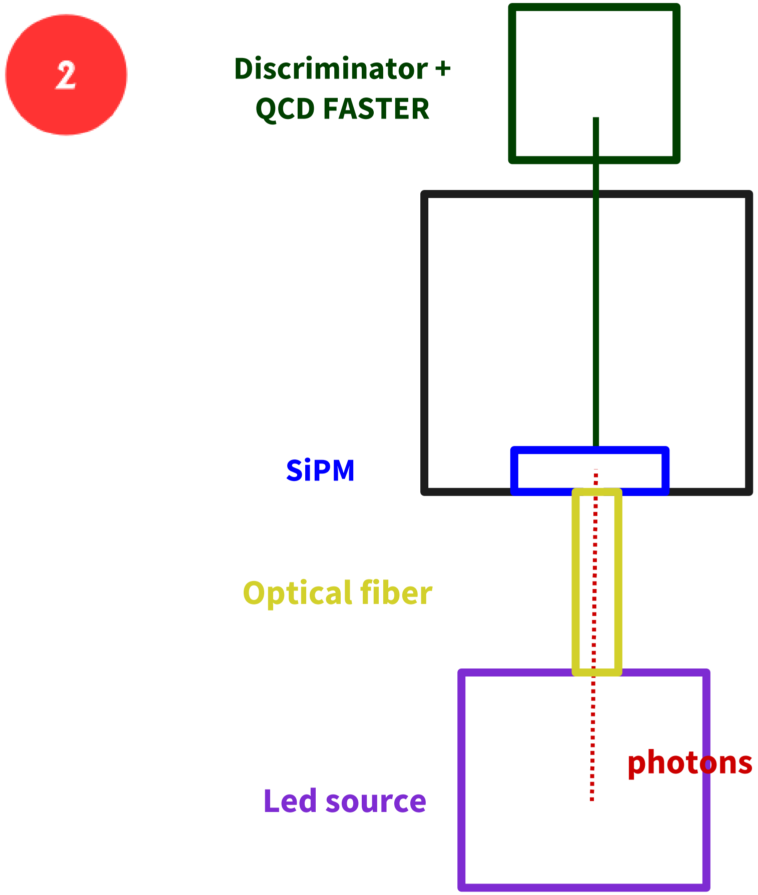
1. Monoenergetic e^- beam ($E_e \leq 1.8$ MeV)
2. LED source ($E > 1.8$ MeV)

Experimental set-up

Monoenergetic electron beam

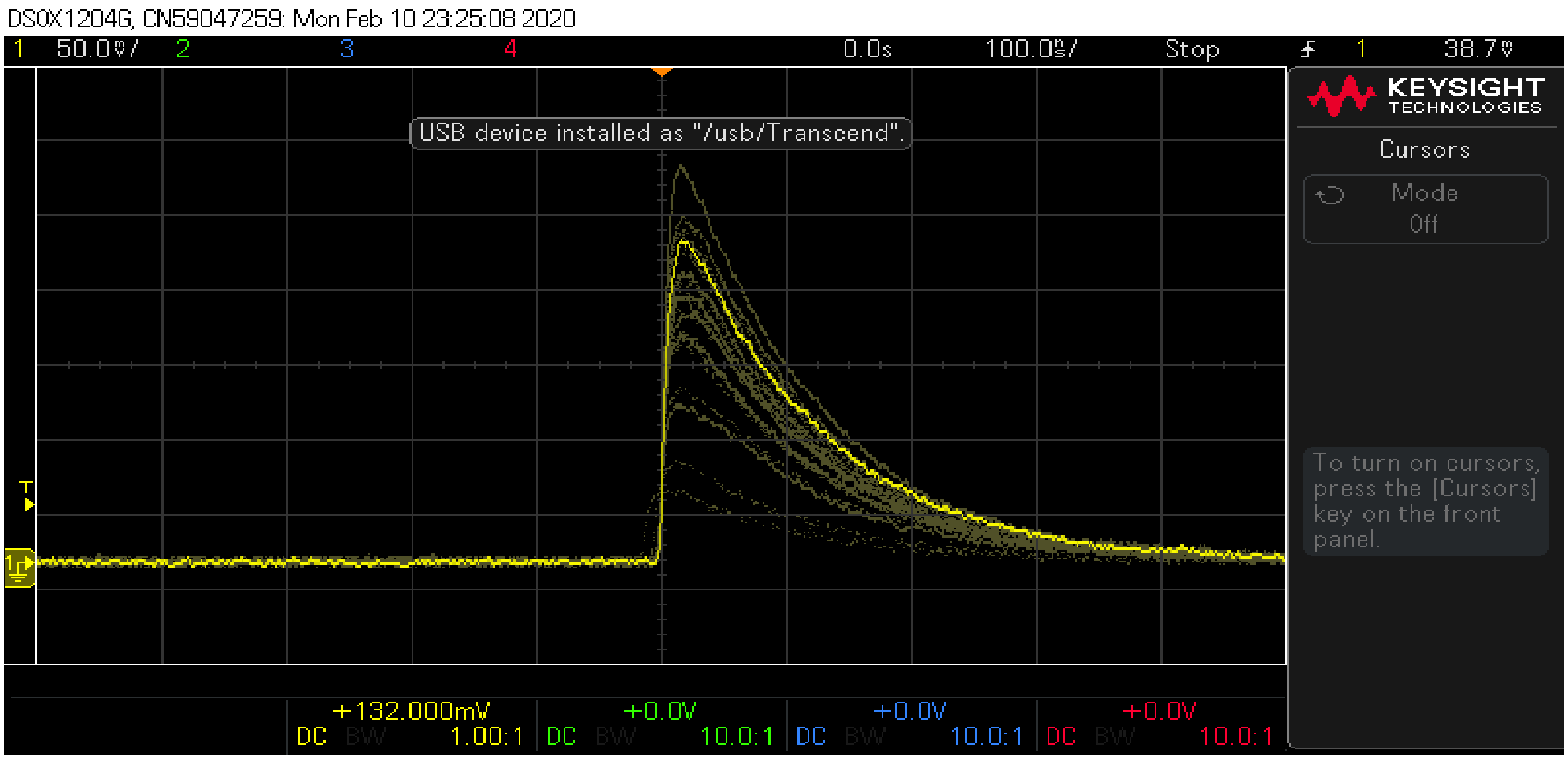


LED source



Experimental set-up

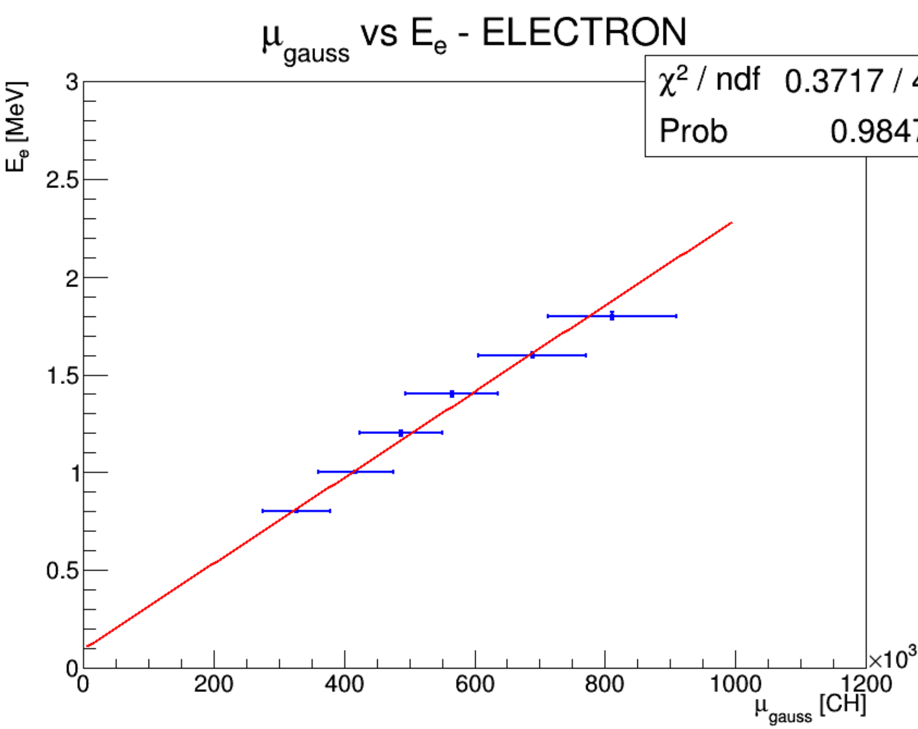
The SiPM output signal can be displayed on the oscilloscope
→ useful for amplitude measurements

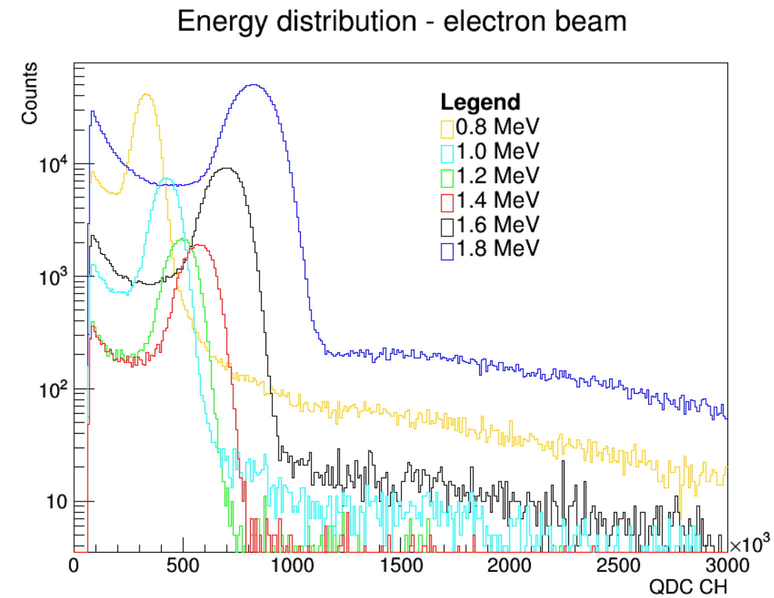


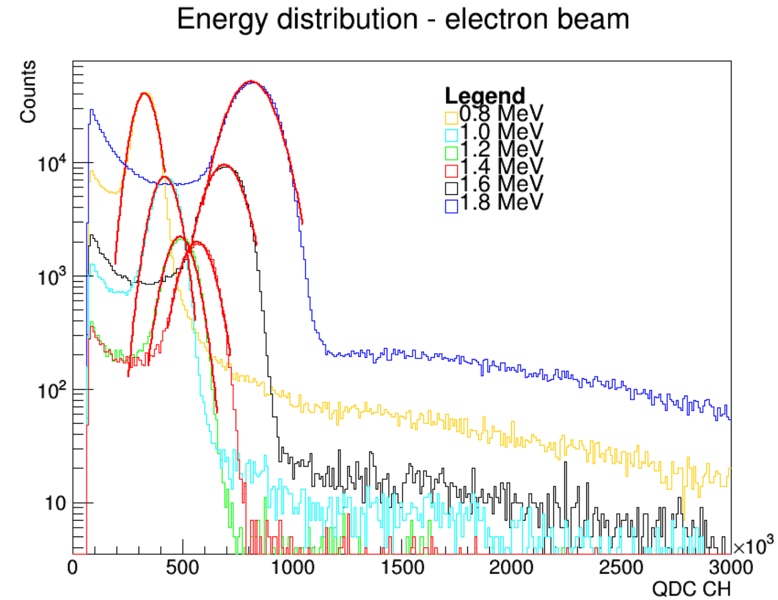
QDC spectra – Electron beam

OBS:

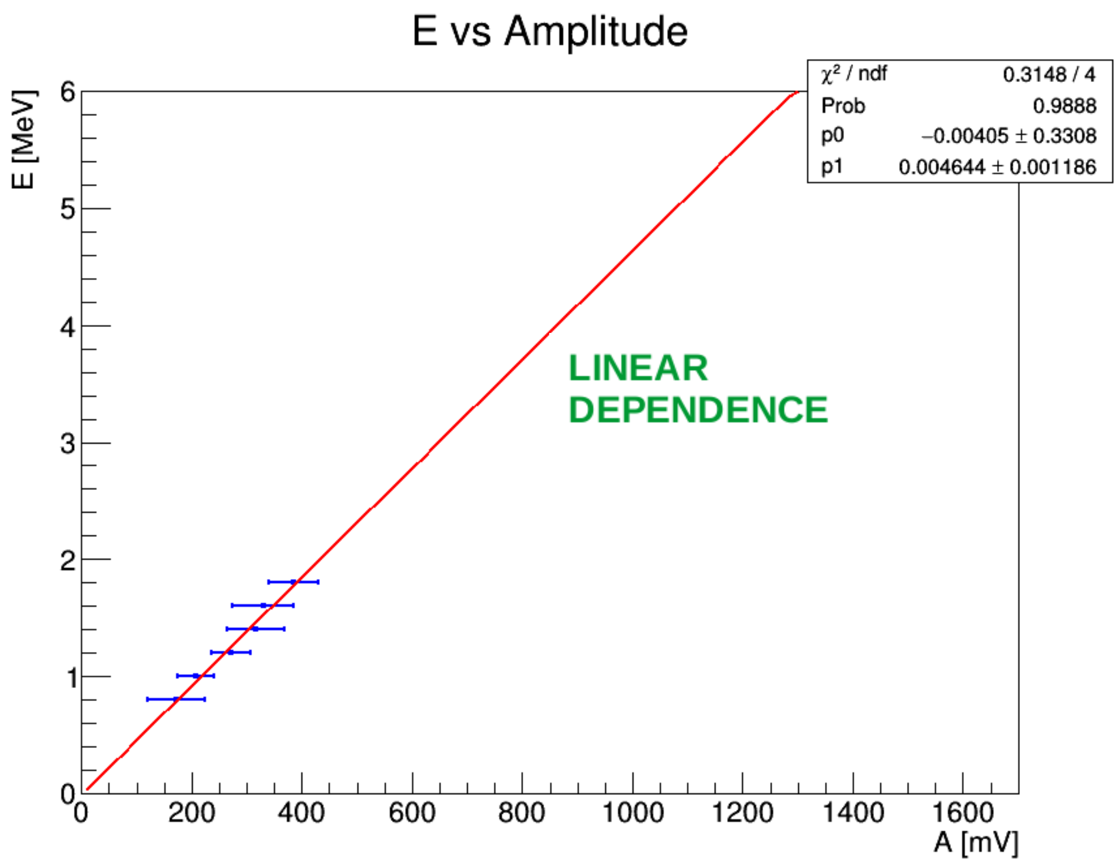
- QDC spectra
- 6 runs, $0.8 < E_e < 1.8$ MeV
- Gaussian peak shapes
- Energy calibration → linearity







Energy-amplitude calibration



OBS:

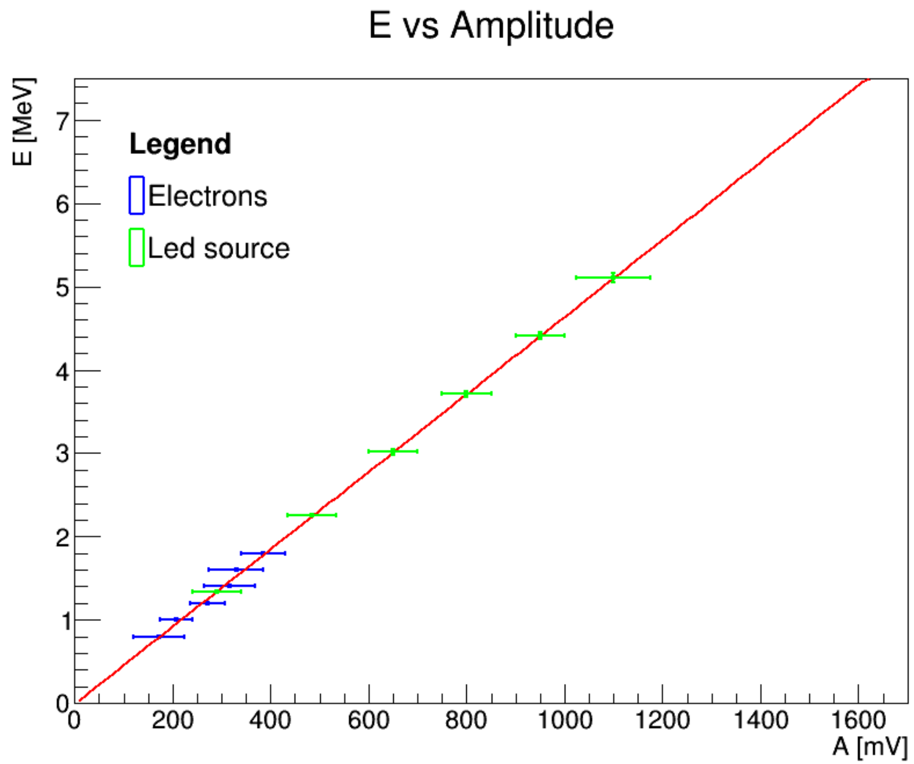
- E_e vs A → linear dependence
- Data collected up to E_e = 1.8 MeV
- Highest E_e achievable with e spectro → 1.9 MeV (poor statistics)

→ LED source needed to have data at higher equivalent deposited energies and define the saturation point

Tests with the LED source

Additional tests have been performed with the LED source
by varying the signal amplitude

The correspondent energy values are given
by the Energy-Amplitude calibration (linear fit)

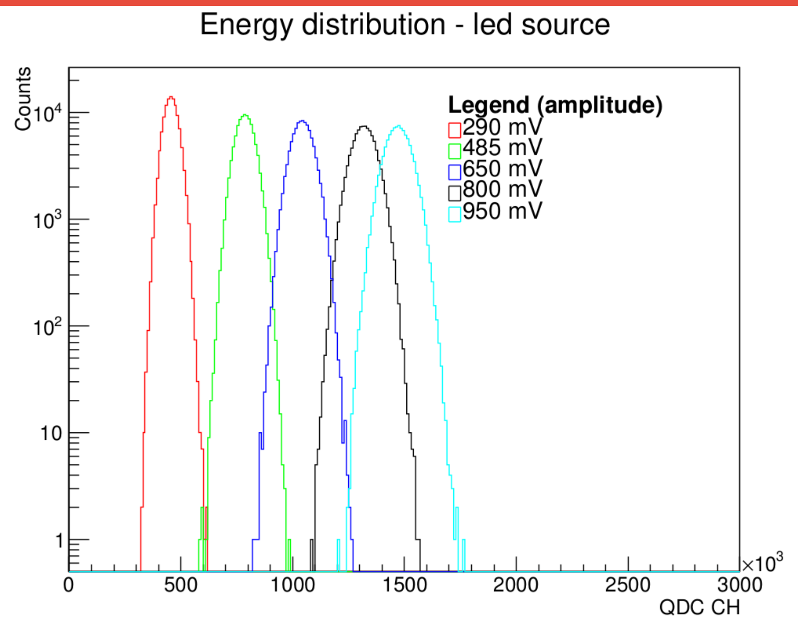


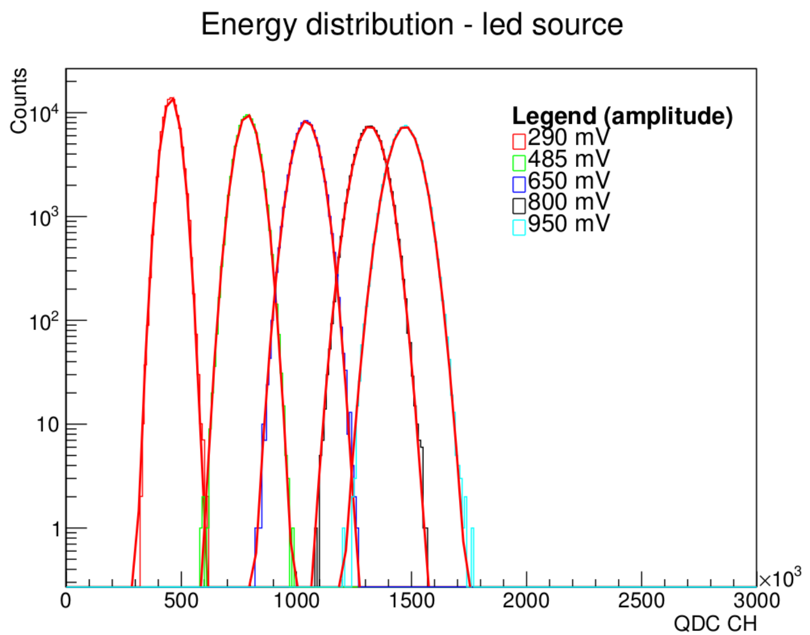
QDC spectra – LED source

OBS:

- QDC spectra
- 5 runs, by varying the amplitude
  290 mV < A < 950 mV
- Correspondent energy
  1.34 MeV < E_{led} < 5.10 MeV

- Gaussian peak shapes

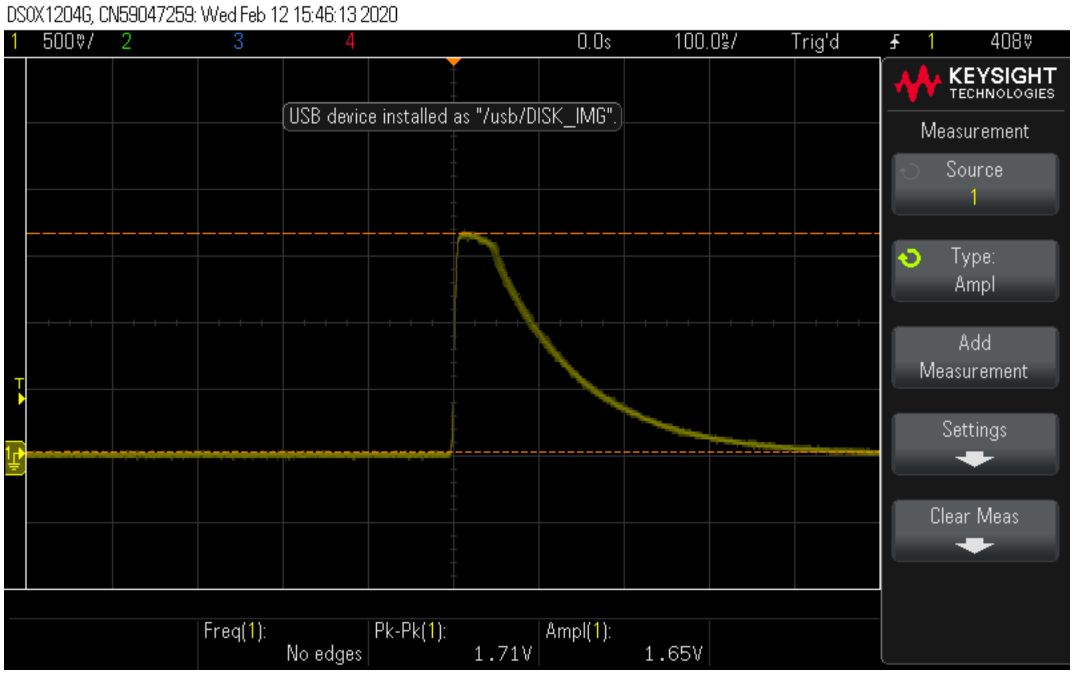




Saturation point

The amplitude of the LED source has been varied in order to spot the saturation point

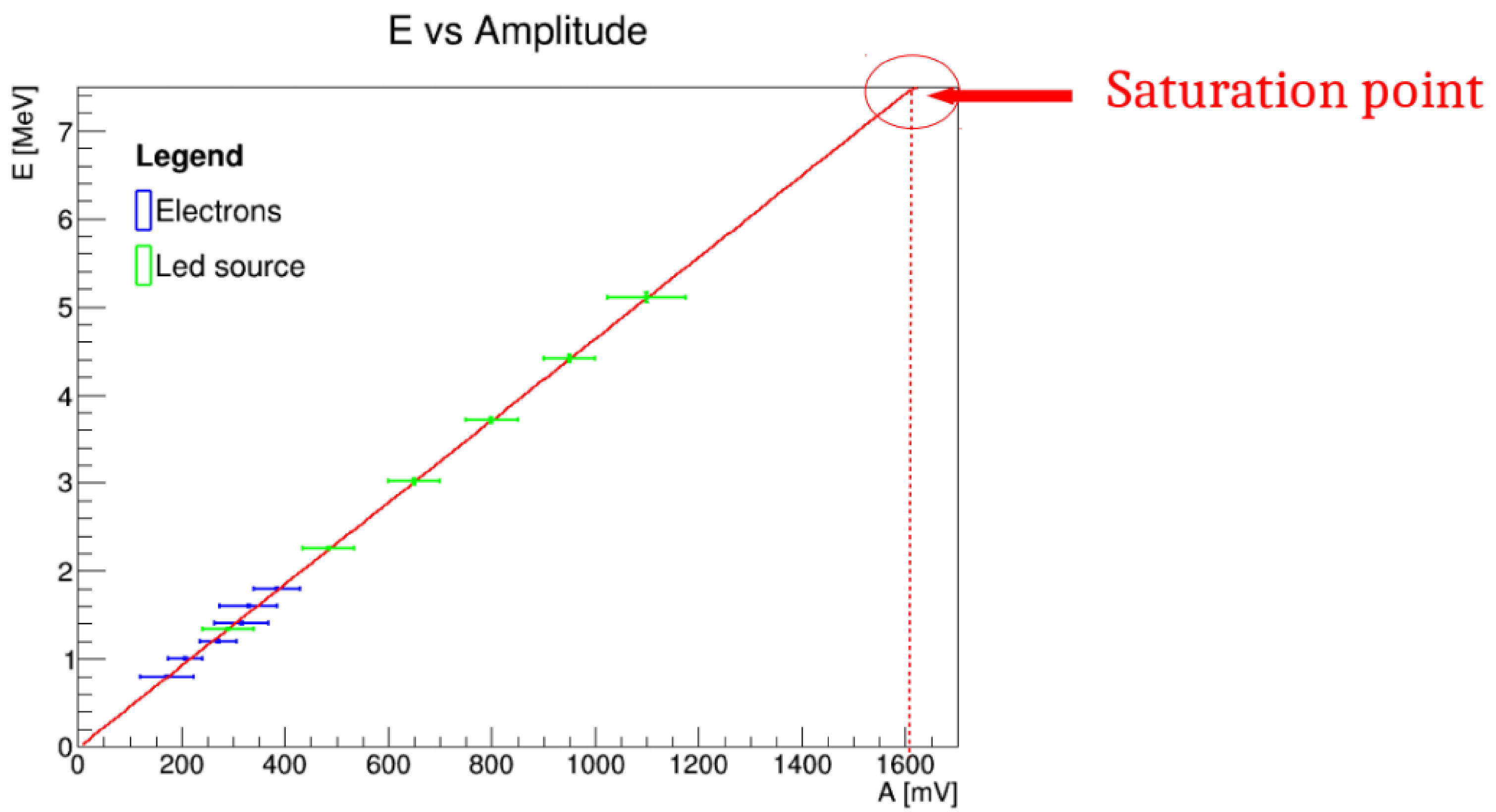
Signal saturation begins at 1.6 V



The correspondent value of energy saturation can be computed via the energy-amplitude calibration

Tests with the LED source

The saturation point (A=1.6 V) corresponds to E = 7.4 MeV



Conclusions

- Positive results of the tests performed → **linearity in energy calibration** until the **saturation point** (**A=1.6 V**, correspondent to **E = 7.4 MeV**)
  → SiPM can be used in the [0, 2] MeV energy range for the measurements with ^{114}In (also in [0, 4] MeV energy range for double-count measurements)

- Hamamatsu module C12332-01 (driver circuit) + Hamamatsu MPPC (SiPM) S13360-60CS } **A second module ordered** (~ 670 €)

ONGOING

- Tests performed on the two new SiPMs S13360-60CS
  - same experimental set-up (e^- beam + led source)
  - linearity in energy calibration, but different saturation points (correspondent to E = 8 and 15 MeV respectively) → effects of the different HV applied?
  - battery of tests performed by varying the HV applied
    → parallel curves E-Amplitude
    → not seen the saturation point for lower energies → more powerful led needed