Status of the laboratory studies of J-PET prototype: light signal velocities, single photoelectron signals and measurement campaigns

Symposium on Positron Emission Tomography 19th – 22nd September

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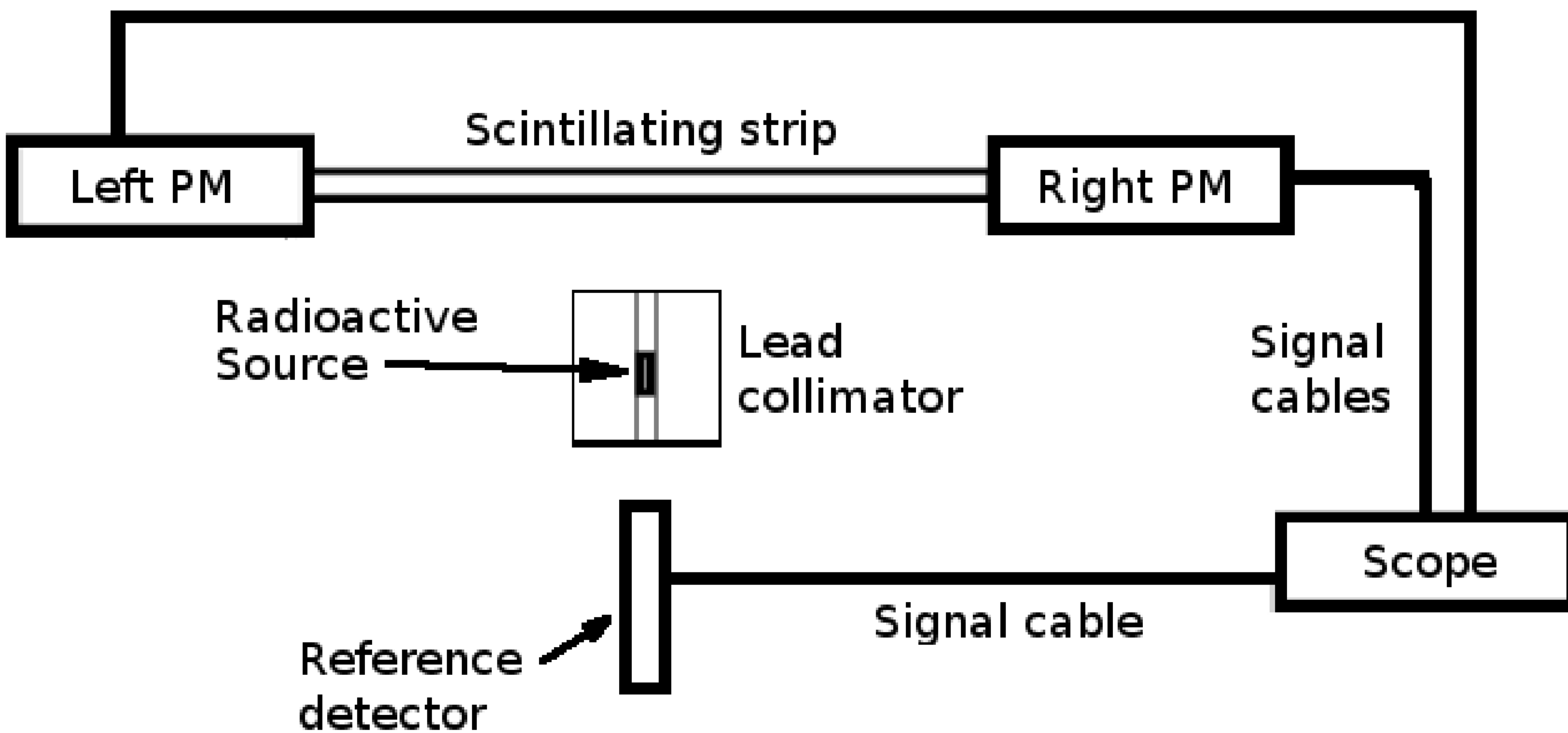
Plan of presentation

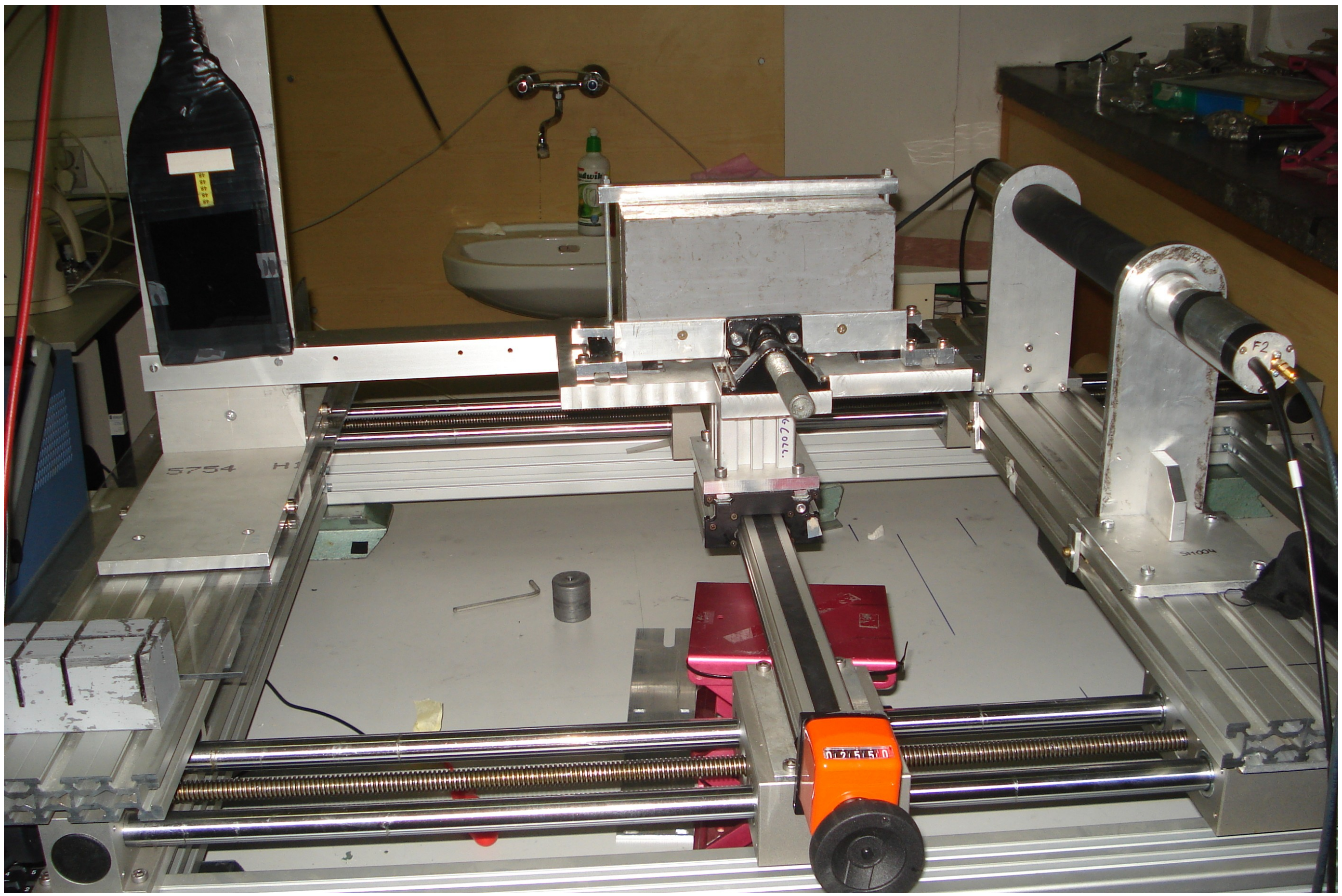
1. Description of experimental setup
2. Photomultiplier callibration
3. Experimental campaigns
4. Light velocity for different scintillator shapes
5. Preliminary results from Strip Scan

Description of experimental setup

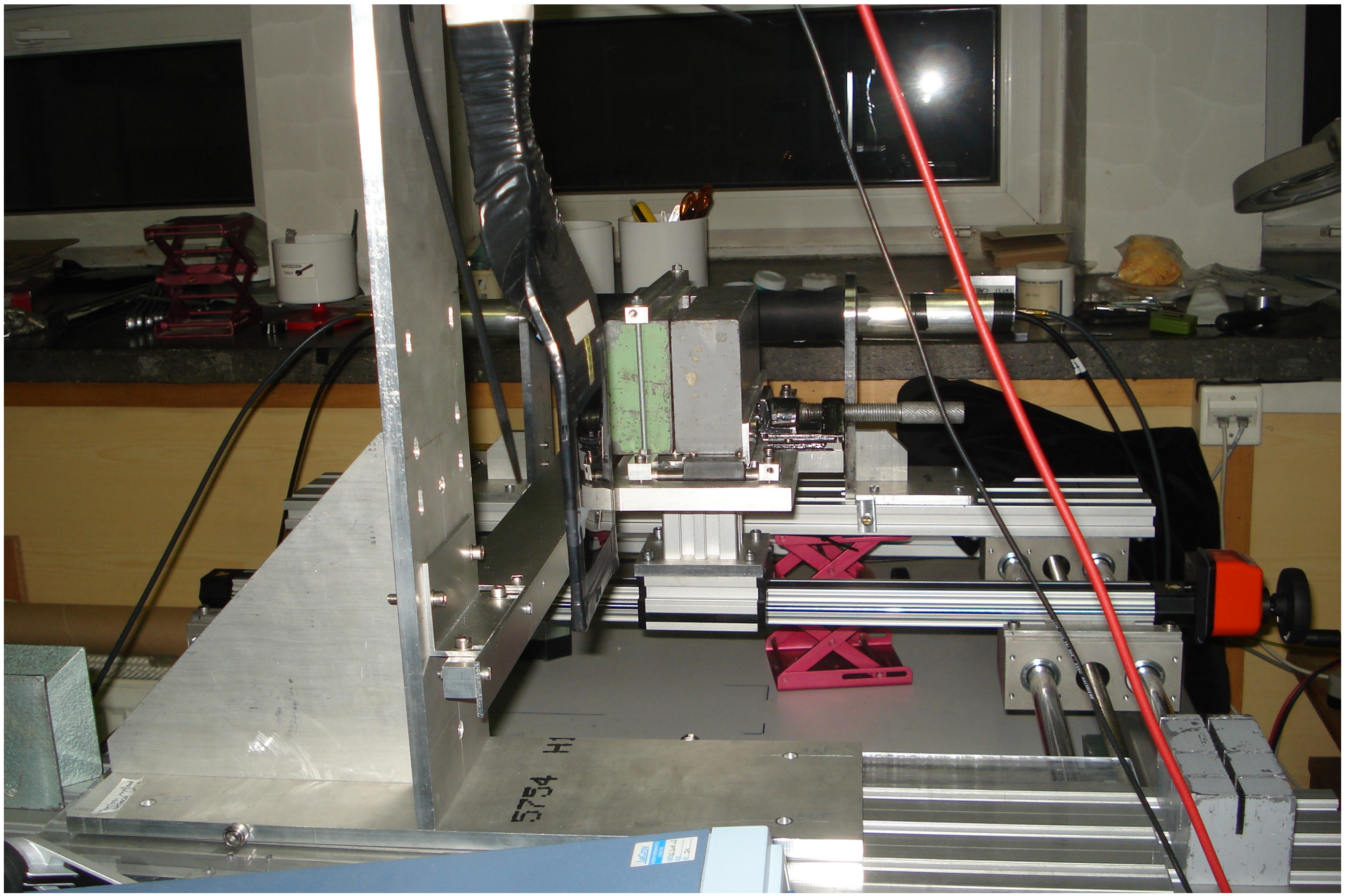
Scheme of the experimental setup



Description of experimental setup



Description of experimental setup



Degrees of freedom

- Two sources
- Source position
- Strip shapes
- Strip covering
- Photomultiplier type
- Photomultiplier gain

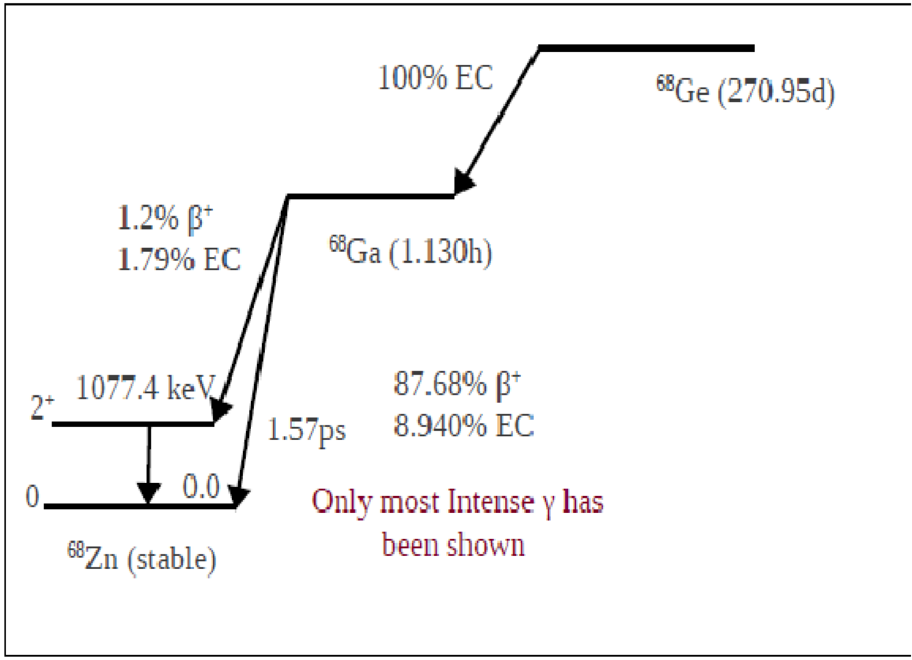
Radioactive sources

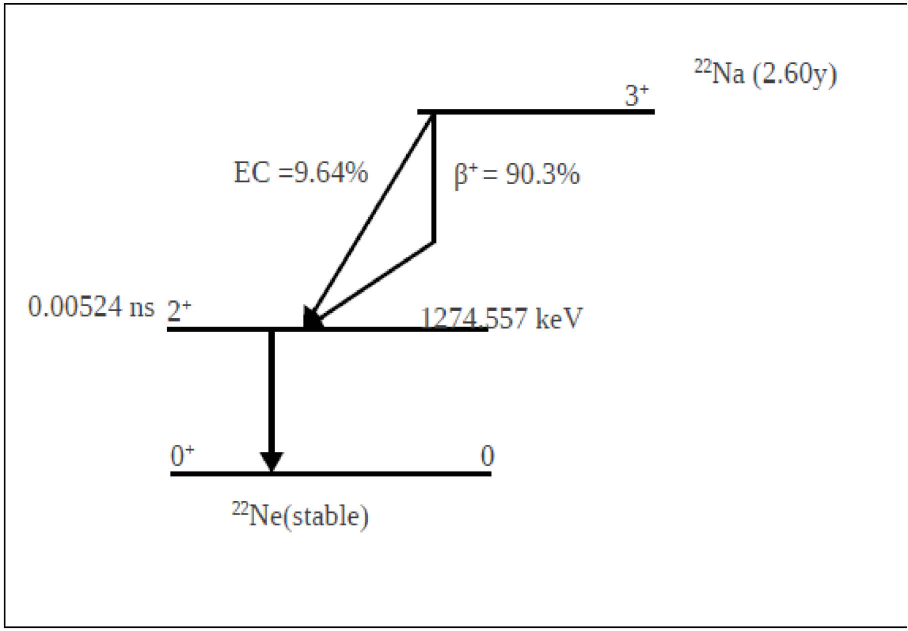
Germanium 68:

- annihilation gamma quanta
- very small background
- short lifetime

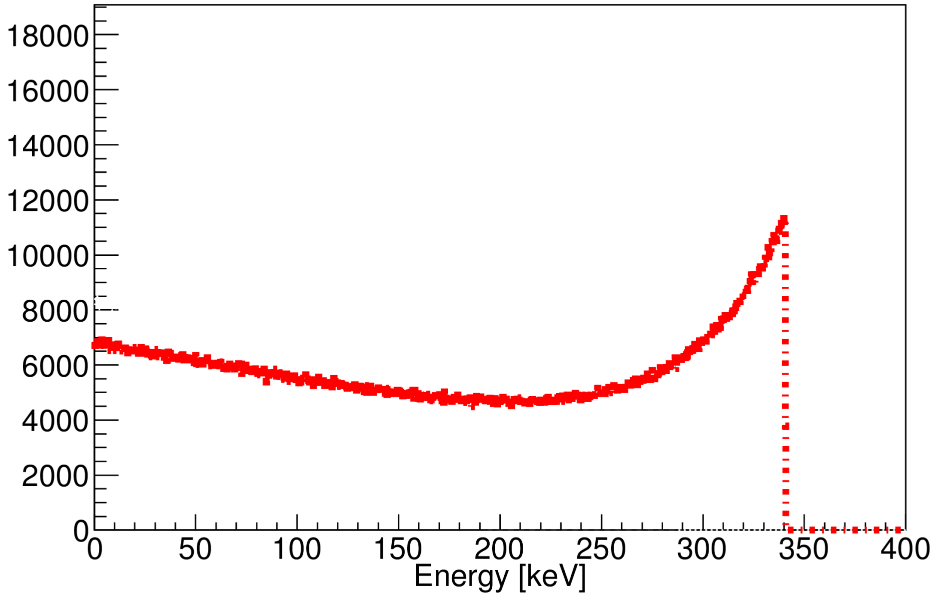
Sodium 22:

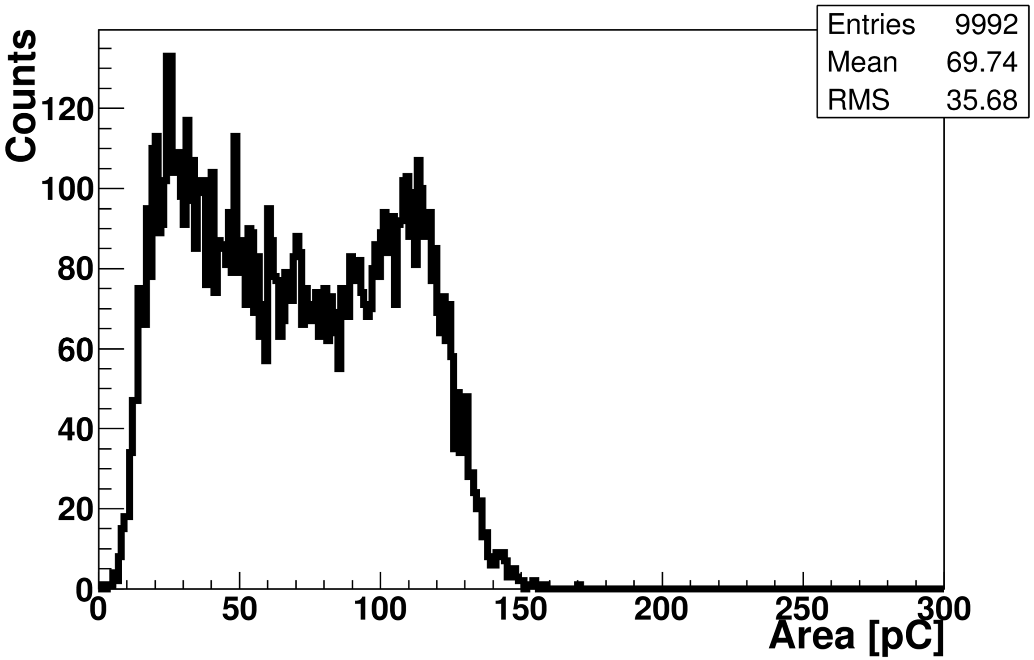
- annihilation gamma quanta
- background from neonium deexcitation
- longer lifetime





Radioactive sources





Simulation of compton spectrum

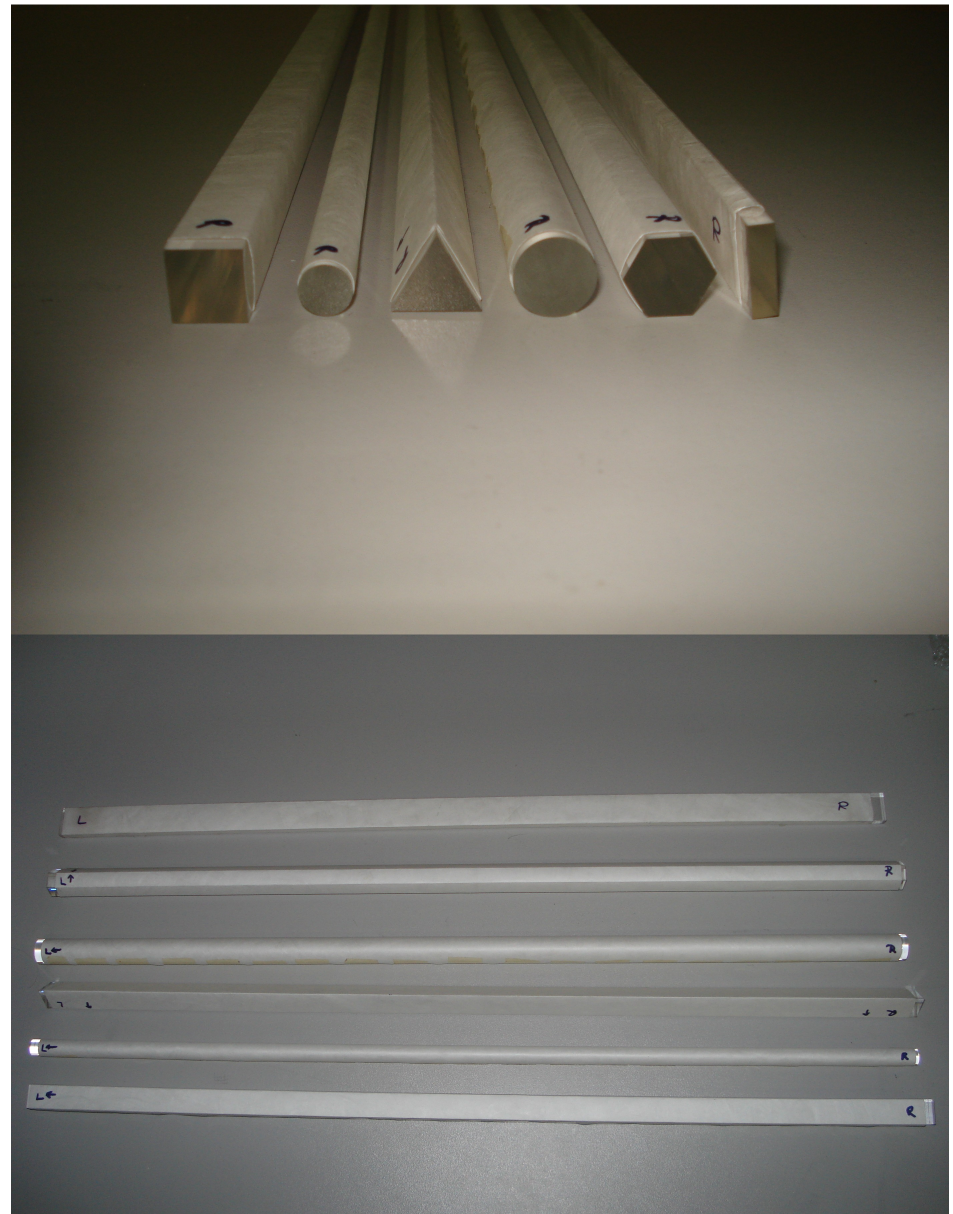
Experiment

Source position

Determination of source position along strip is equal to 0.1mm

Strip shapes

- Square
- Small rod
- Triangle
- Big rod
- Hexagonal
- Rectangular



Strip covering

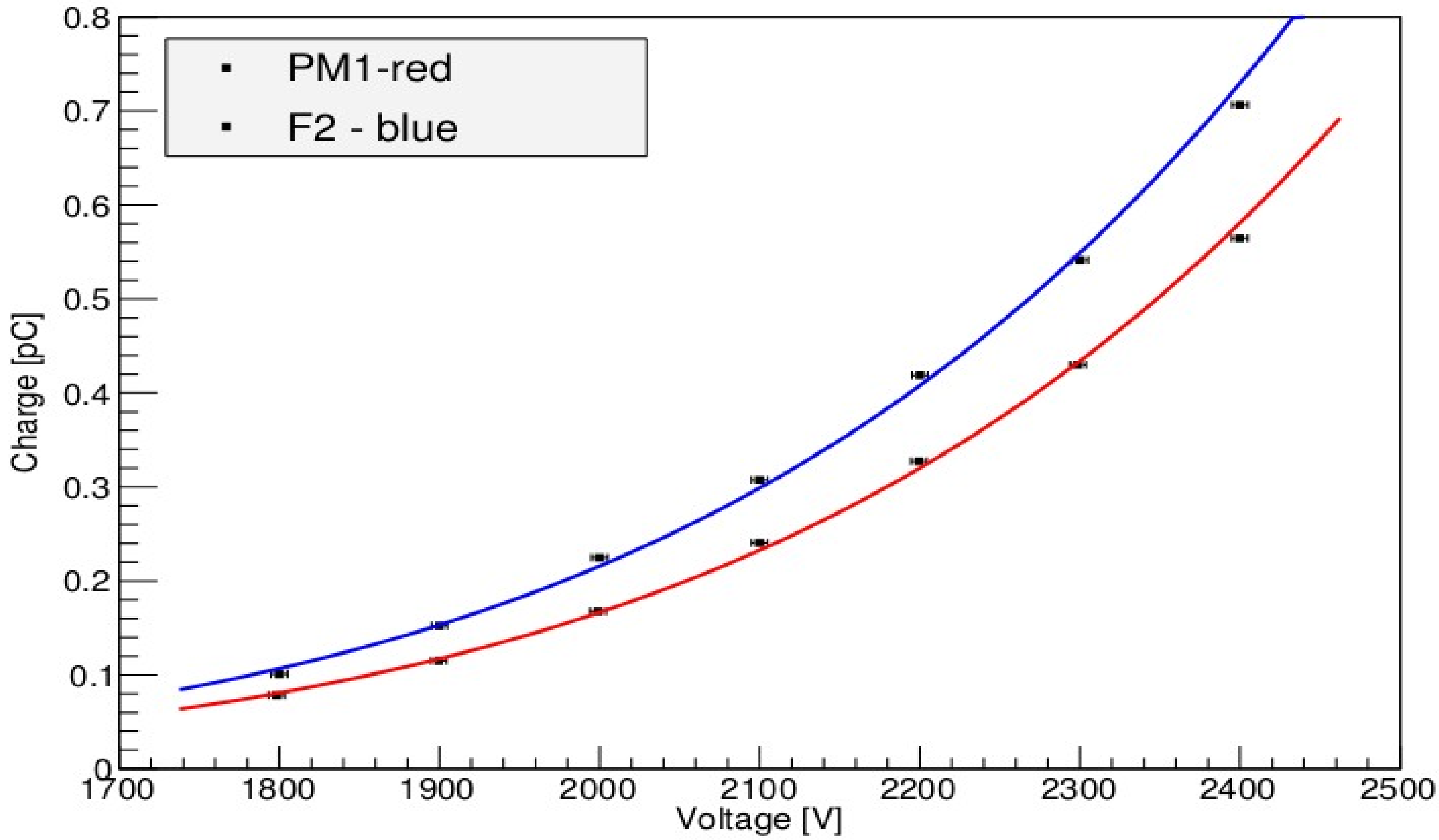
- Tyvek
- Aluminium
- Mylar
- Mirrors
- Paint

Photomultiplier type

Type	Rise time [ns]	Transit time [ns]
R4998	0.7	10
R5320	0.7	10
R9800	1.0	11

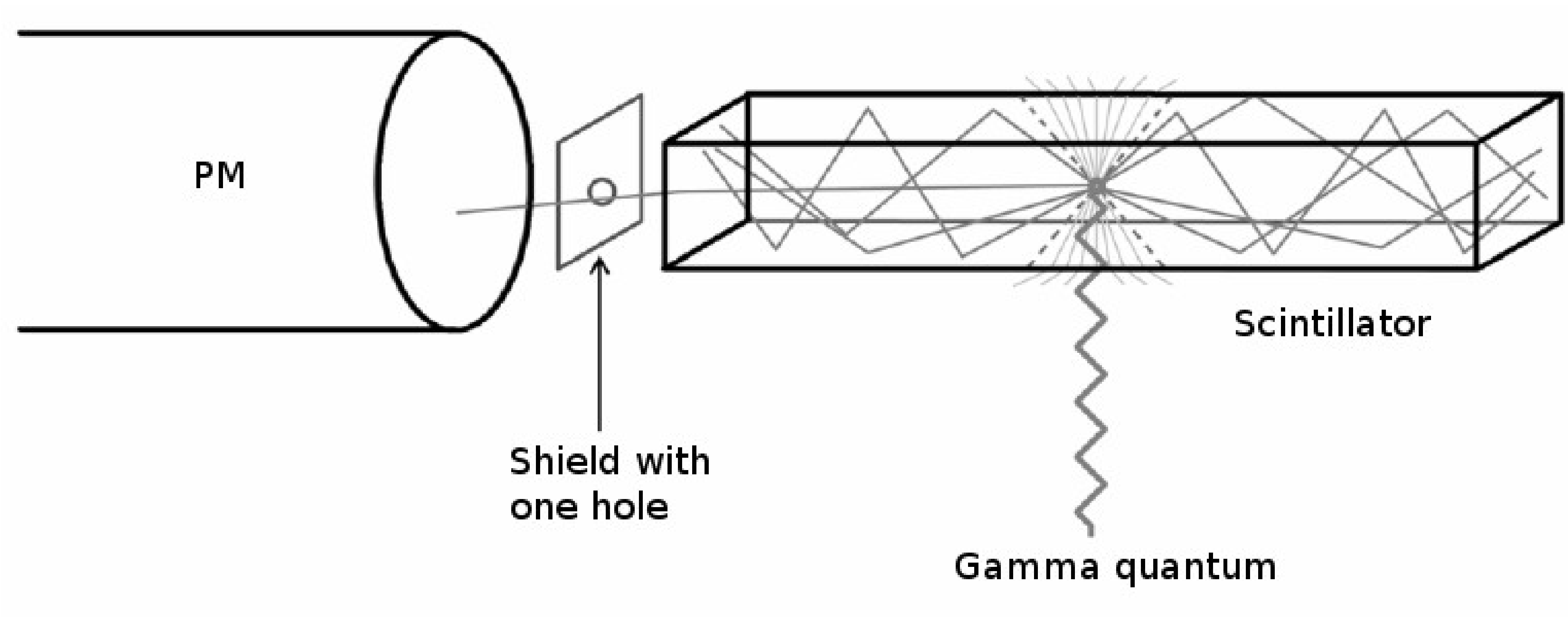
Type	Transit time spread (FWHM) [ns]	Spectral response range [nm]
R4998	0.16	300-650
R5320	0.16	160-650
R9800	0.27	300-650

Photomultiplier Gain

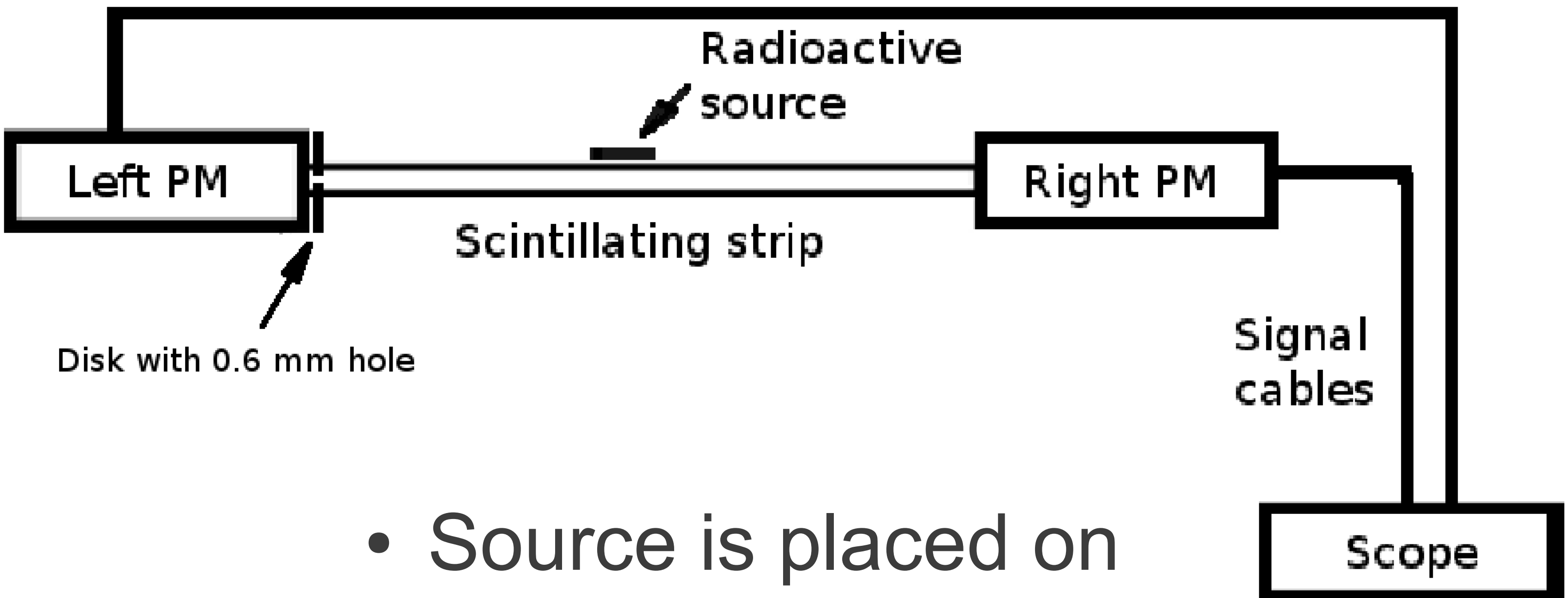


Photomultiplier callibration

Photomultiplier callibration

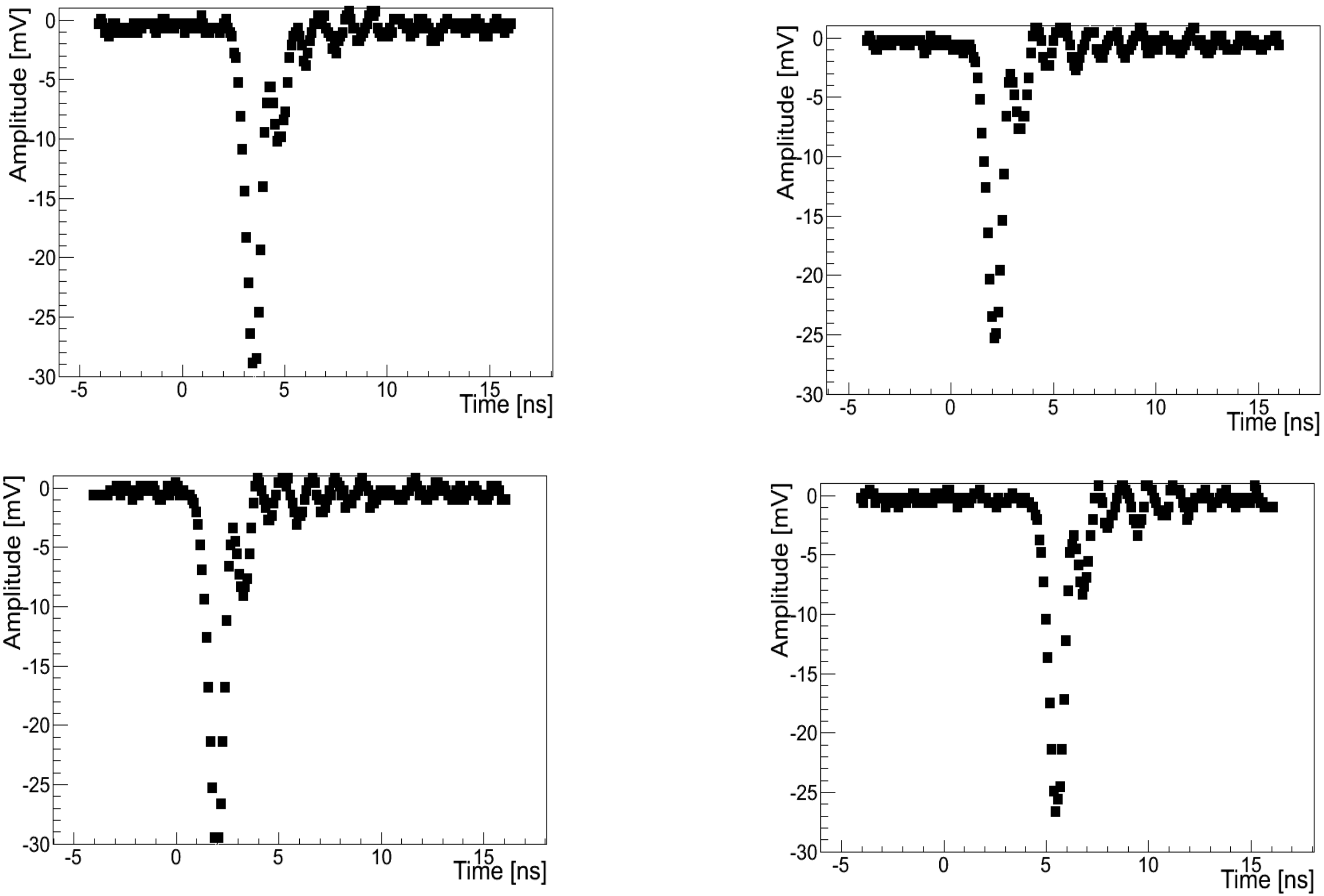


Experimental setup

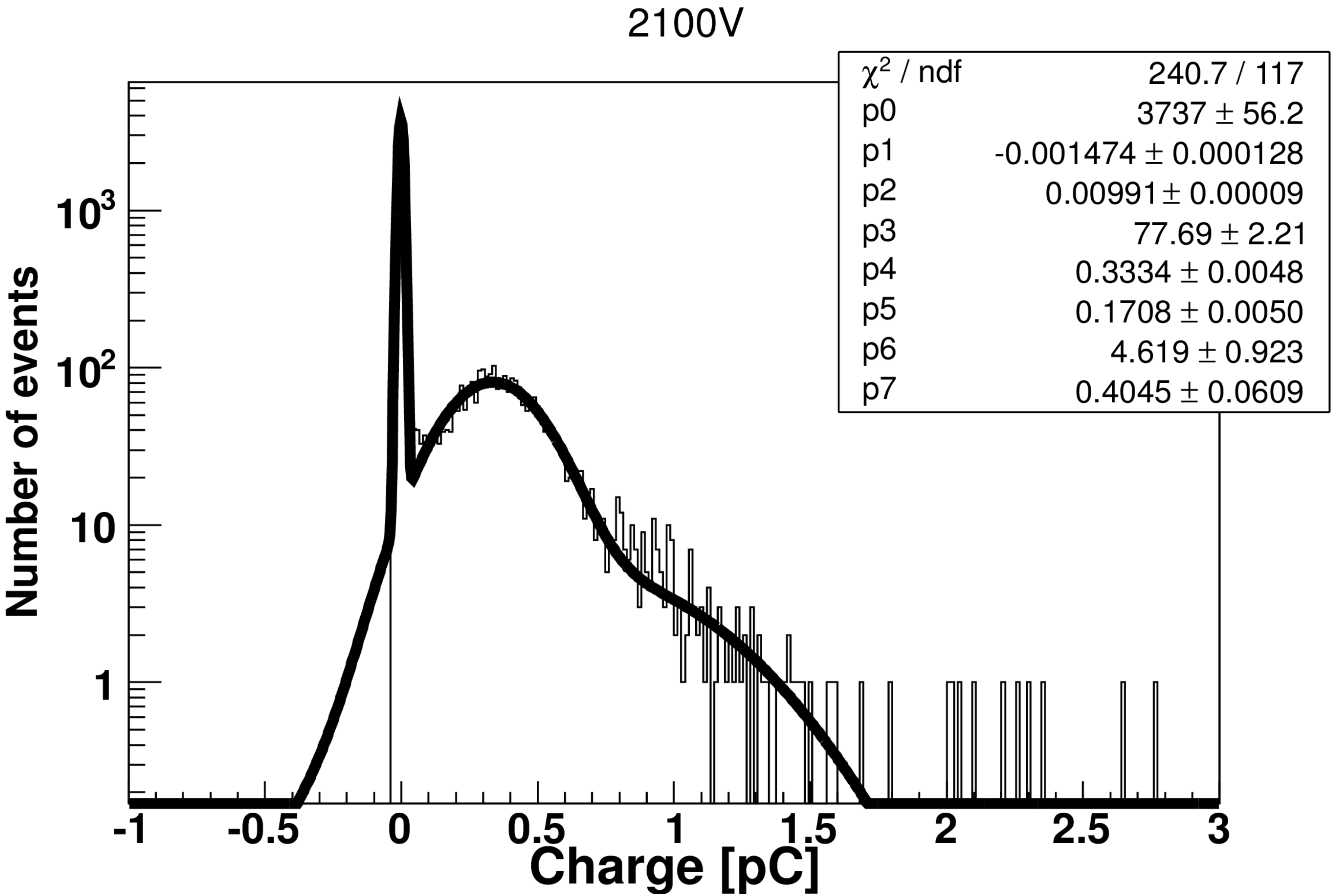


- Source is placed on scintillator
- Signals from left PM are aquired only when another signal appears on right PM

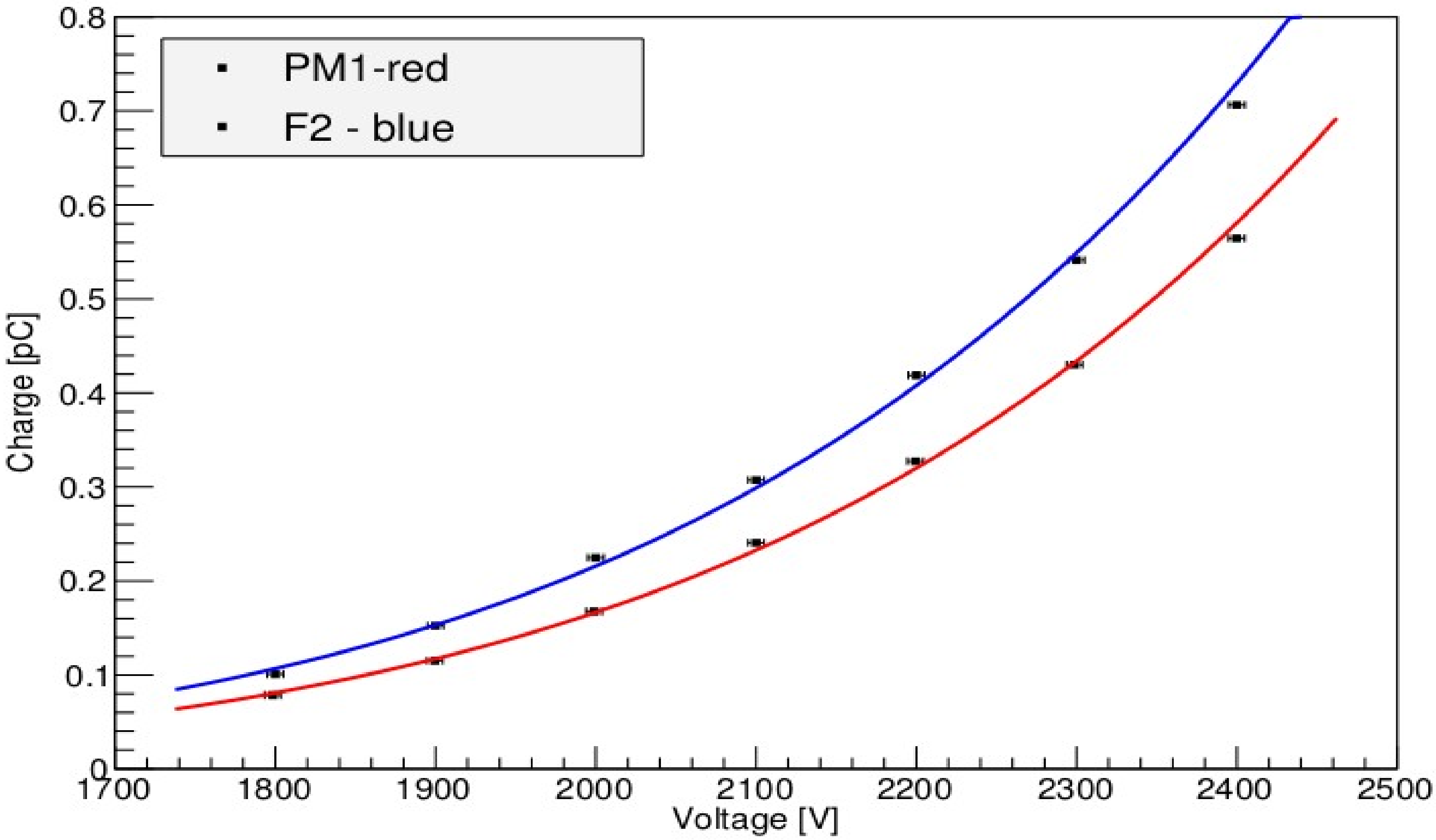
Single photoelectron signals



Single photoelectron spectrum

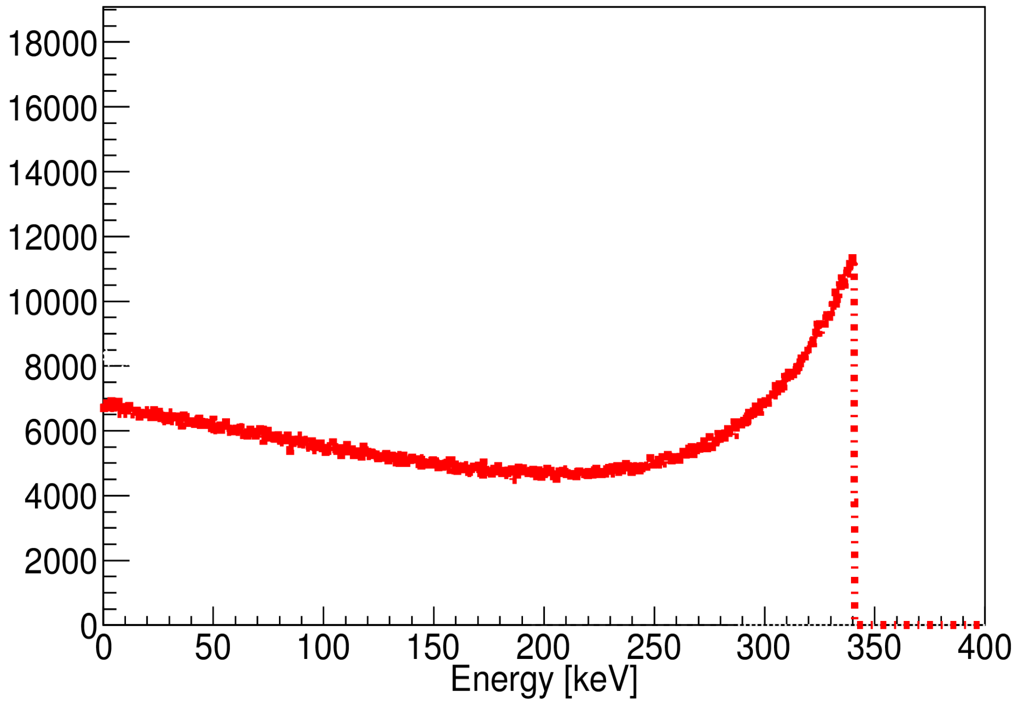


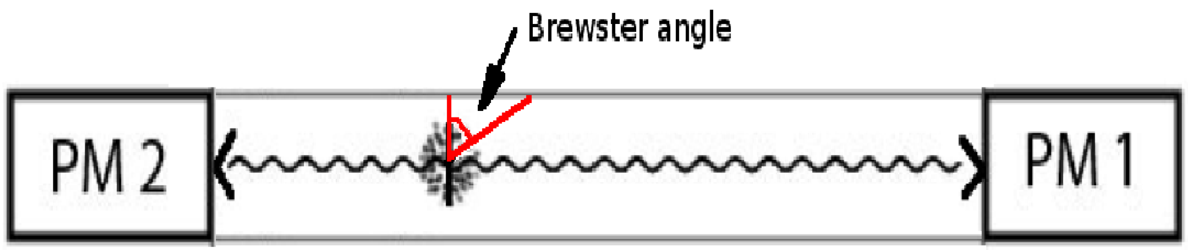
Photomultiplier Gain



Estimation of light reaching photocathode

- Scintillator produces 10 photons / keV deposited
- Mean value of compton spectrum is equal to ~200 keV
- Refraction index of scintillator is about 1.5
- Brewster angle is equal to 33.69°
- So ~63% of photons remain inside scintillator

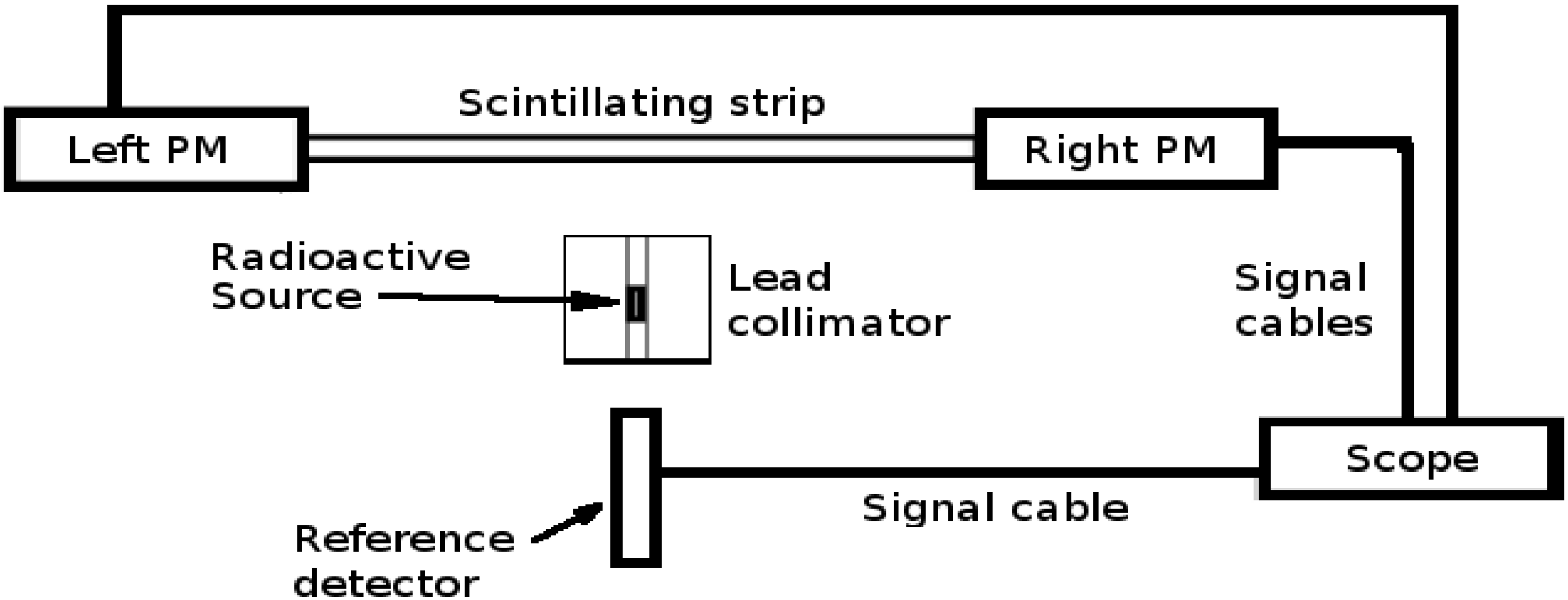




- This gives about 600 photons per photomultiplier

Experimental campaigns

Experimental campaigns



Three types:

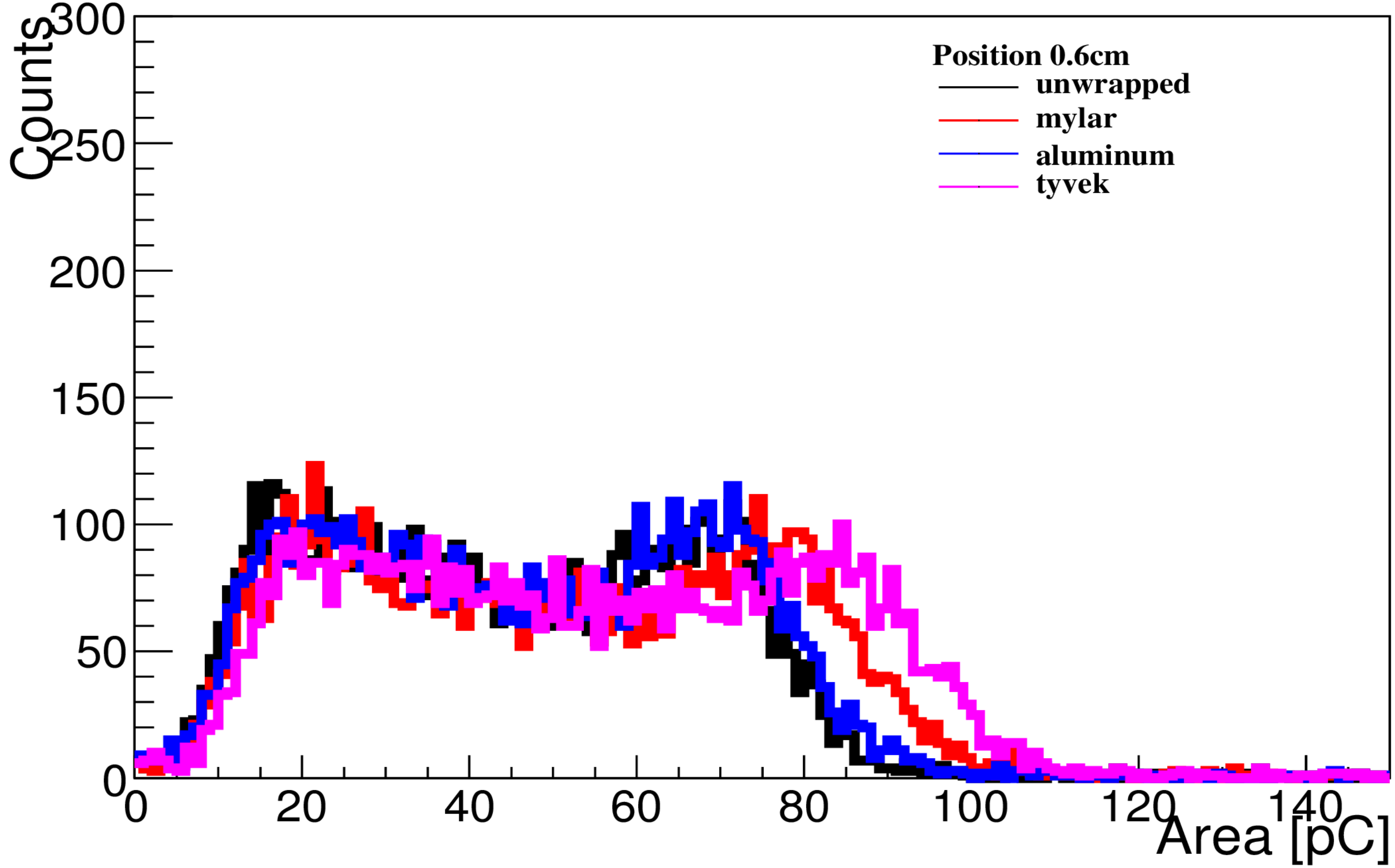
1. Shape measurements
2. Covering measurements
3. Precise scans

Covering measurements

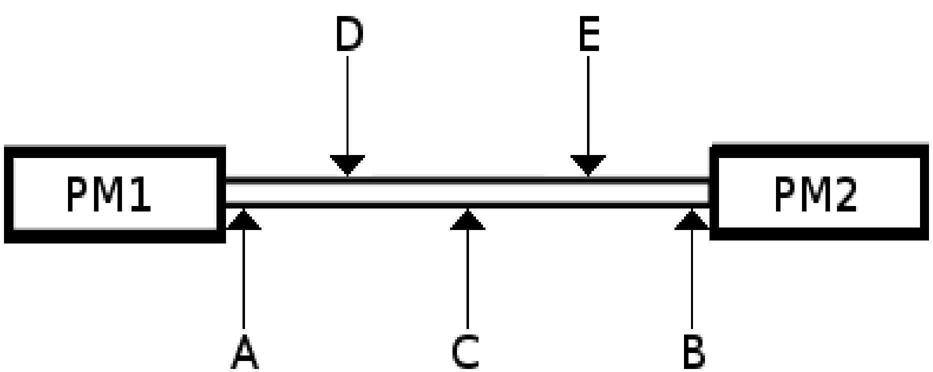
- scintillator covered with different materials
- radioactive source placed in collimator and moved along scintillator strip in constant intervals
- Distance from 28.5cm to 0.6cm (along strip) with 9mm steps
- Each position with ~6.5 kev

<u>Tyvek chosen as covering</u>

Results from covering measurements



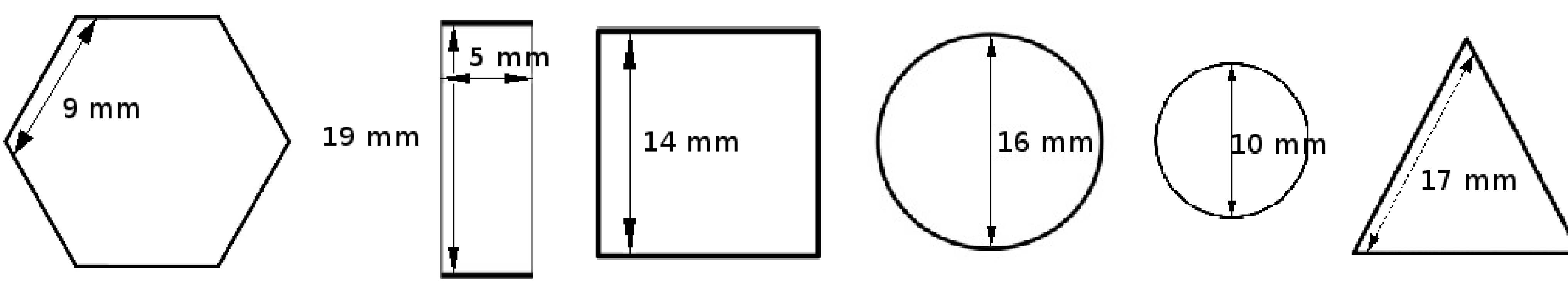
Shape measurements



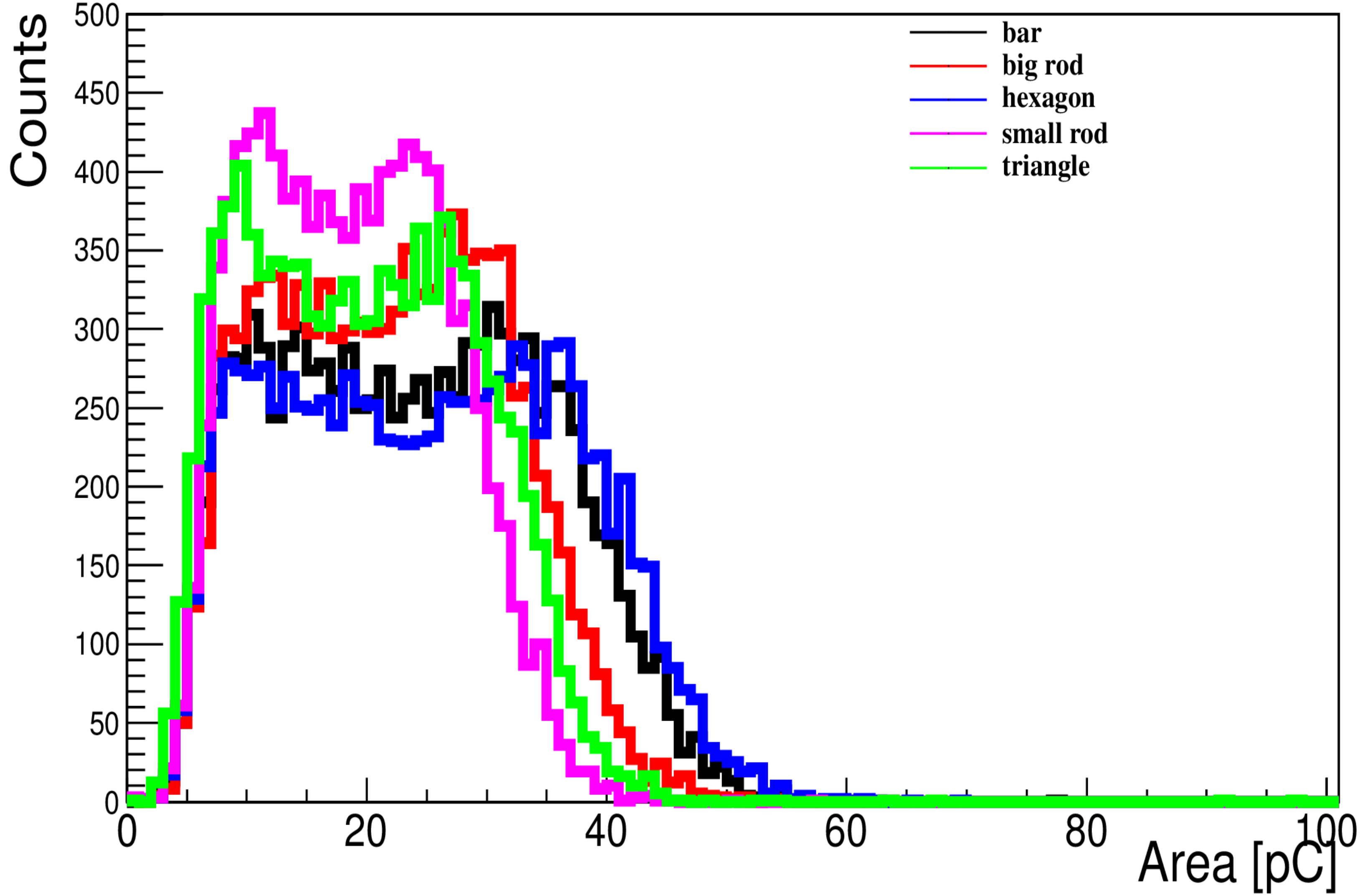
- different transverse shapes of scintillators tested
- radioactive source placed in collimator and moved along scintillator strip in constant intervals
- five positions along strip were measured
- each position with ~6.5 kev

<u>data is still being analysed</u>

<u>preliminary results will be presented</u>

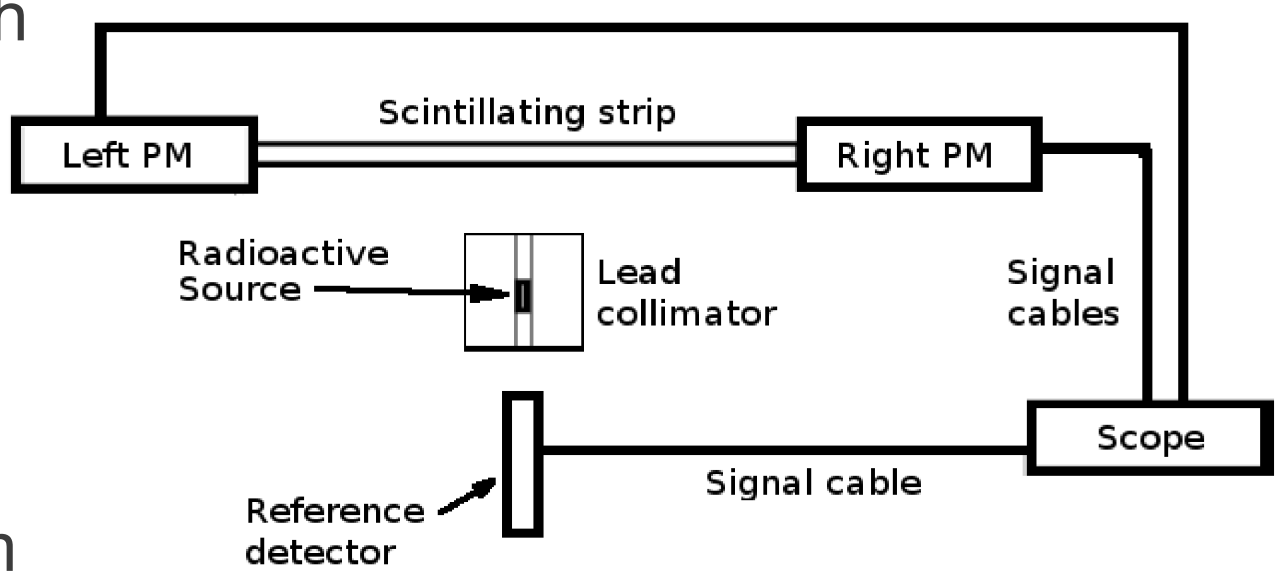


Preliminary results from shape measurements



Precise scan campaings

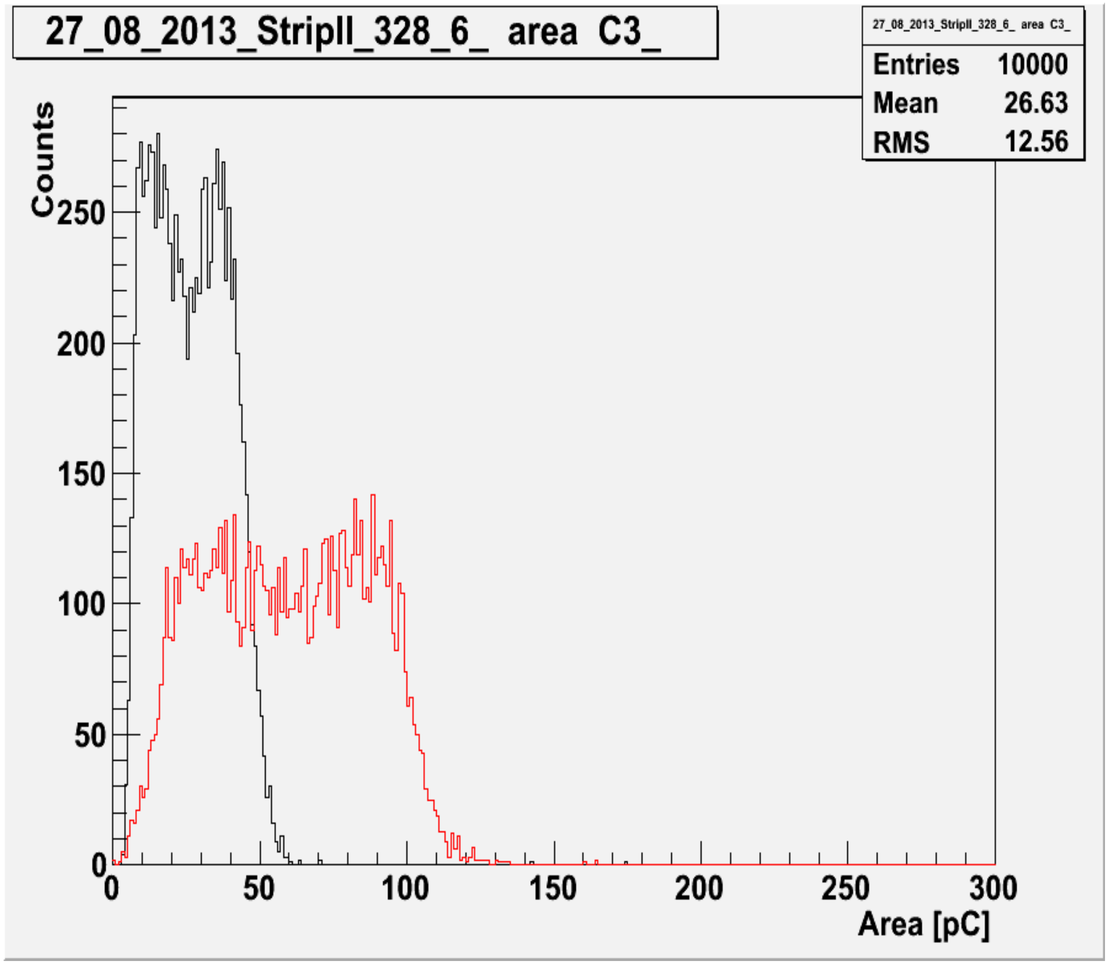
- Scintillator strip scanned with smaller interval with each campaign
- Leads to many improvements of experimental setup
- Data will be used for reconstruction algorithm and simulations



Most recent precise scan campaign

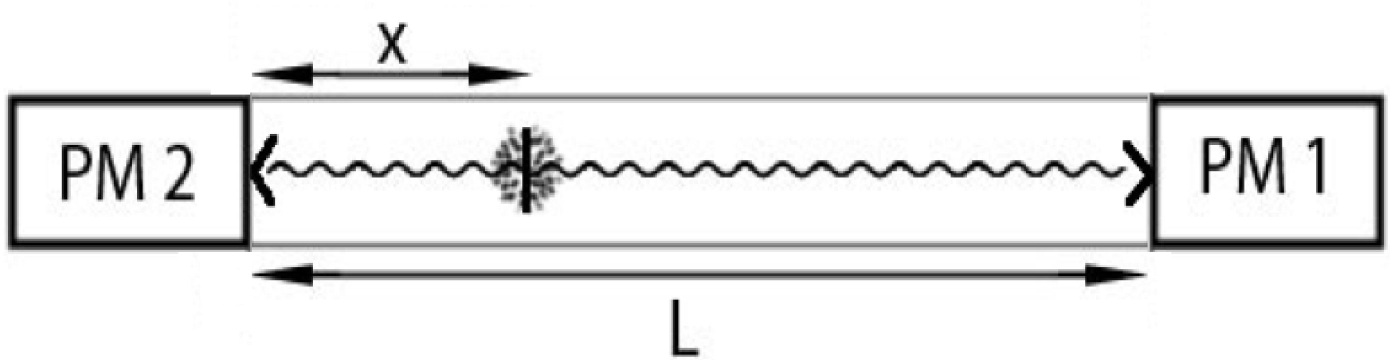
- rectangular 30cm EJ230 strip was scanned with 3mm intervals
- 10k signals from both PMs on each were gathered

<u>data recently collected only preliminary results will be presented</u>

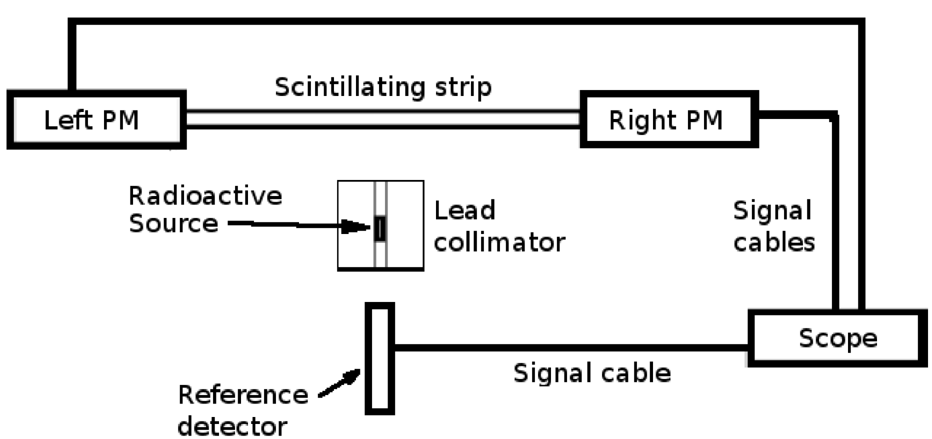


Light velocity for different scintillator shapes

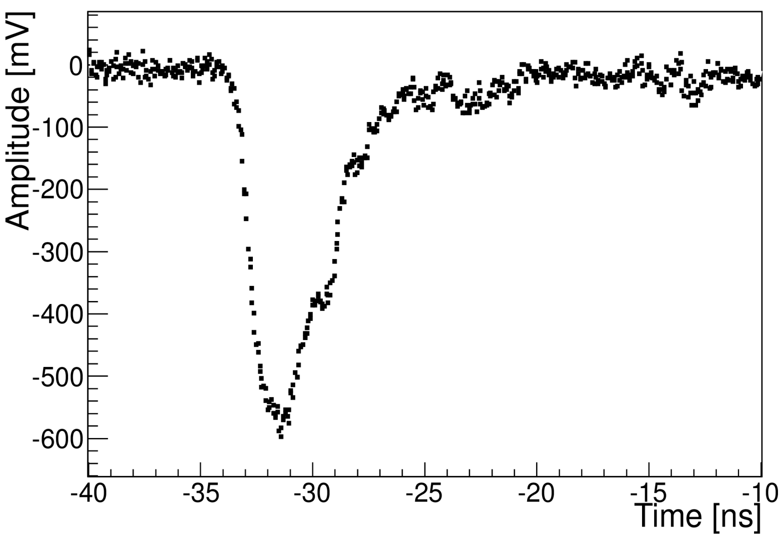
Dependence of scintilator shape on light velocities

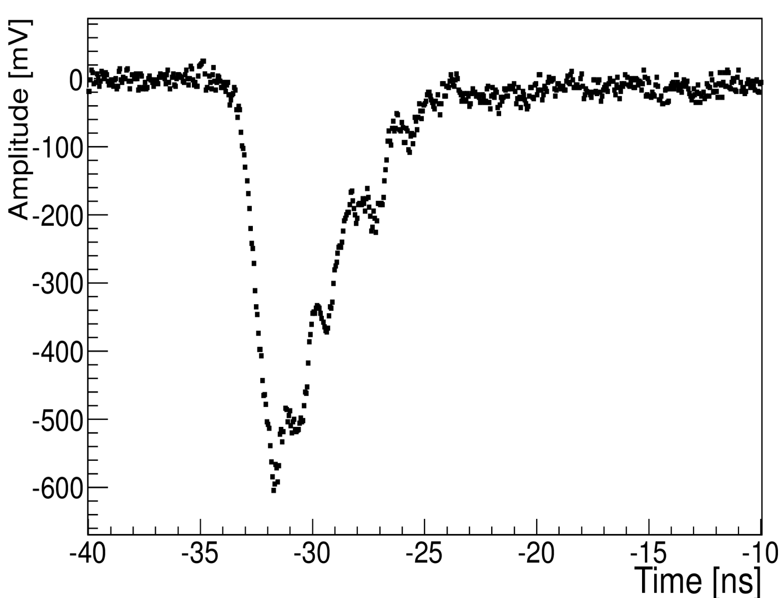


$$\Delta t^{exp} = t_2^{exp} - t_1^{exp} = \frac{L - 2x}{v_{eff}}$$



Aquired signals



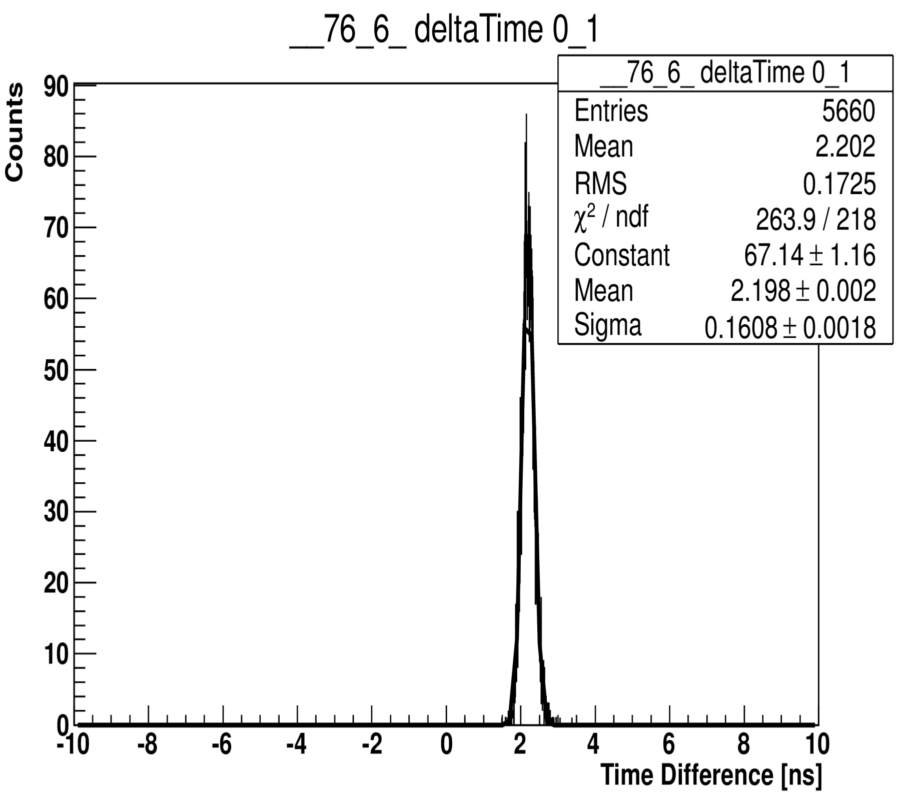


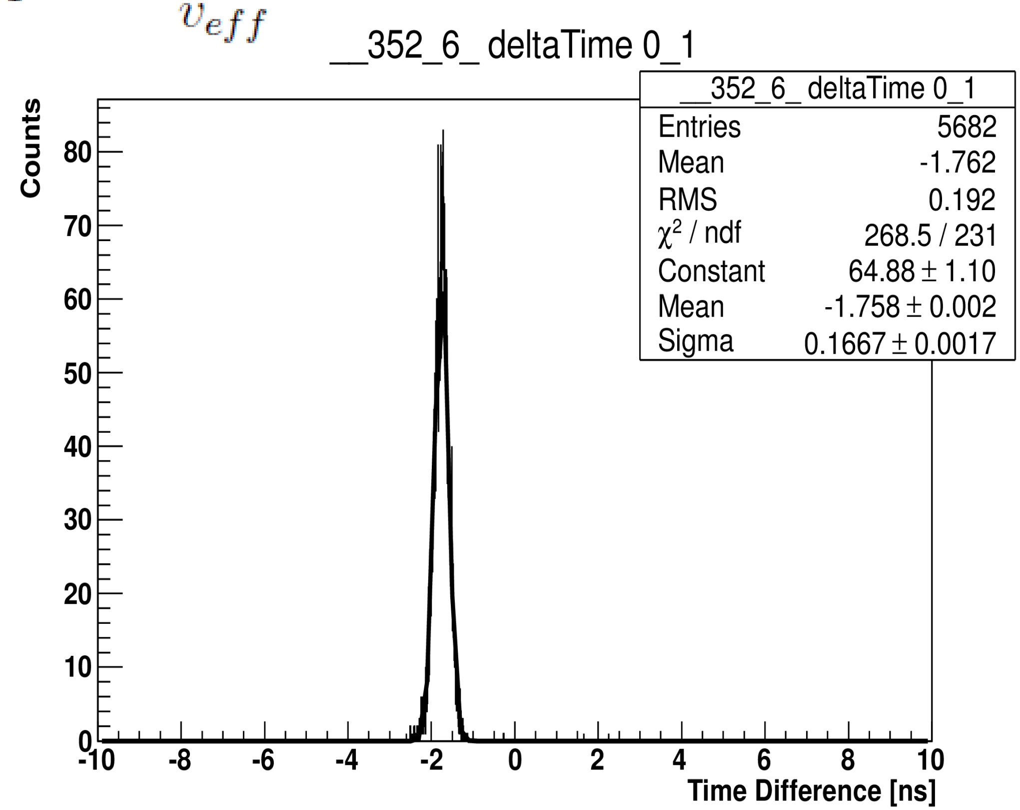
Each signal consists of about 200 points

Time difference between signals was measured at 100mV

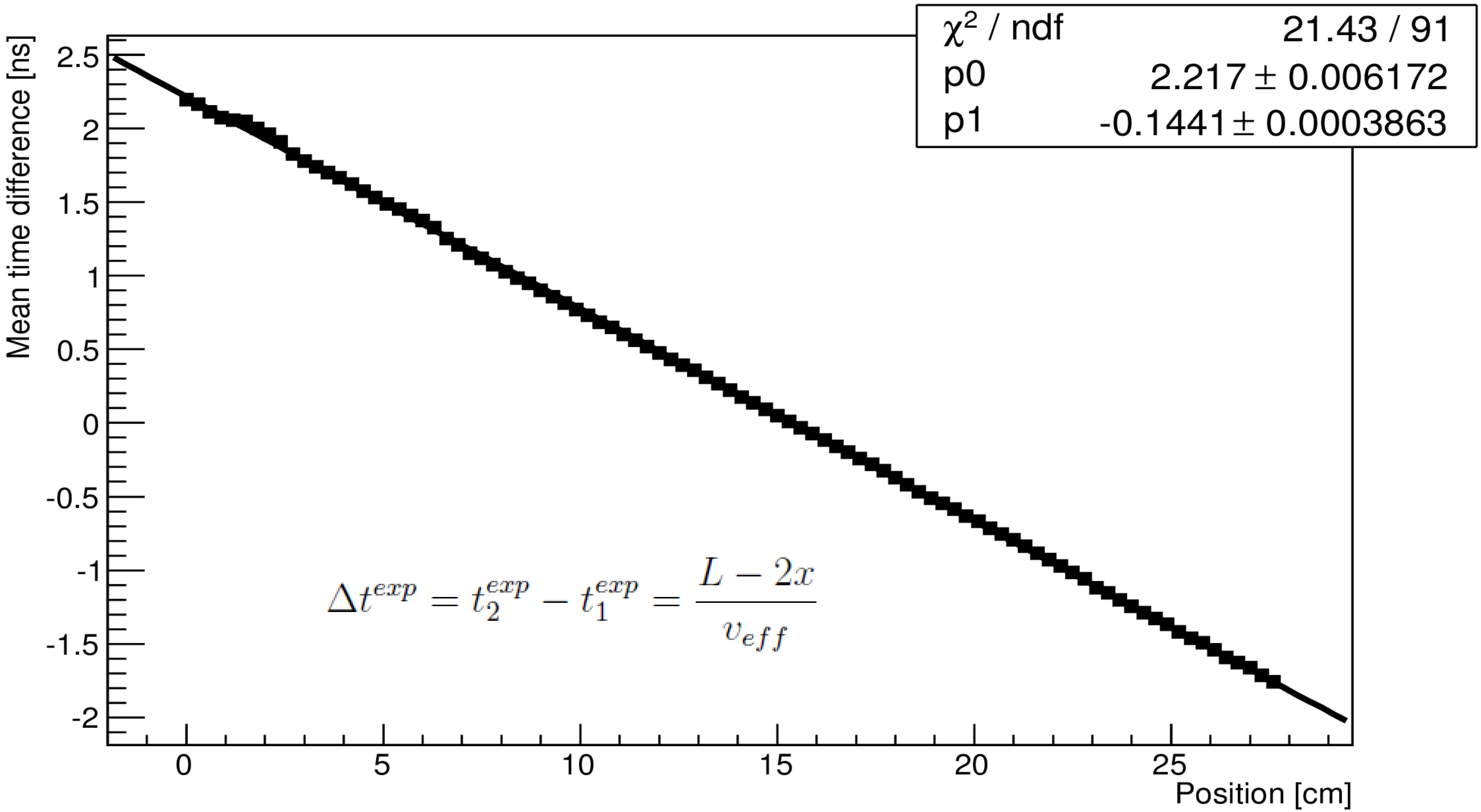
Time difference distributions

$$\Delta t^{exp} = t_2^{exp} - t_1^{exp} = \frac{L-2x}{v_{eff}}$$





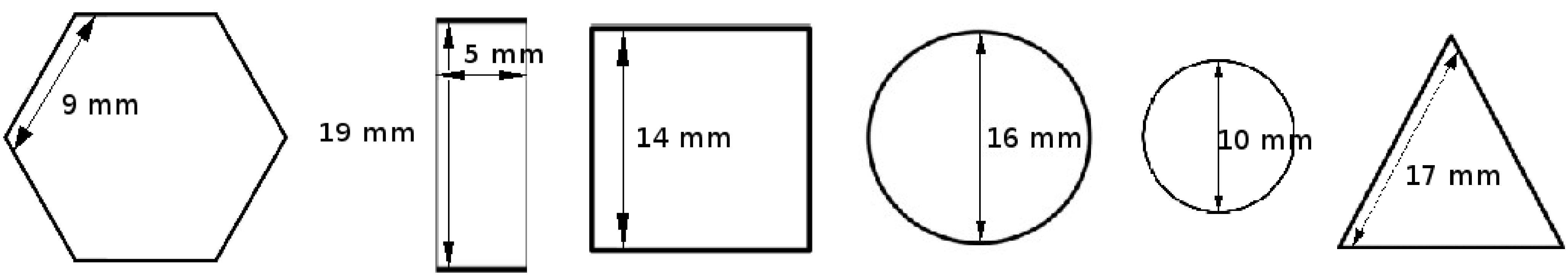
Mean value vs position



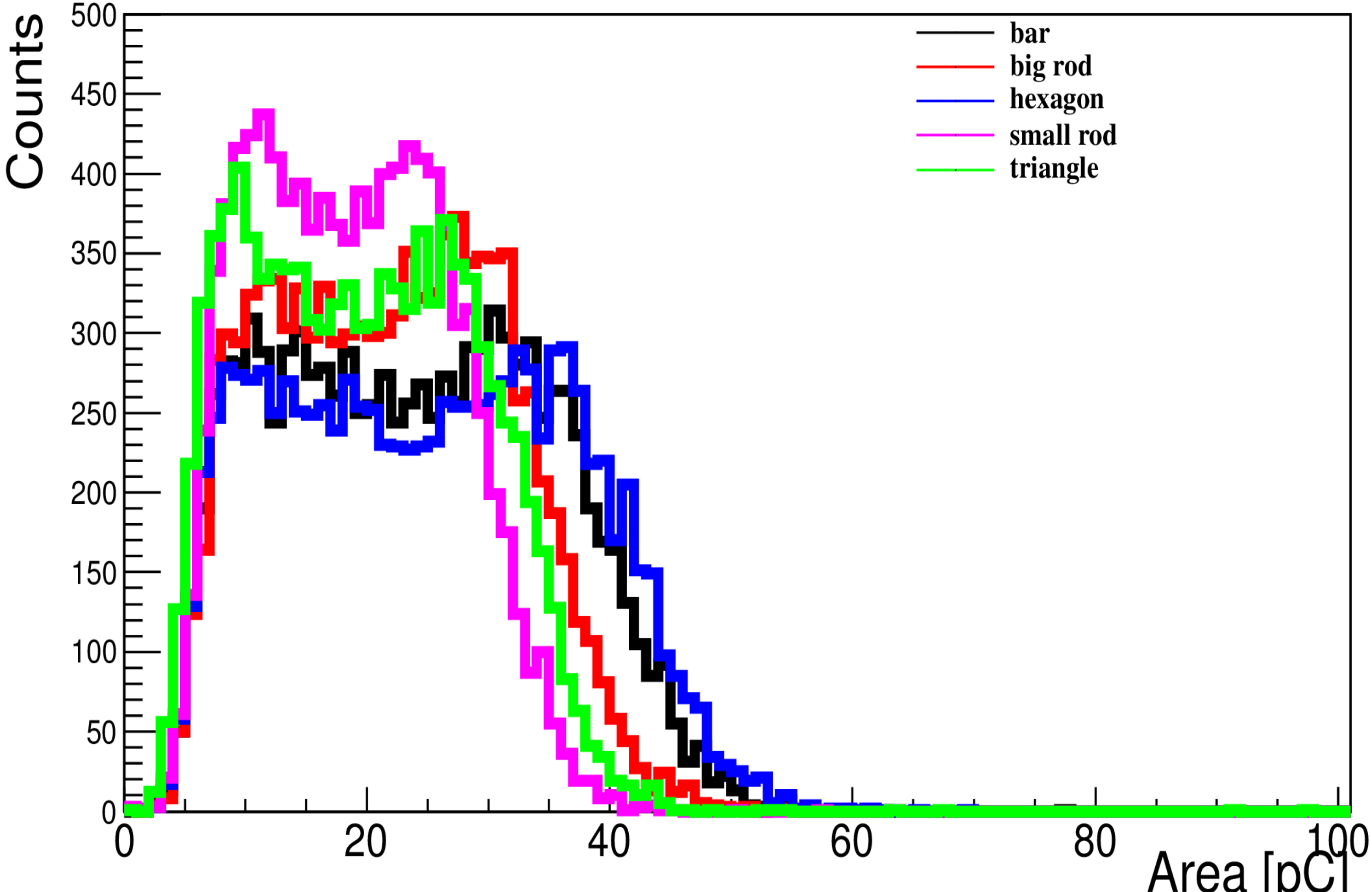
$$\Delta t^{exp} = t_2^{exp} - t_1^{exp} = \frac{L - 2x}{v_{eff}}$$

Light velocity

Shape	Velocity [cm/ns]	Dimensions [cm X cm X cm]
Small rod	9.12 ± 0.04	1 cm dia x 50 cm lenght
Big rod	9.46 ± 0.04	1.6 cm dia x 50 cm lenght
Triangle	10.89 ± 0.05	1.7 cm side x 50 cm lenght
Square	11.20 ± 0.05	1.4 cm side x 50 cm lenght
Hex	11.57 ± 0.06	0.9 cm side x 50 cm lenght
Rectangular	13.88 ± 0.04	0.5 cm x 1.9 cm x 30 cm



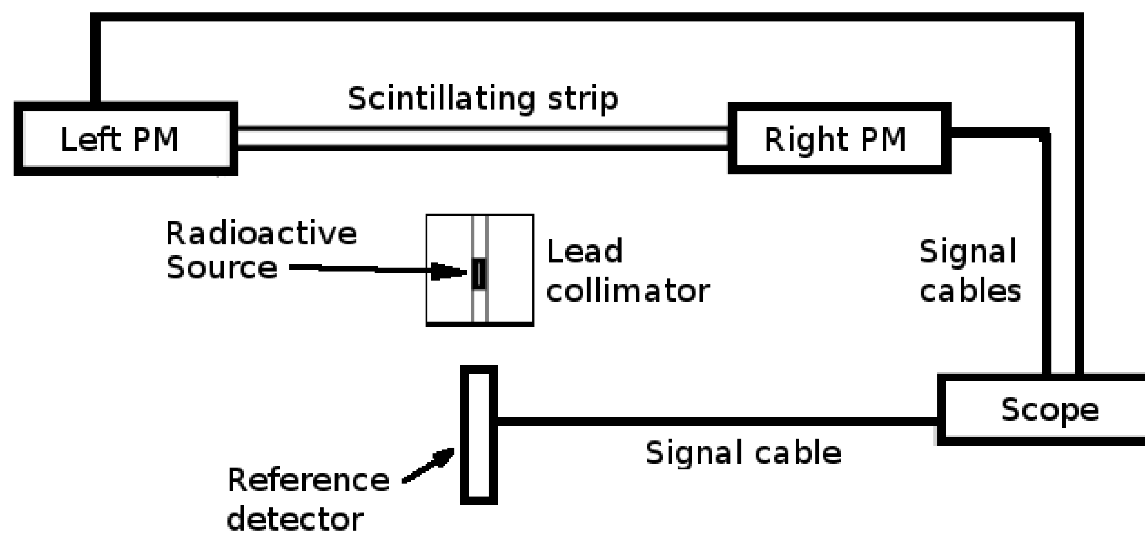
Preliminary results from shape measurements



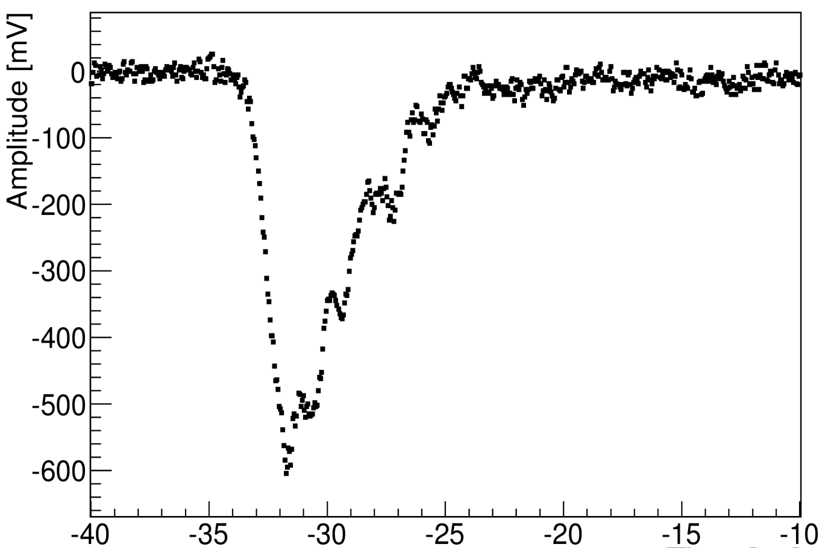
Preliminary results from Strip Scan

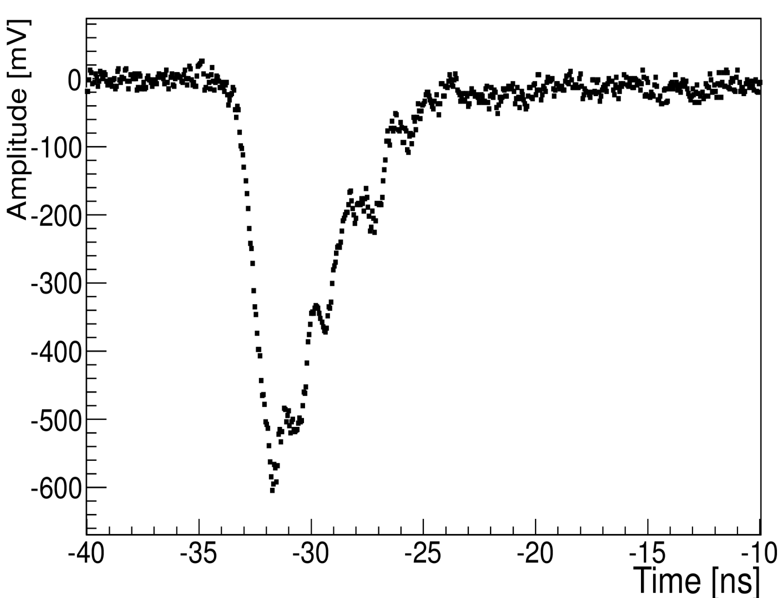
Preliminary results from Strip Scan

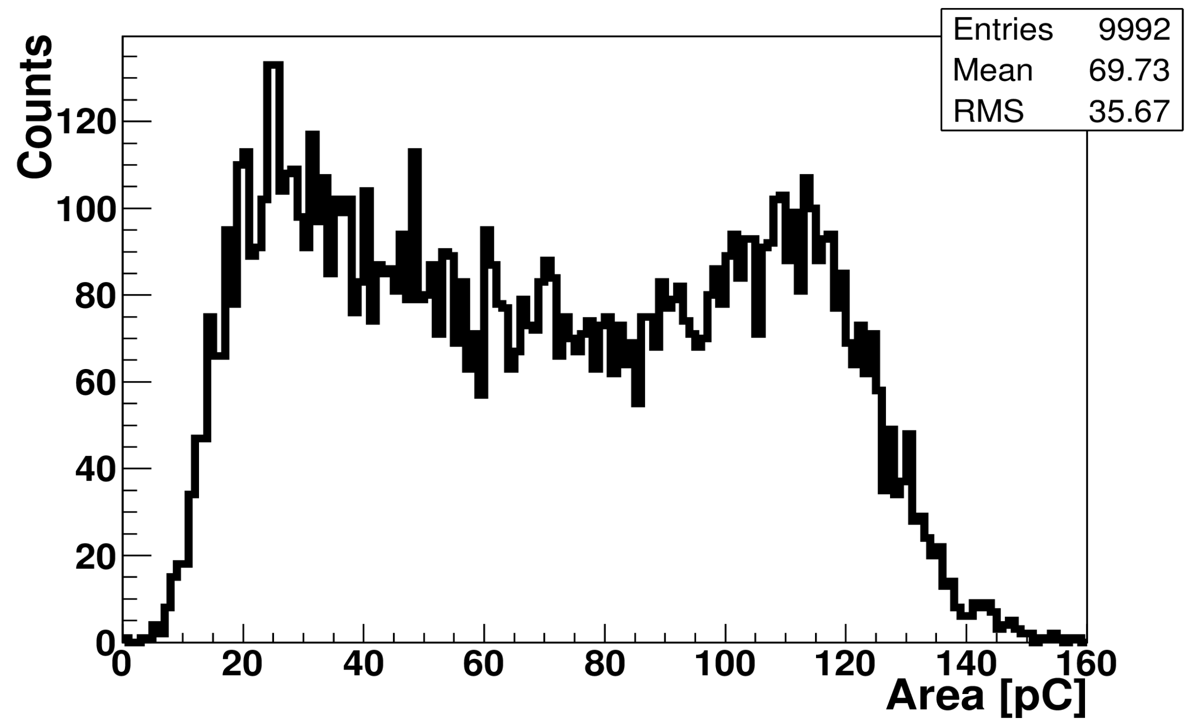
- Two R5320 PMs were used
- Scan of 30cm strip with 3mm interval
- 10k signals/per position from both sides collected



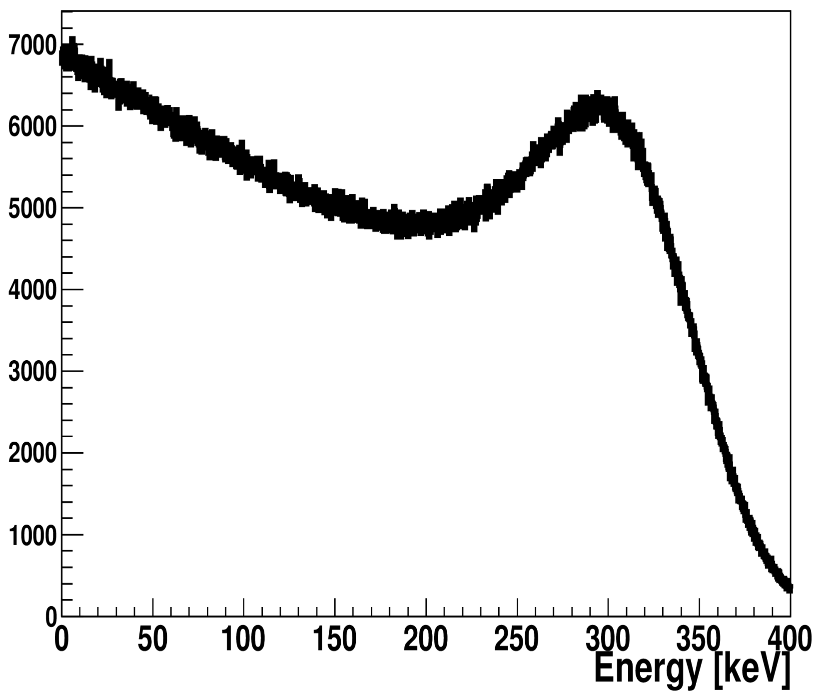
Sum of area spectrum



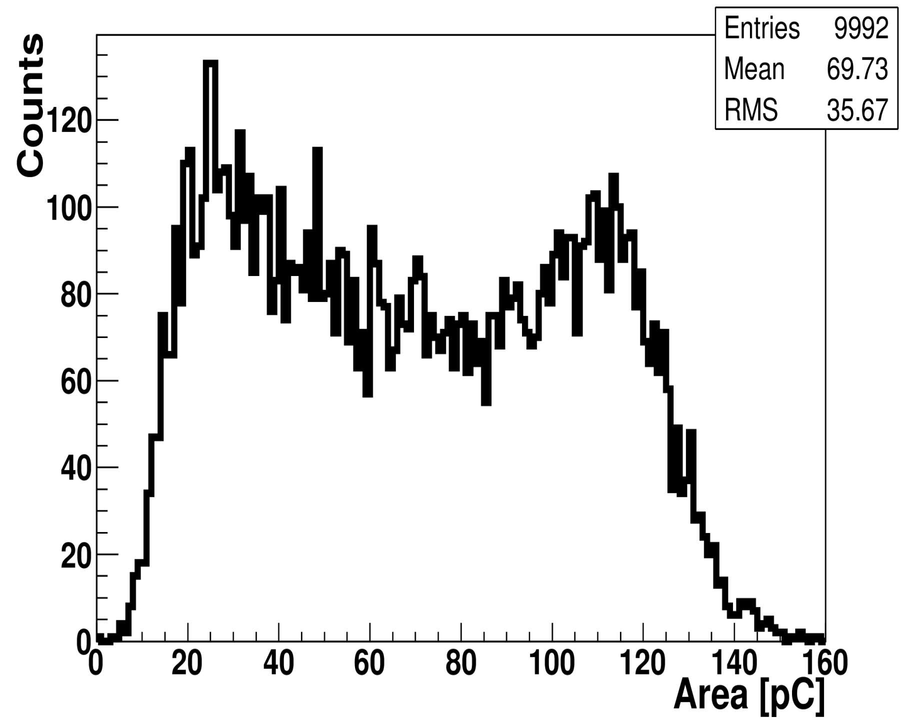




Energy resolution

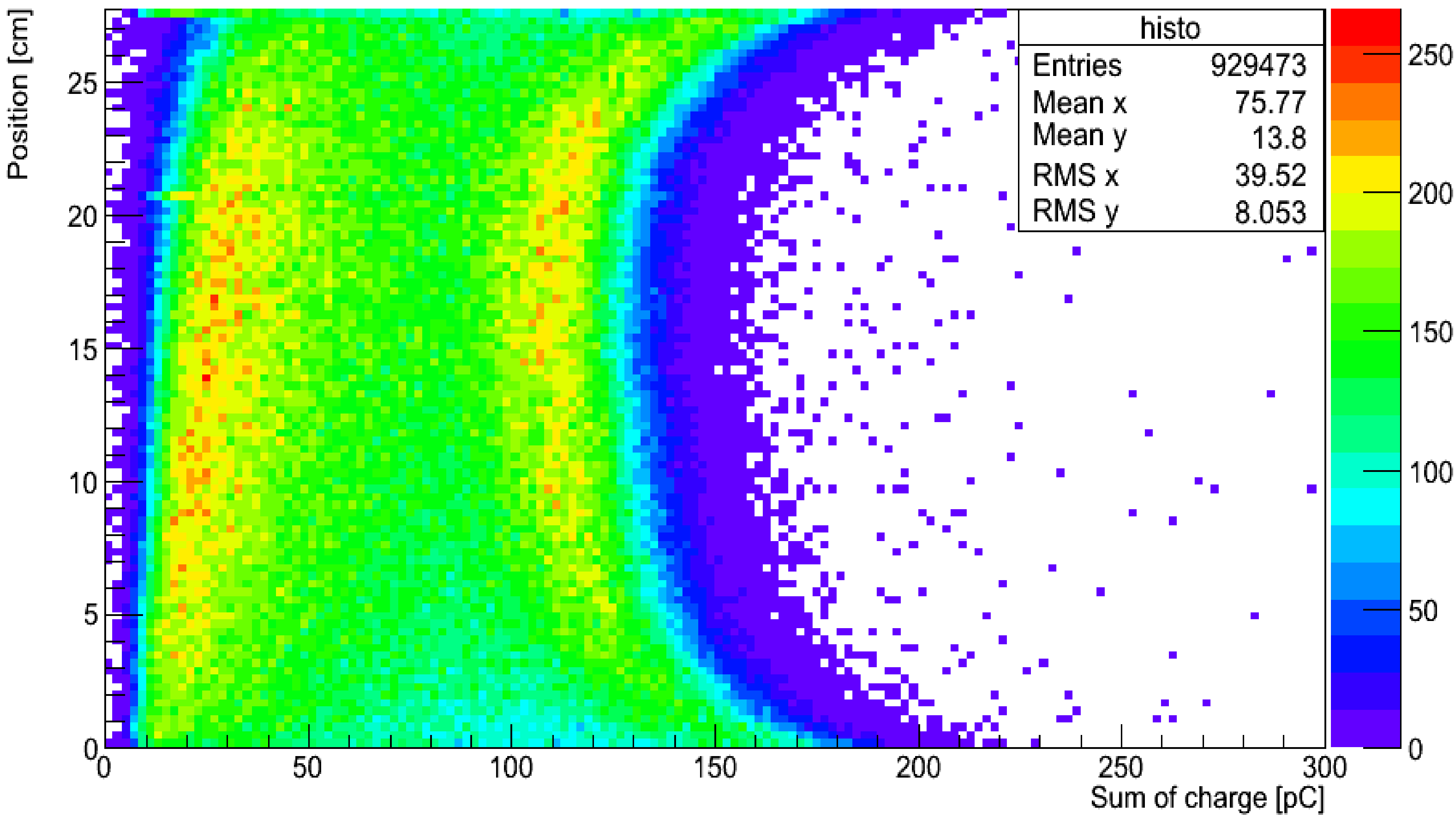


Simulation of compton spectrum with 10% smearing

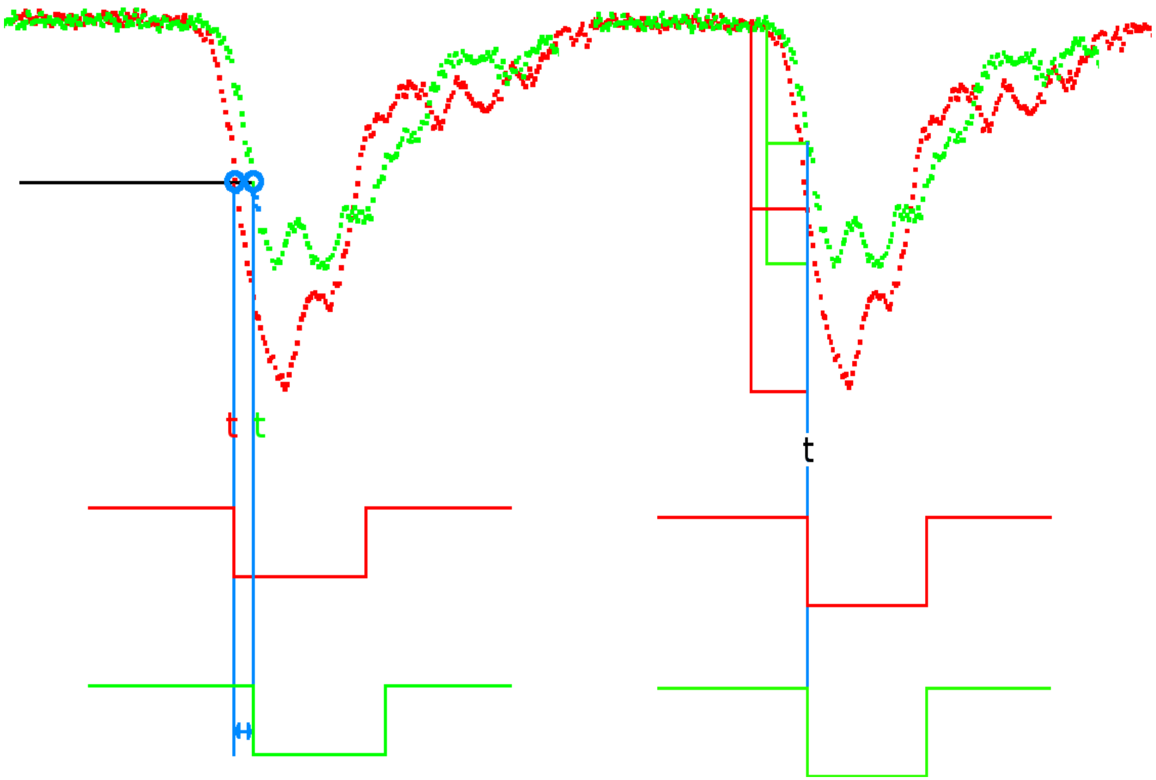


Experiment

Charge vs position spectra

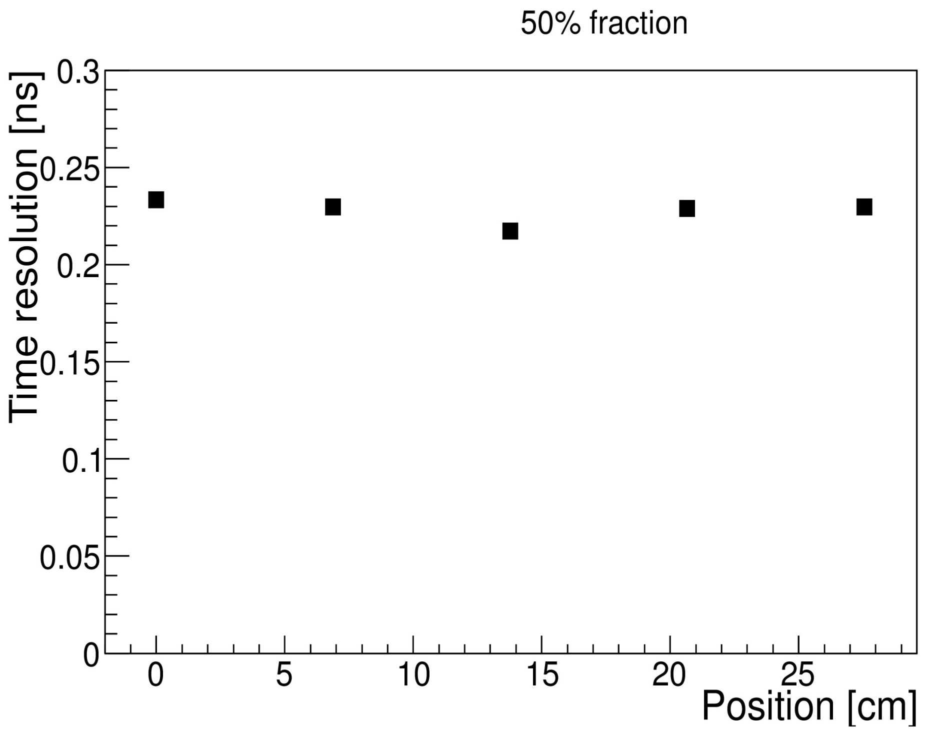


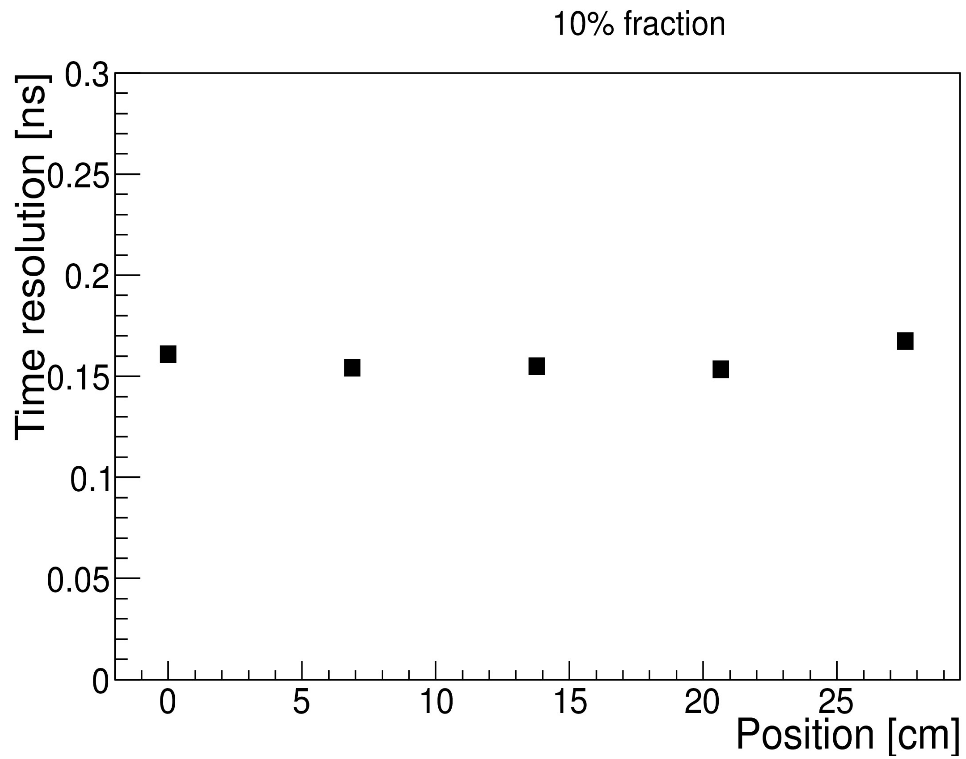
Threshold and fraction discriminators



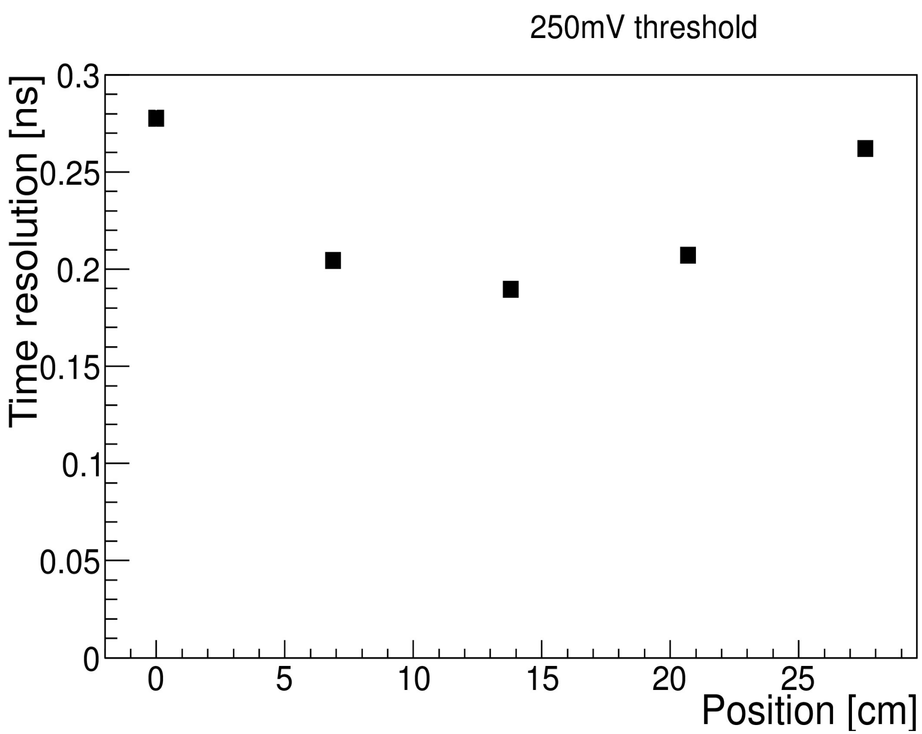
- Constant threshold discriminator (left picture) suffers from walk effect
- Constant fraction discriminator does not cut smaller signals

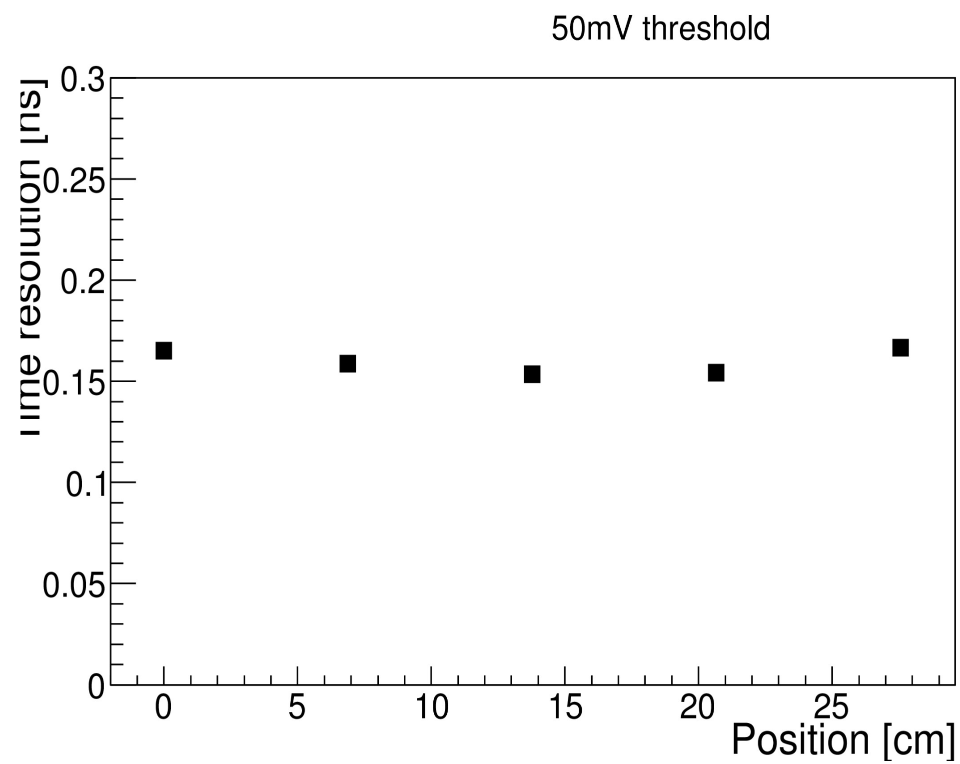
Precision vs fraction



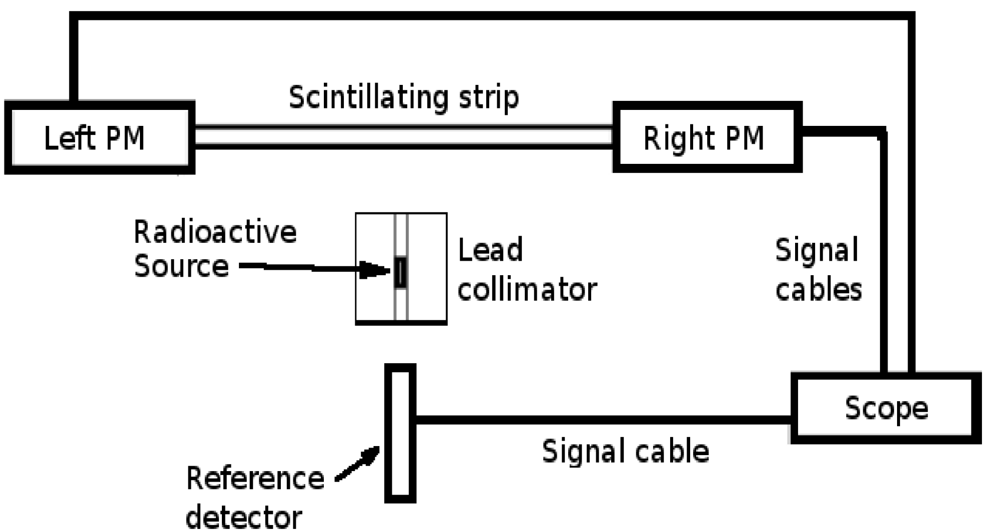


Precision vs threshold



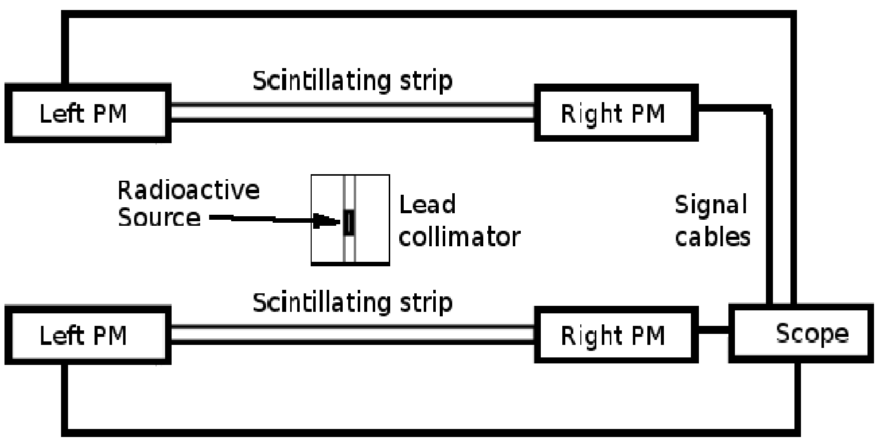


Future plans



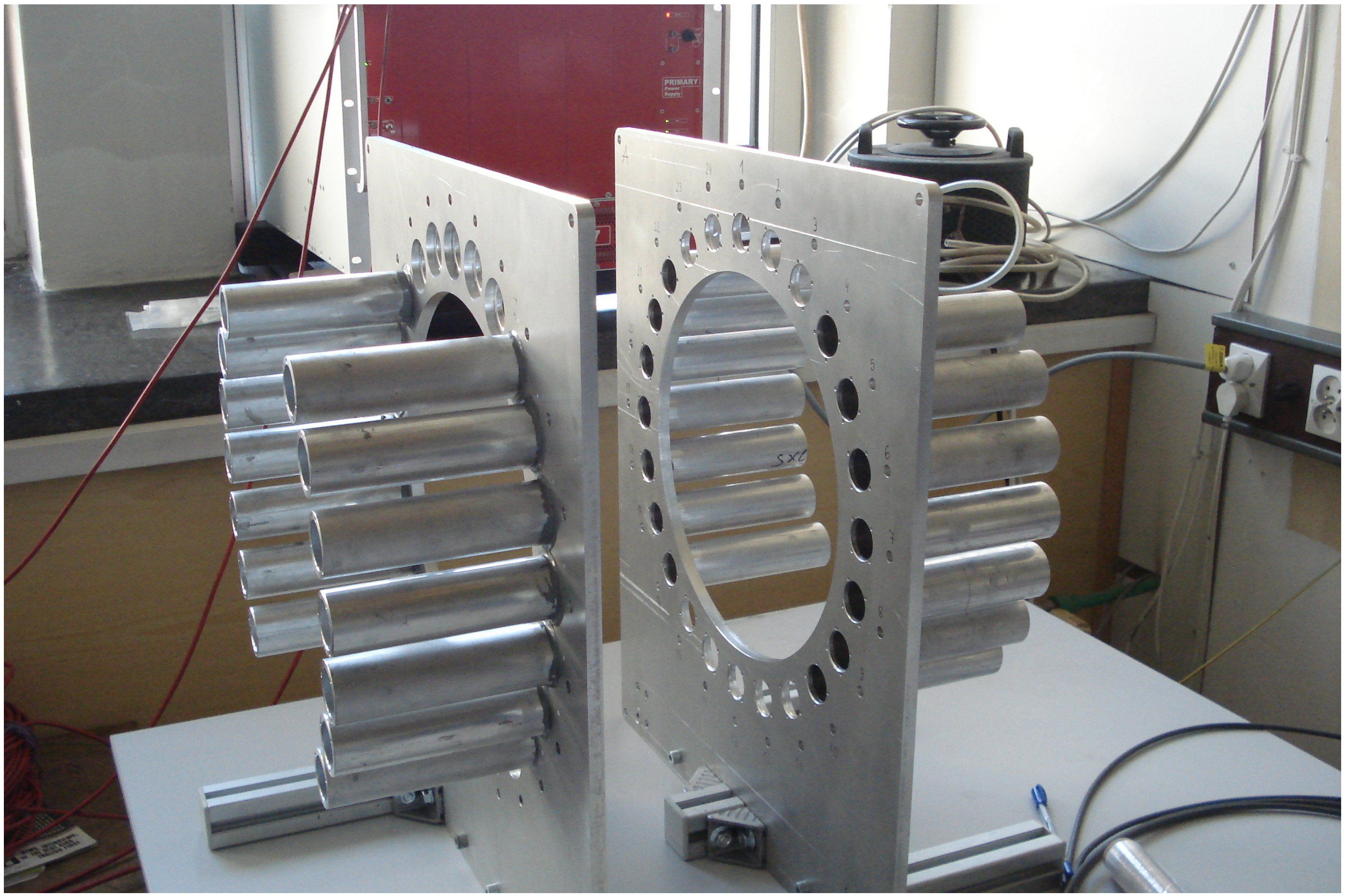
- Two strips measurements
- Barrel assembling

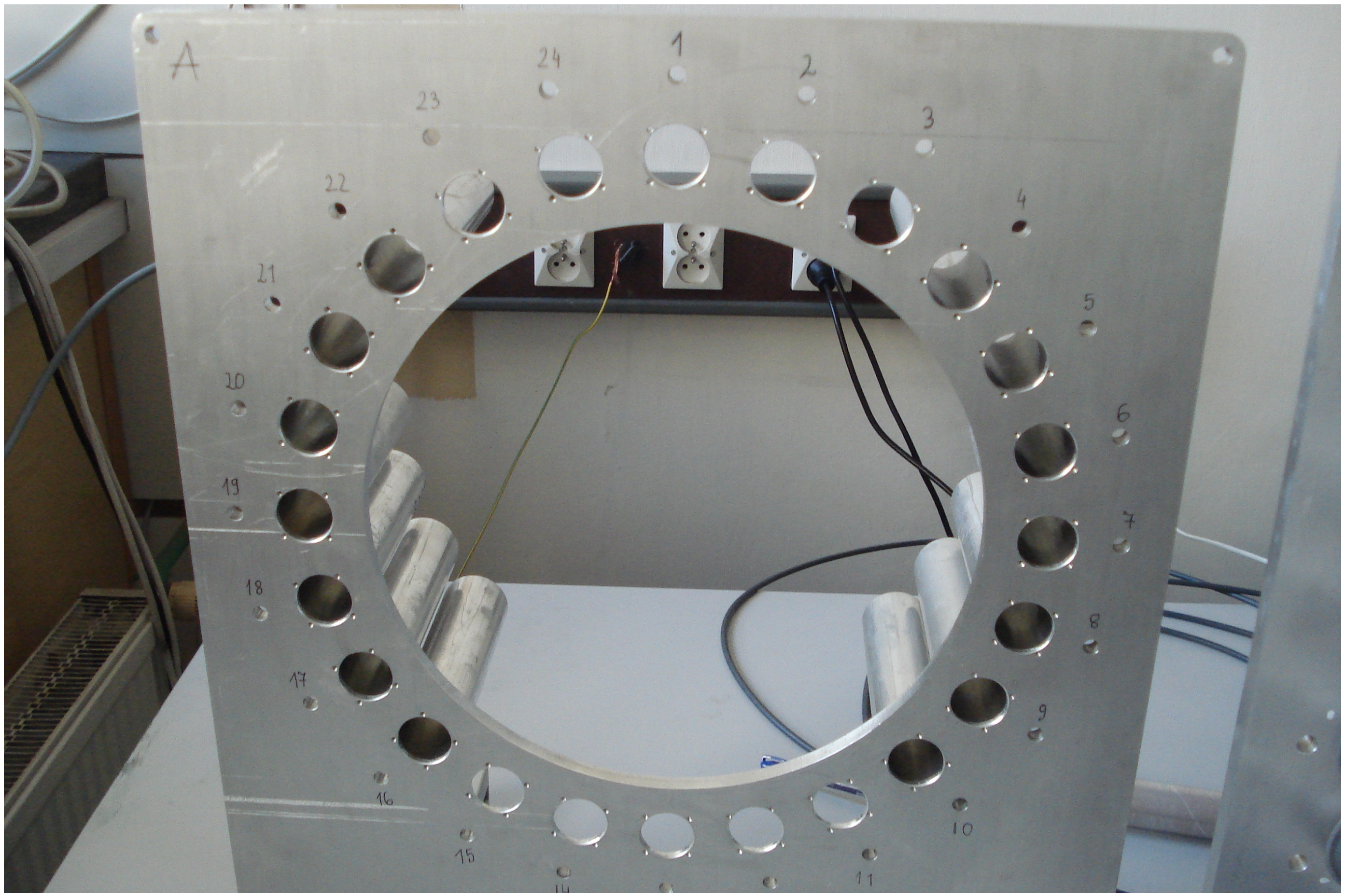
Two strips measurement



- Signals from four PMs aquired on the scope
- Experimental data for reconstruction group
- Gaining experience neccesary for barrel assembling

Barrel assembling

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Summary

- Preliminary results of area comparison for different shapes indicate that hex shape should be the best choice
- Yet light velocities for different shapes indicate that small rod shape is the best choice
- Time resolution equal to ~160ps was obtained with single threshold discrimination
- Estimated energy resolution is ~10% or better

Thank you for your attention