Calibration of MCP and image plates (IP) for multi-MeV ion spectroscopy

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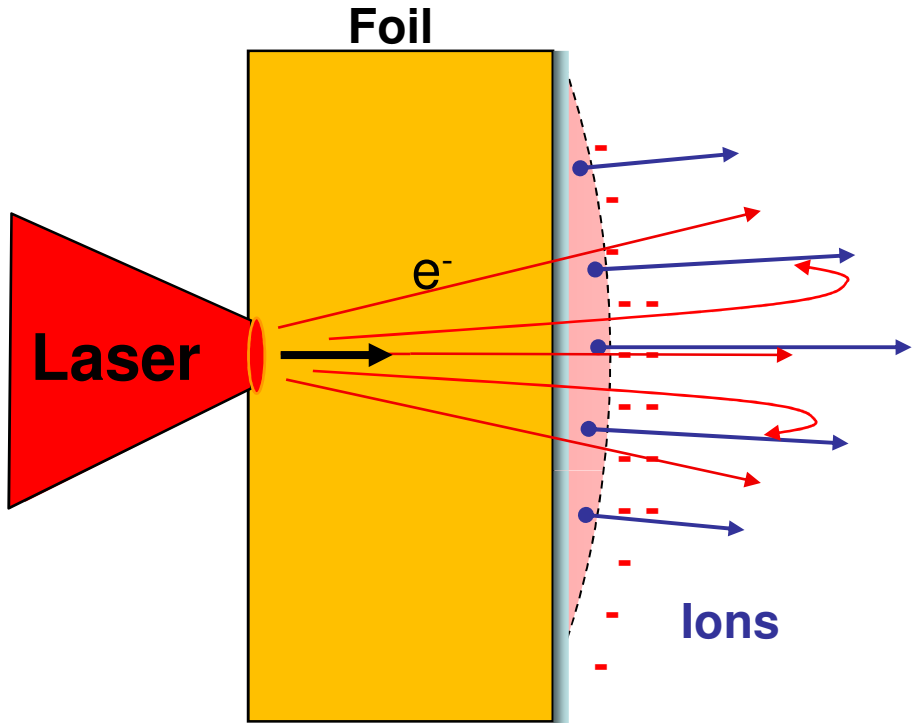
Outlines:

- Protons/ ions beam in laser plasma interaction
- Detectors
- *In situ* calibration (MCP/ Image plate)
- *Response to higher energy ions*
- Summary

➢Proton/ion beam generation in laser solid interaction



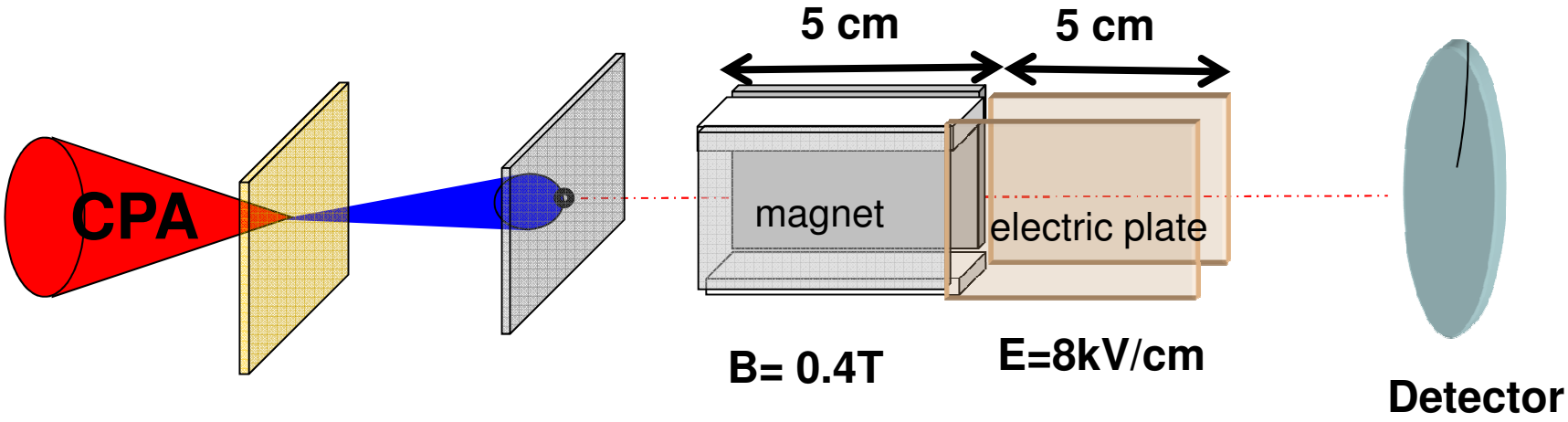
•Target normal sheath acceleration- TNSA

$$E \sim \frac{kT_e}{e\lambda_D}$$

•Radiation Pressure Acceleration-RPA

Acceleration of foil as a whole

➢Thomson Parabola spectrometer as a charge particle analyser



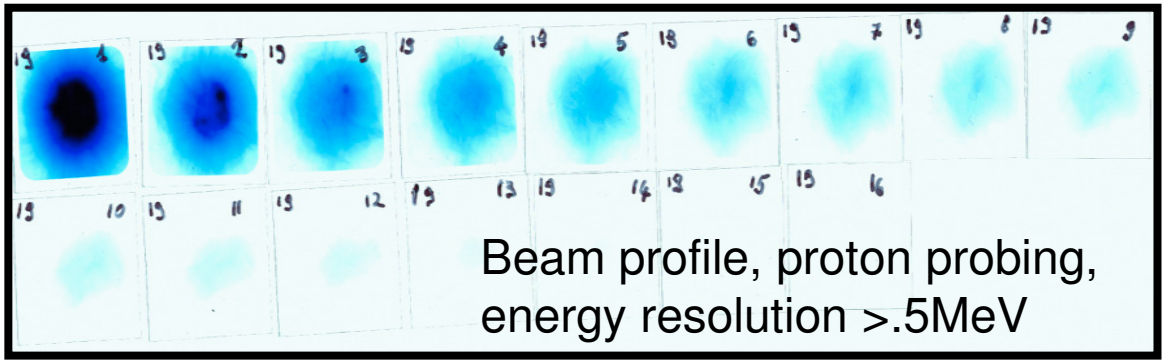
Lorentz Force $\vec{F}(+\hat{y}) = q\left(\vec{v}(\hat{z}) \times \vec{B}(\hat{x})\right)$

Electrostatic Force $\vec{F} = q\vec{E}(\hat{x})$

➢Detectors

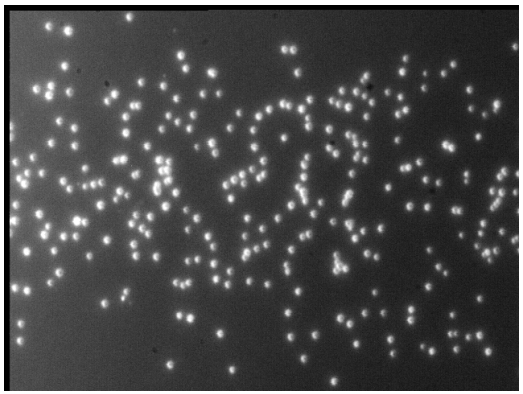
(1) Radio-chromic Film (RCF)

Sensitive layer (7-15 μm)
Polyester base (60- 100 μm)



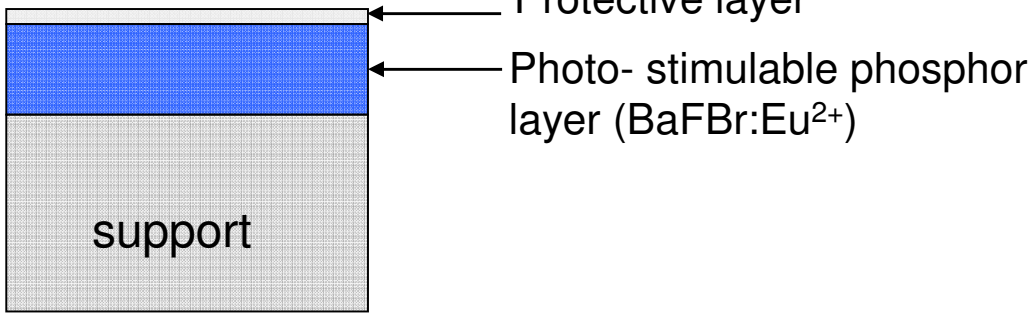
(2) CR-39 Track Detectors

Clear plastic $C_{12}H_{18}O_7$



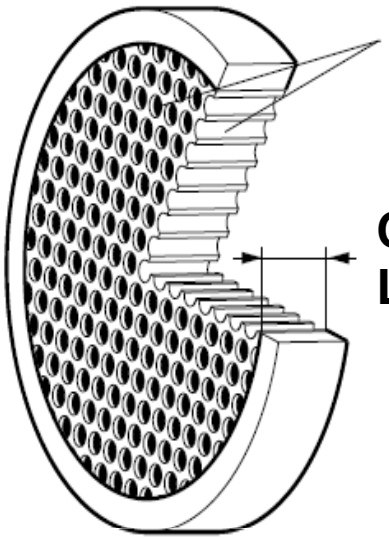
absolute particle detection

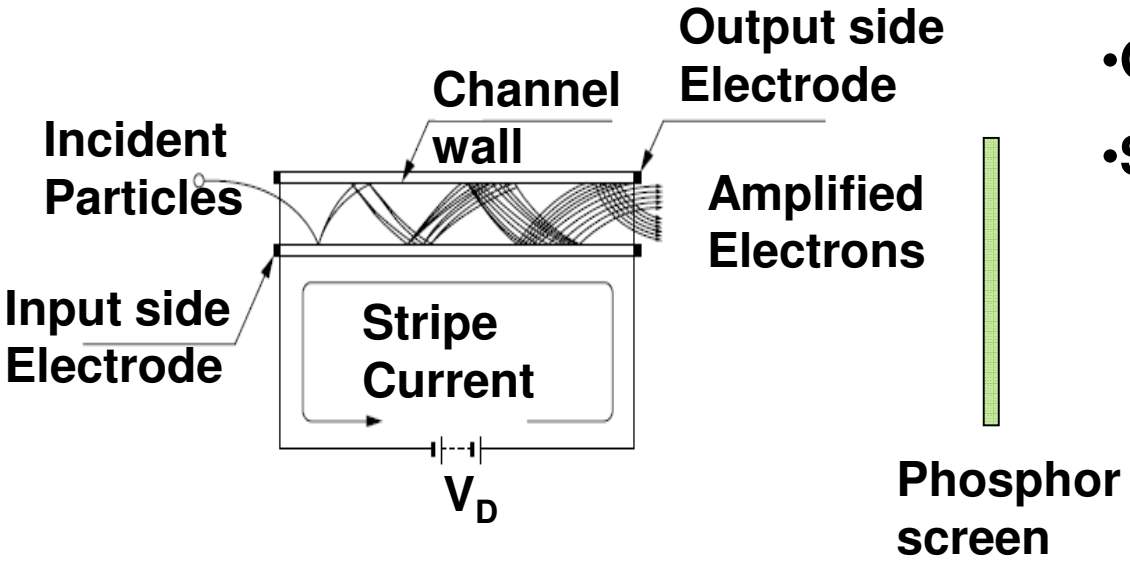
(3) Image Plates (IP)



sensitive, reusable

Micro Channel Plate (MCP) Detector





Single stage MCP

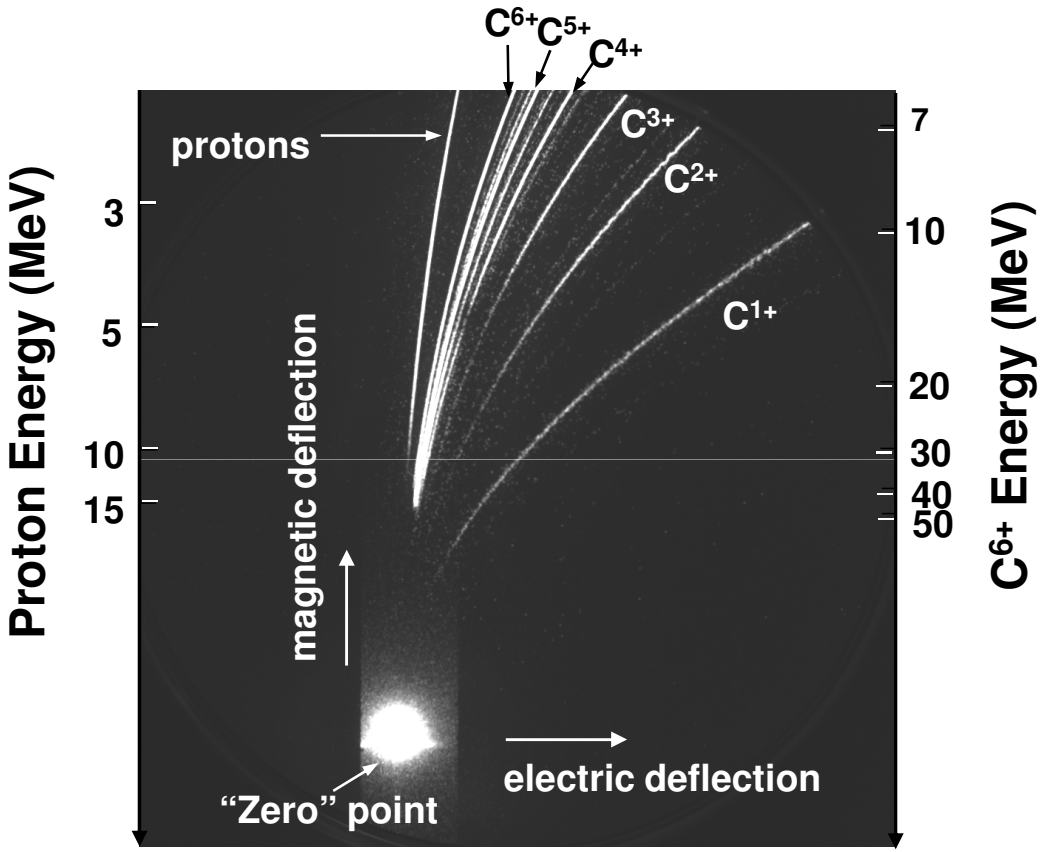
- Typical gain at 1 kV: 10^4

(10^6/10^7 in two/ three stage MCP)

- Dynamic range: 10^3
- Time response: order of ns
- Spatial resolution: 6- 25 µm
- Online data measurement
- Single particle detection

http://www.hamamatsu.com

➢Ion tracks on phosphor screen coupled to MCP



	MCP	RCF	CR-39	Image plate
rep rate	kHz time response~ms (due to phosphor screen)	single shot	single shot	single shot
spatial resolution	15 μm depends on channel diameter, pitch	~ *μm	~ *μm depends on energy and etching time	5 *μm
sensitivity	single particle	10^4 - 10^6 protons/MeV/sr	single particle	single particle
dynamic range	10^3 - 10^4	10^2 (10 - 400 Gy)	10 - 100	10^4 - 10^5
online acquisition	Y	No	No	No
detection	e^-, ions, X-ray, n (solar blind)	e^-, protons	ions, H^+ (>50 keV)	e^-, ions, X-ray, n, γ

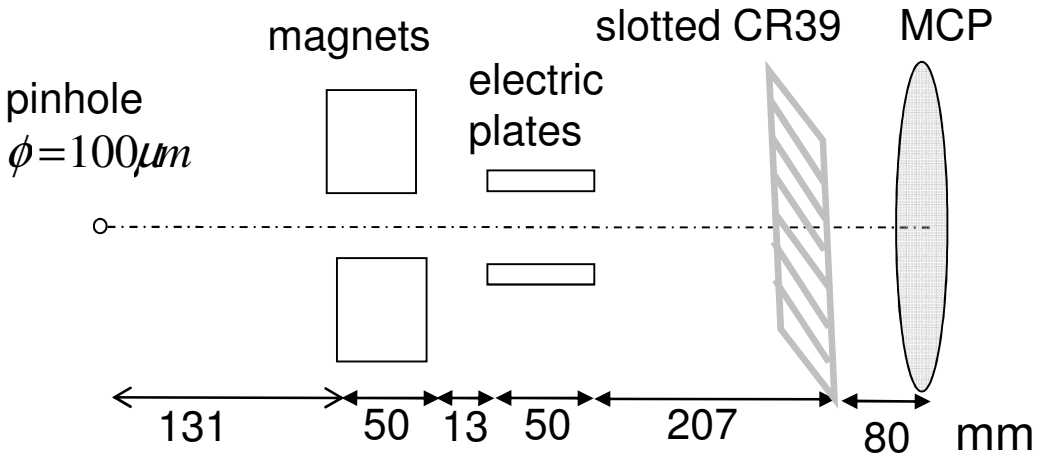
*However the actual resolution depends on scanner (normally 25-50 μm)

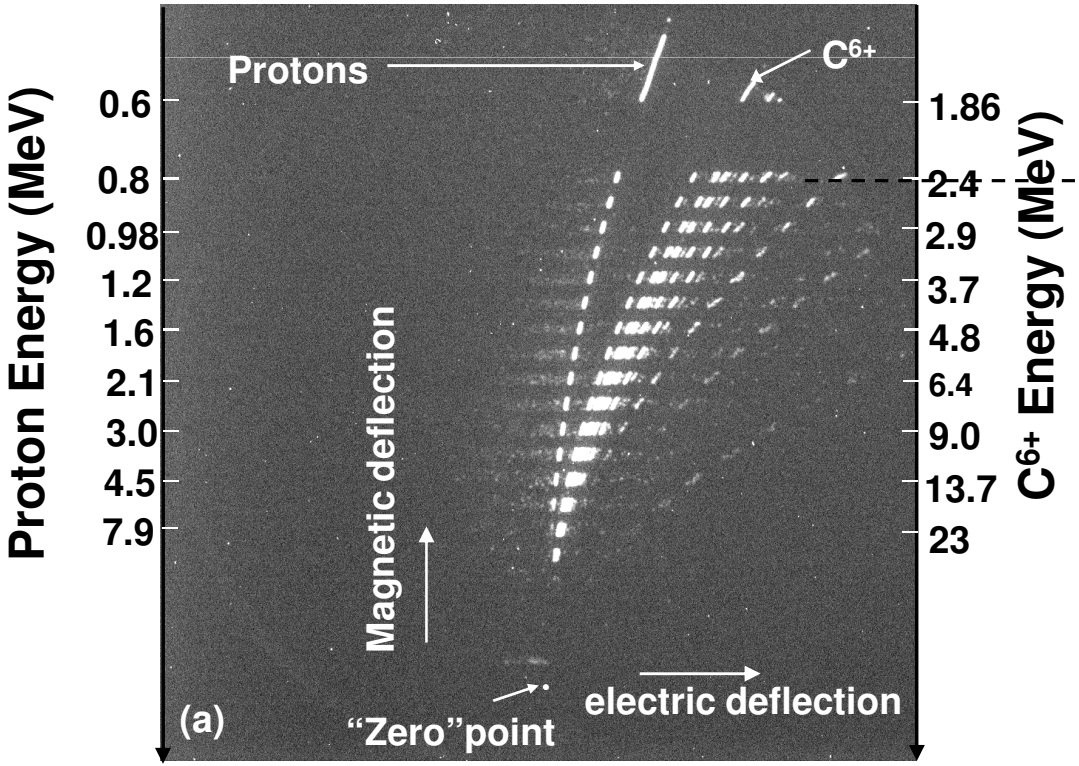
➢Calibration:

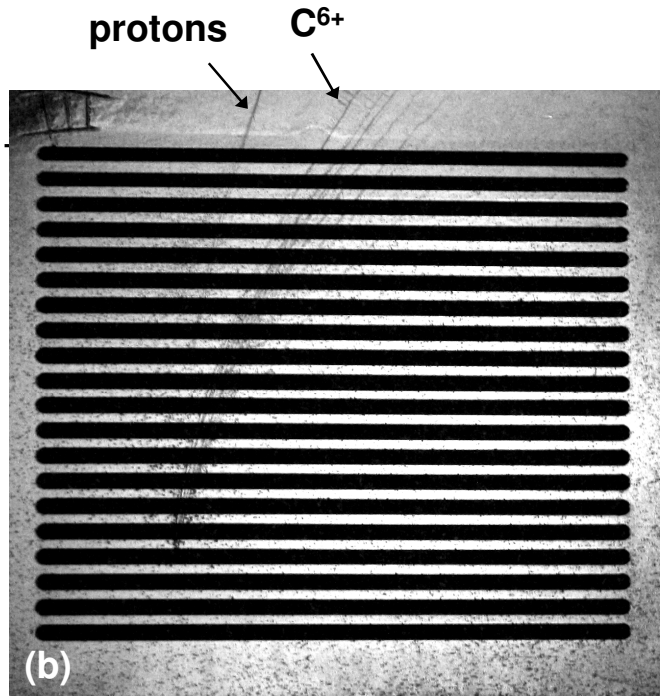
- Absolute number of accelerated particles
- Spectra in absolute term
- Conversion efficiency
- Response of the detectors

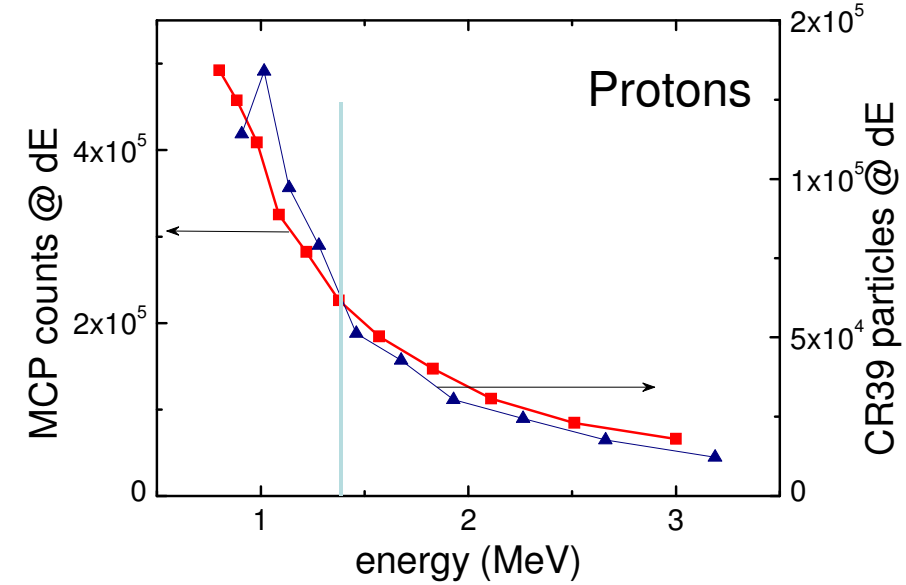
MCP Calibration

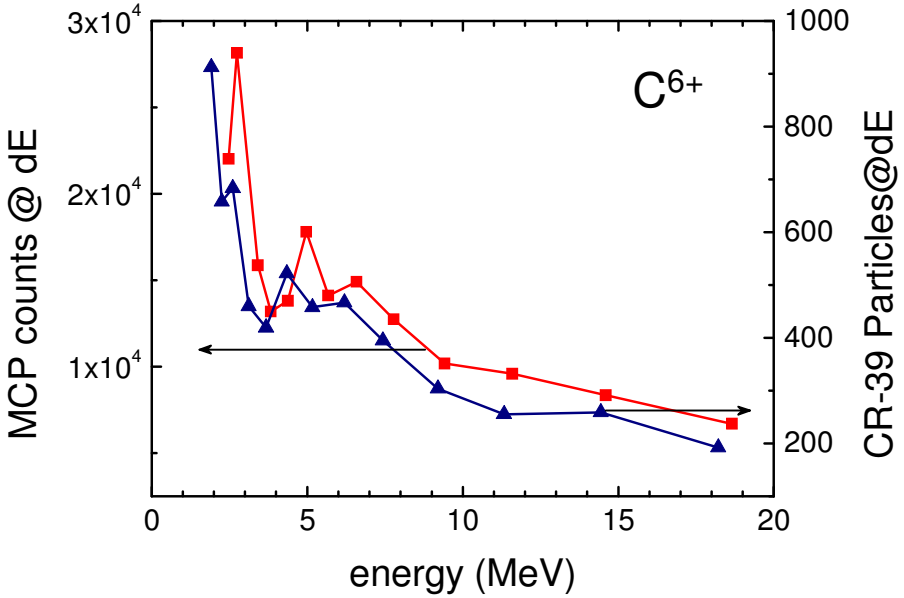
➢Set up for Calibration











•Experimental data for protons up to 3 MeV and for Carbons up to 16 MeV

➢Theoretical Model

$$\text{Response} \propto \gamma_s \cdot g_{mcp}$$

(i) Secondary electron yield

$$\gamma_s \propto \frac{1}{\cos\theta} \cdot \left(\frac{dE}{dx}\right)_e$$

θ: angle of incidence

$(dE/dx)_e$: electronic stopping power

(ii) Gain of MCP

$$g_{mcp} = e^{G\cdot(L-z)/L}$$

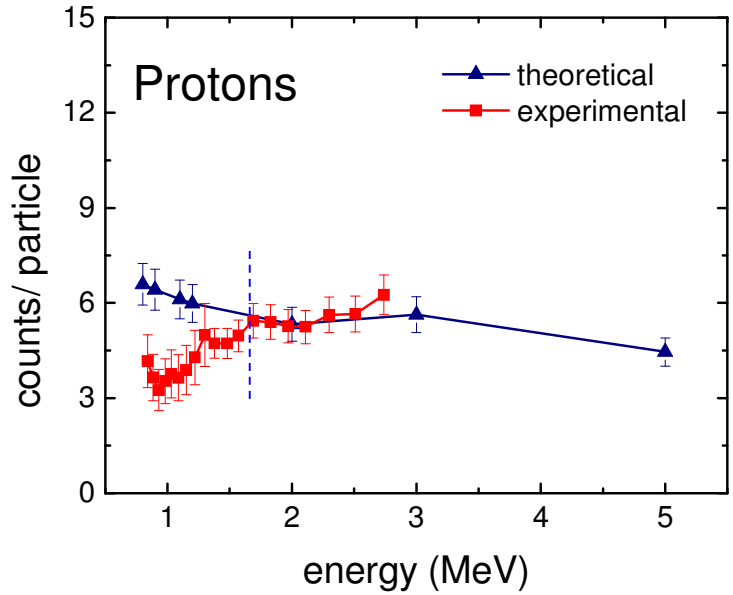
L: Channel length,

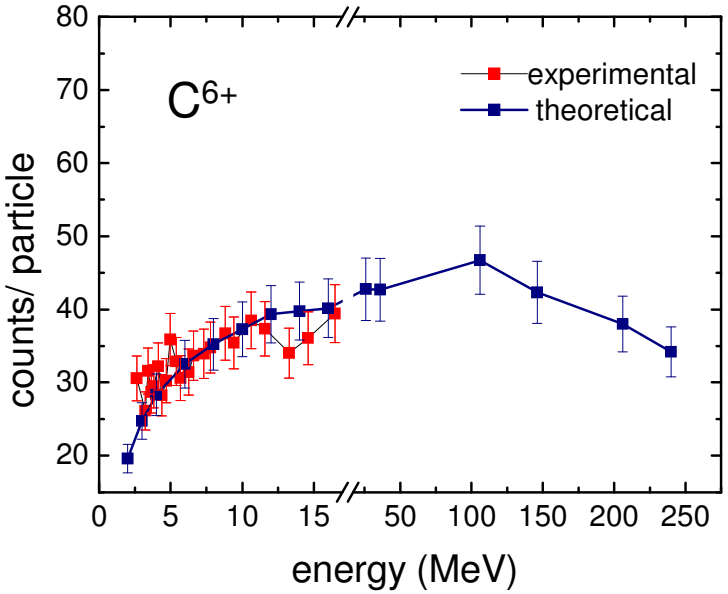
G: function of electric field,

z: penetration depth

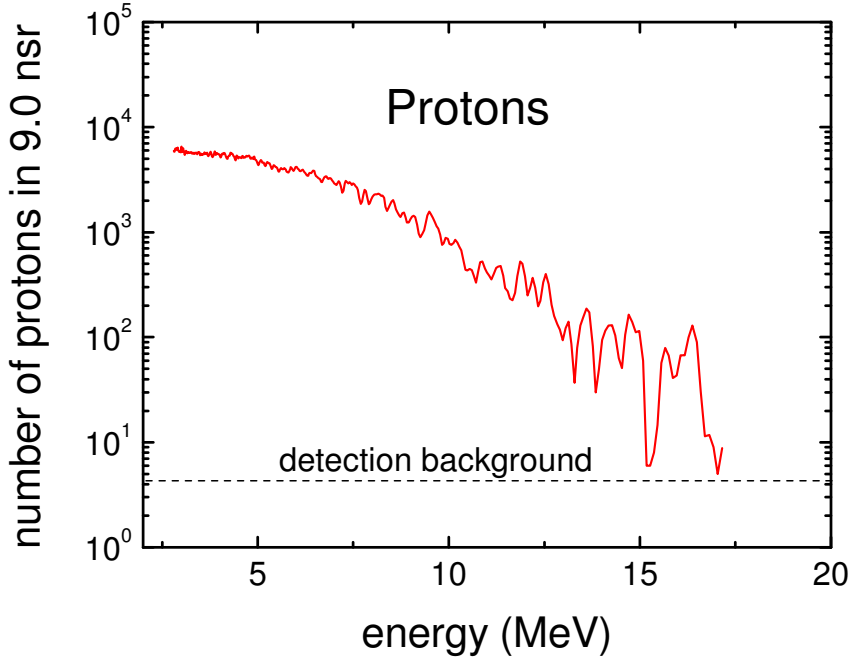
- A monte carlo simulation has been performed to get the most probable gain
- To get the dE/dx we used the SRIM program
- Angle θ has been calculated from the geometry of the experiment

➢Response


Protons
theoretical
experimental
counts/ particle
energy (MeV)
0
3
6
9
12
15
1
2
3
4
5


C6+
experimental
theoretical
counts/ particle
energy (MeV)
20
30
40
50
60
70
80
0
5
10
15
50
100
150
200
250

Calibrated spectra



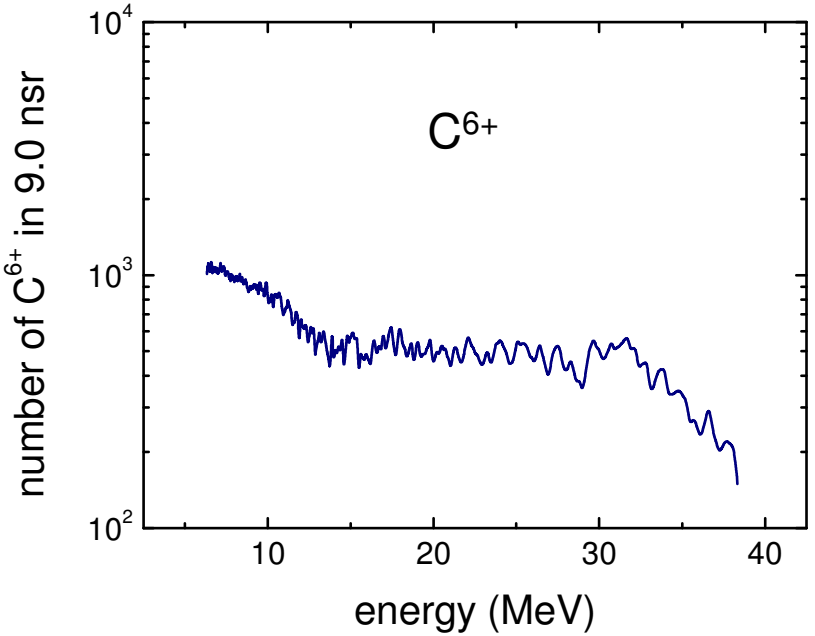


Image Plate Calibration

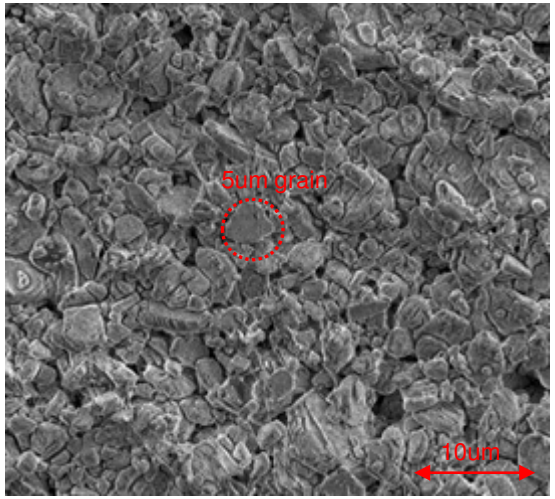
➢Structure of image plate

Queen's University Belfast

Imaging Plate Type
BAS-III
BAS-IIIS
BAS-MP 2040
BAS-MP 2040 S
BAS-SR 2040
BAS-TR 2040
BAS-TR 2040S
BAS-MS 2040
BAS-ND 2040

Layer	Weight (g/m^2)	Depth (microns)
Back	27 - 670	28 - 290
Base	270 - 445	190 - 320
Undercoat	14 - 25	10 - 20
Phosphor	**140 - 575**	**50 - 180**
Protective Coat	**10 - 16**	**6 - 11**
Total	**960 - 1720**	**480 - 810**

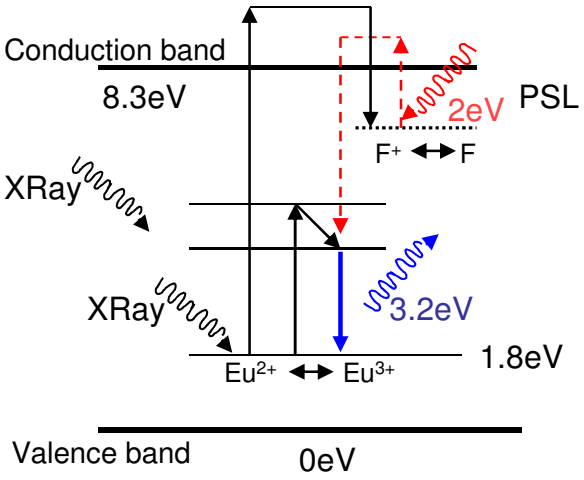
BAS-TR2040

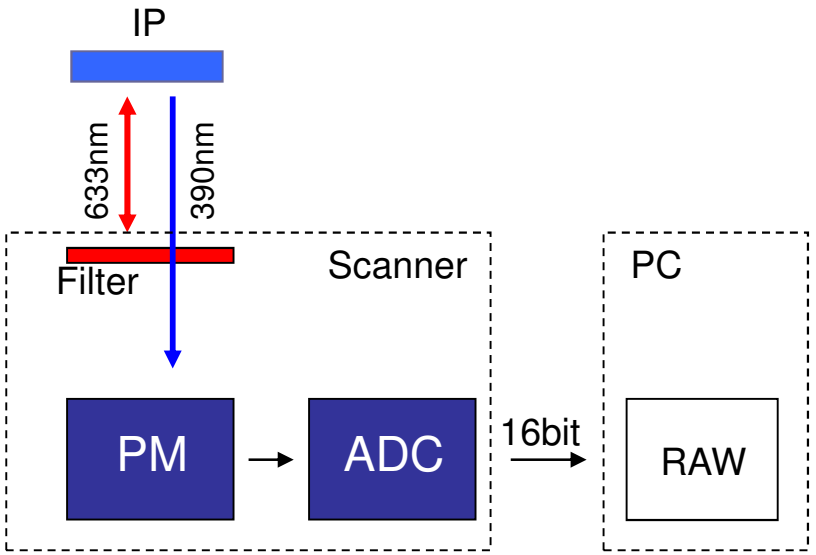


➢Working principle

$BaFBr_{0.85}:I_{0.15}$ $\xrightarrow{1:10^4\ \text{doping}}$ $BaFBr_{0.85}:Eu^{2+}{}_{0.15}$

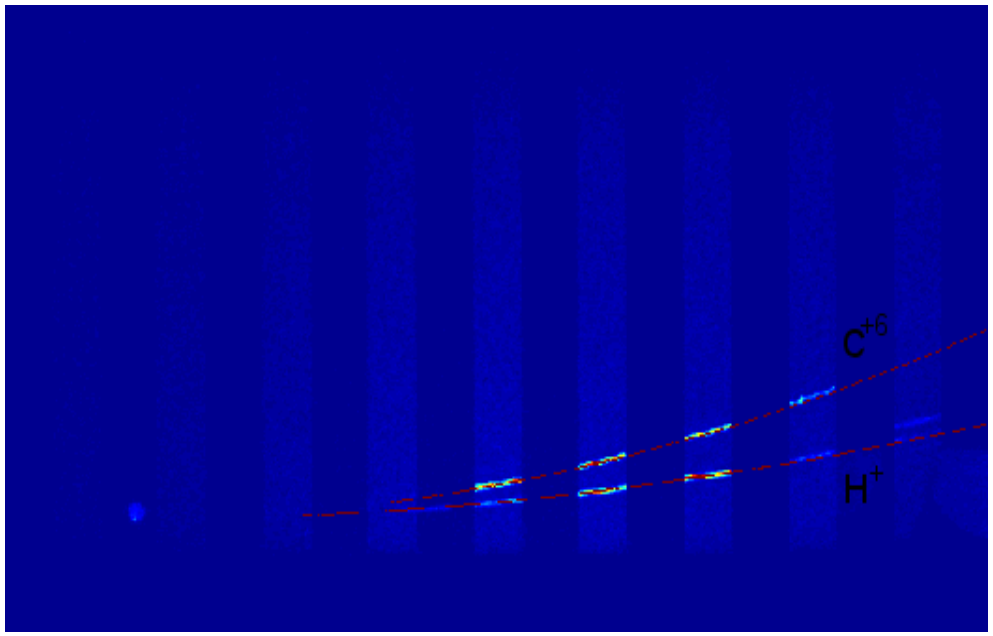
Polycrystal bound by organic agent





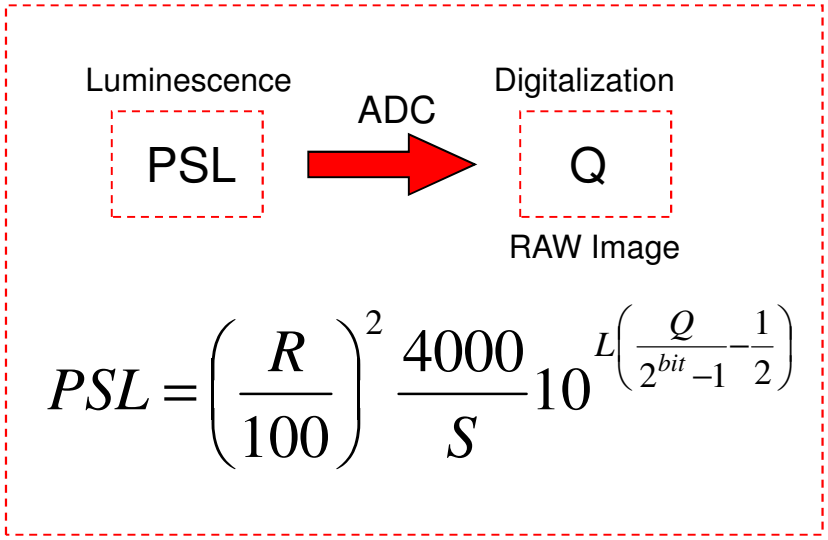
In the region of 300 to 500 nm, the photomultiplier works with the highest efficiency.

➢Calibration



Scanner settings:

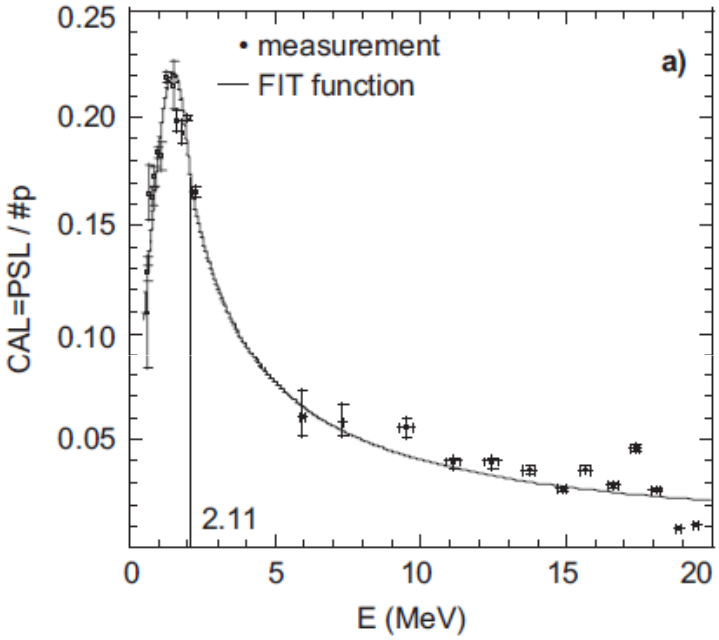
R= 5^2-200^2 um^2
S= 1000-10000
L= 4,5
bit= 16



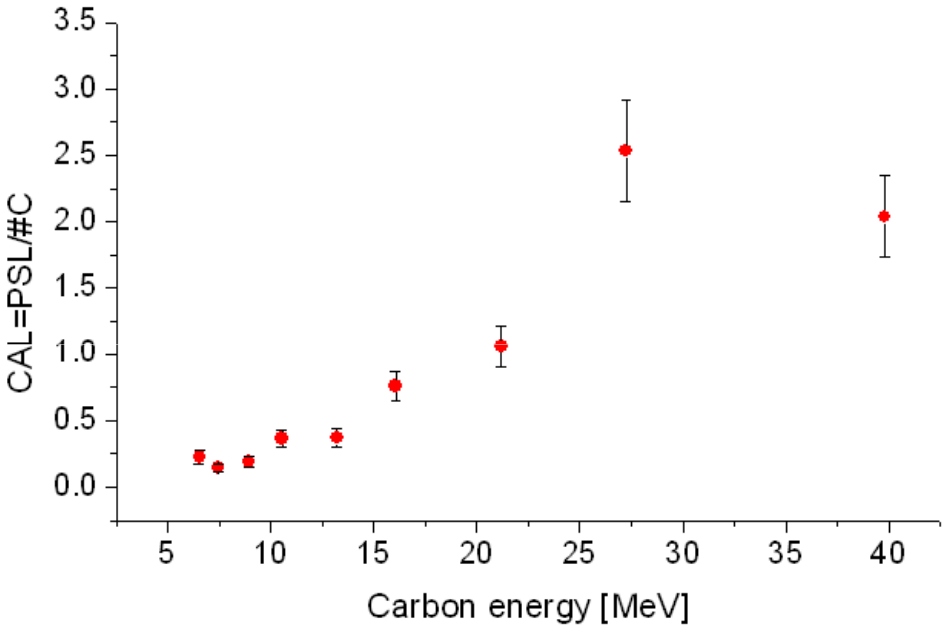
$$PSL = \left(\frac{R}{100}\right)^2 \frac{4000}{S} 10^{L\left(\frac{Q}{2^{bit}-1}-\frac{1}{2}\right)}$$

➢Response of image plate to protons and C^{6+}

proton



C^{6+}



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➢Summary

- The experimental calibration data has been shown for protons up to 3 MeV and for C^{6+} up to 16 MeV
- The response has been extended to higher energies for protons and C^{6+}
- MCP response to higher energies changes by a factor of ~2 for C^{6+} ions from 20 MeV to 240 MeV
- The response of image plate appears to be max at~27 MeV
- The response of image plate to higher energy is being modelled

Thanks