

AstroBoX:

An instrument to measure Light Ion
Energy Spectra in a Strong β background



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IPN Orsay, France



MPGD Workshop 6-8 Dec, IRFU Saclay



Novae



Apologetics

Observations
Models

Reaction-Decay Chains

Cat's eye Nebula

Why AstroBoX:-

■ Hands On Experience

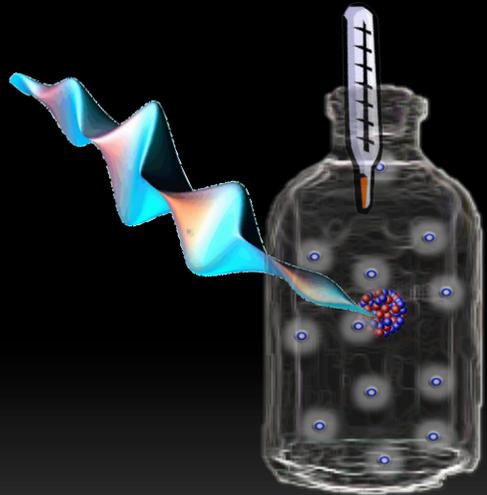
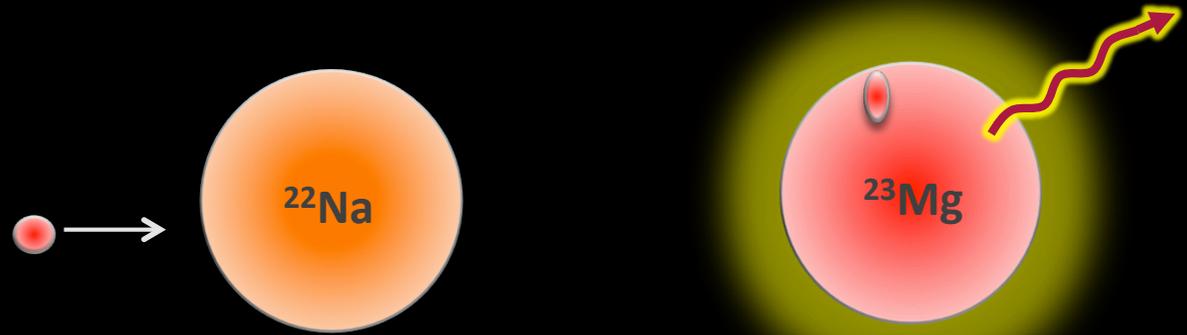
- GET – Electronics System for Gaseous Micro-Pattern Gaseous Detector -MPGD
- MINOS – TPC with MPGD
- ACTAR-TPC – Active Target with MPGD
- Characterizing MPGD for the HI domain
 - High energy deposits in gas
 - Charge resolutions limits
 - Beam & Magnetic Spectrometers using for HI community (SPIRAL2, FAIR, ISOLDE, TEXAS A&M ...) using MPGD

■ Astrophysics – Initiation of a transverse Collaboration within IRFU with IPNO and Texas A&M.

What is shown here is preliminary.

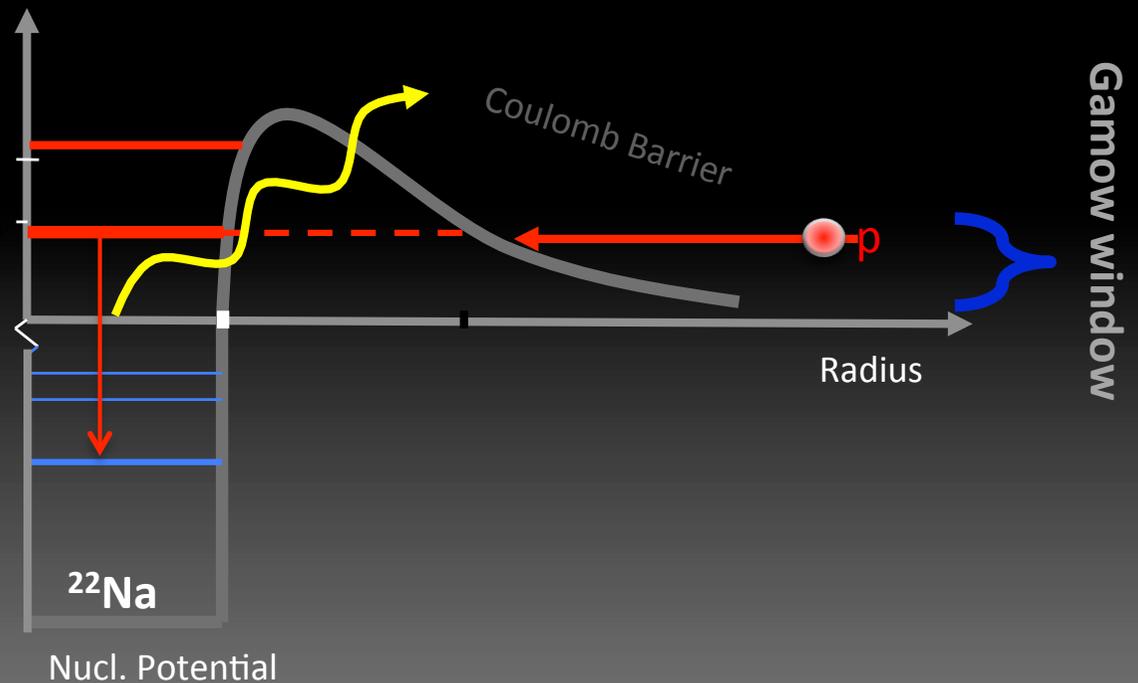
It is meant to show you that the ideas are ... you to ...

Proton resonant capture (p,γ)

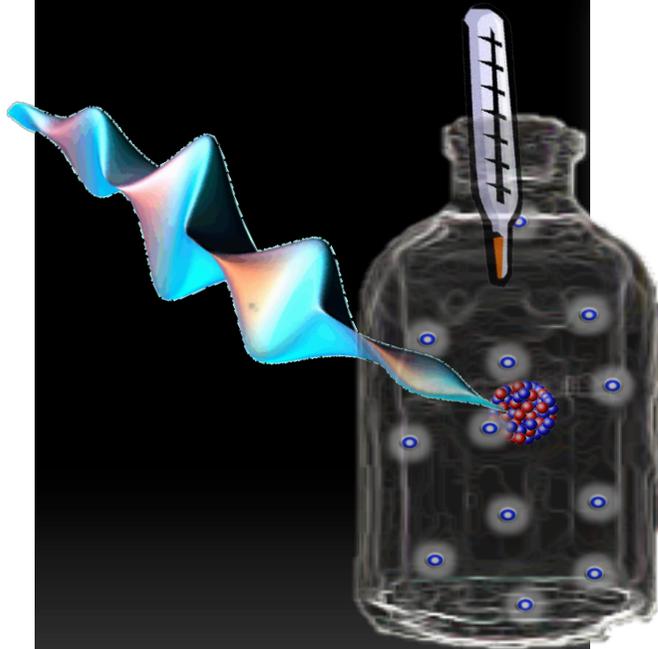
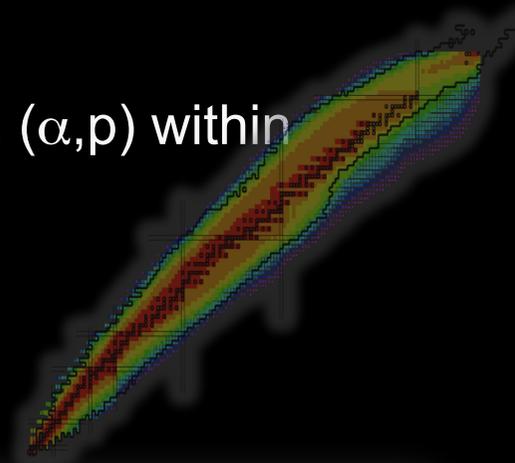


$^{22}\text{Na}(p,\gamma)$

Reaction Rates
 ^{22}Na in hot H_2 plasma



Astro Physicists: Reaction rates (p,γ) , (α,γ) , (α,p) within Gamow window $\rightarrow \langle\sigma v\rangle \rightarrow$ Abundances



$^{22}\text{Na}(p,\gamma)$

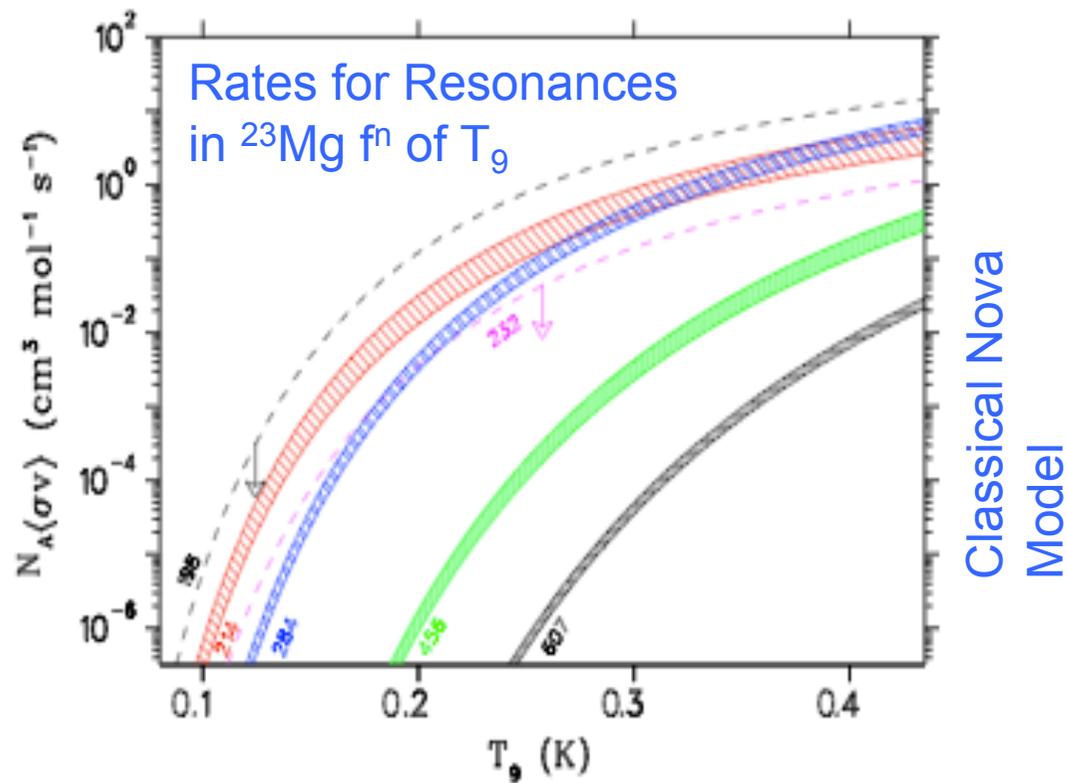
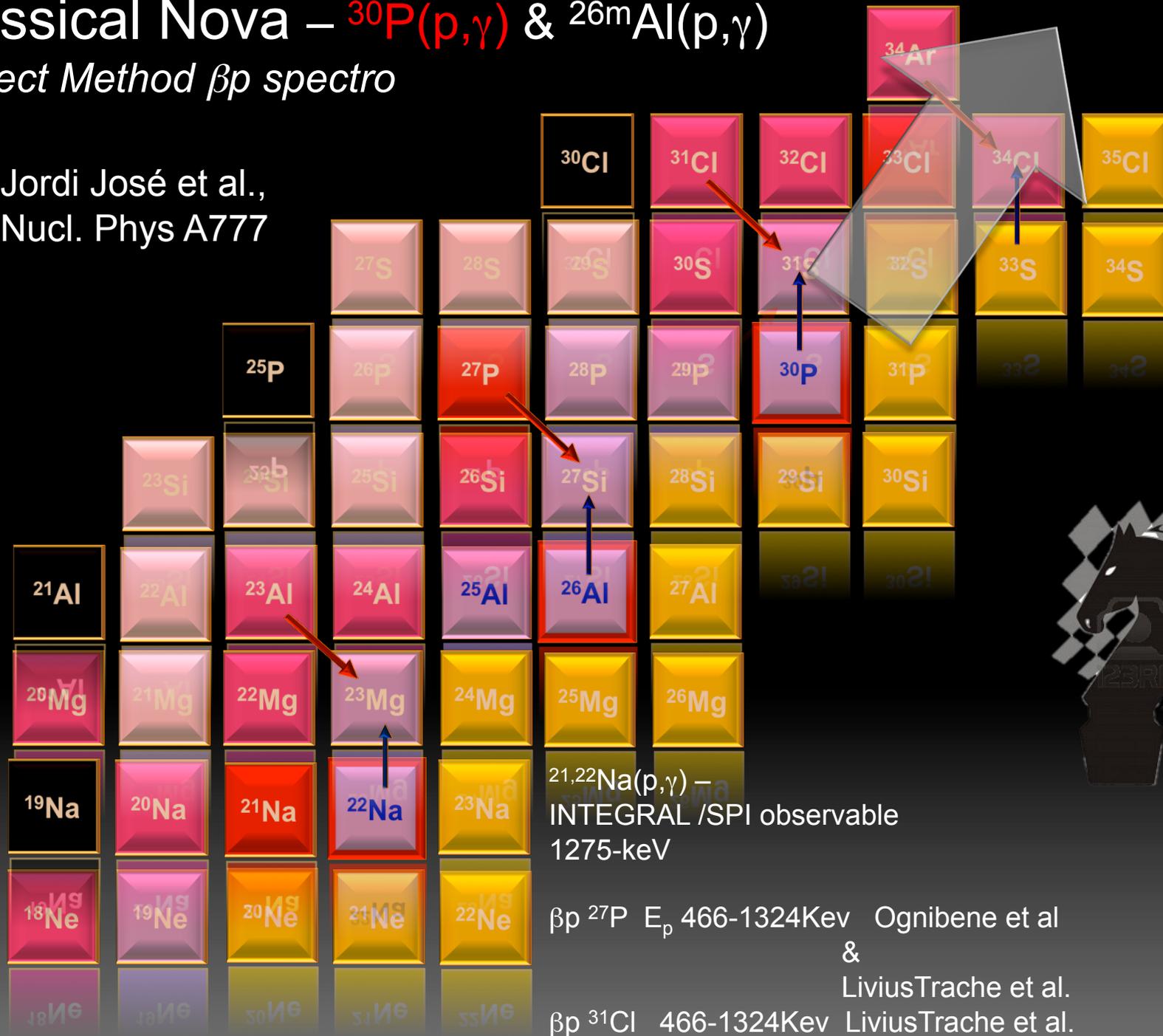


Figure 1.1: Individual resonance contributions to the thermonuclear reaction rate for $^{22}\text{Na}(p,\gamma)$ derived from the strengths and energies tabulated in Jenkins *et al.* [1]. Uncertainties shown are calculated analytically.

Classical Nova – $^{30}\text{P}(p,\gamma)$ & $^{26\text{m}}\text{Al}(p,\gamma)$

Indirect Method βp spectro

Jordi José et al.,
Nucl. Phys A777



Influence of reaction rate variations on isotopic abundances in nova nucleosynthesis^a

Reaction rate variation ^b	Isotopic abundance change ^c
CO nova models	
$^{17}\text{O}(p, \gamma)^{18}\text{F}$	^{18}F
$^{17}\text{O}(p, \alpha)^{14}\text{N}$	$^{17}\text{O}, ^{18}\text{F}$
$^{18}\text{F}(p, \alpha)^{15}\text{O}$	^{18}F
$^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$	$^{22}\text{Ne}, ^{23}\text{Na}, ^{24}\text{Mg}, ^{25}\text{Mg}, ^{26}\text{Al}$
$^{23}\text{Na}(p, \gamma)^{24}\text{Mg}$	^{24}Mg
$^{26}\text{Mg}(p, \gamma)^{27}\text{Al}$	^{26}Mg
$^{26}\text{Al}^{\text{I}}(p, \gamma)^{27}\text{Si}$	^{26}Al
ONe nova models	
$^{17}\text{O}(p, \gamma)^{18}\text{F}$	$^{17}\text{O}, ^{18}\text{F}$
$^{17}\text{O}(p, \alpha)^{14}\text{N}$	$^{17}\text{O}, ^{18}\text{F}$
$^{17}\text{F}(p, \gamma)^{18}\text{Ne}$	$^{17}\text{O}, ^{18}\text{F}$
$^{18}\text{F}(p, \alpha)^{15}\text{O}$	$^{16}\text{O}, ^{17}\text{O}, ^{18}\text{F}$
$^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$	^{22}Ne
$^{23}\text{Na}(p, \gamma)^{24}\text{Mg}$	$^{20}\text{Ne}, ^{21}\text{Ne}, ^{22}\text{Na}, ^{23}\text{Na}, ^{24}\text{Mg}, ^{25}\text{Mg}, ^{26}\text{Mg}, ^{26}\text{Al}, ^{27}\text{Al}$
$^{23}\text{Mg}(p, \gamma)^{24}\text{Al}$	$^{20}\text{Ne}, ^{21}\text{Ne}, ^{22}\text{Na}, ^{23}\text{Na}, ^{24}\text{Mg}$
$^{26}\text{Mg}(p, \gamma)^{27}\text{Al}$	^{26}Mg
$^{26}\text{Al}^{\text{I}}(p, \gamma)^{27}\text{Si}$	^{26}Al
$^{26}\text{Al}^{\text{II}}(p, \gamma)^{27}\text{Si}$	^{26}Mg
$^{29}\text{Si}(p, \gamma)^{30}\text{P}$	^{29}Si
$^{30}\text{P}(p, \gamma)^{31}\text{S}$	$^{30}\text{Si}, ^{32}\text{S}, ^{33}\text{S}, ^{34}\text{S}, ^{35}\text{Cl}, ^{37}\text{Cl}, ^{36}\text{Ar}, ^{37}\text{Ar}, ^{38}\text{Ar}$
$^{33}\text{Si}(p, \gamma)^{34}\text{Cl}$	$^{33}\text{S}, ^{34}\text{S}, ^{35}\text{Cl}, ^{36}\text{Ar}$
$^{33}\text{Cl}(p, \gamma)^{34}\text{Ar}$	^{33}S
$^{34}\text{S}(p, \gamma)^{35}\text{Cl}$	$^{34}\text{S}, ^{35}\text{Cl}, ^{36}\text{Ar}$
$^{34}\text{Cl}(p, \gamma)^{35}\text{Ar}$	^{34}S
$^{37}\text{Ar}(p, \gamma)^{38}\text{K}$	$^{37}\text{Cl}, ^{37}\text{Ar}, ^{38}\text{Ar}$
$^{38}\text{K}(p, \gamma)^{39}\text{Ca}$	^{38}Ar

Uncertainty in $\langle\sigma v\rangle \rightarrow$



>X2 Abundance

Jordi José et al.,
Nucl. Phys A777

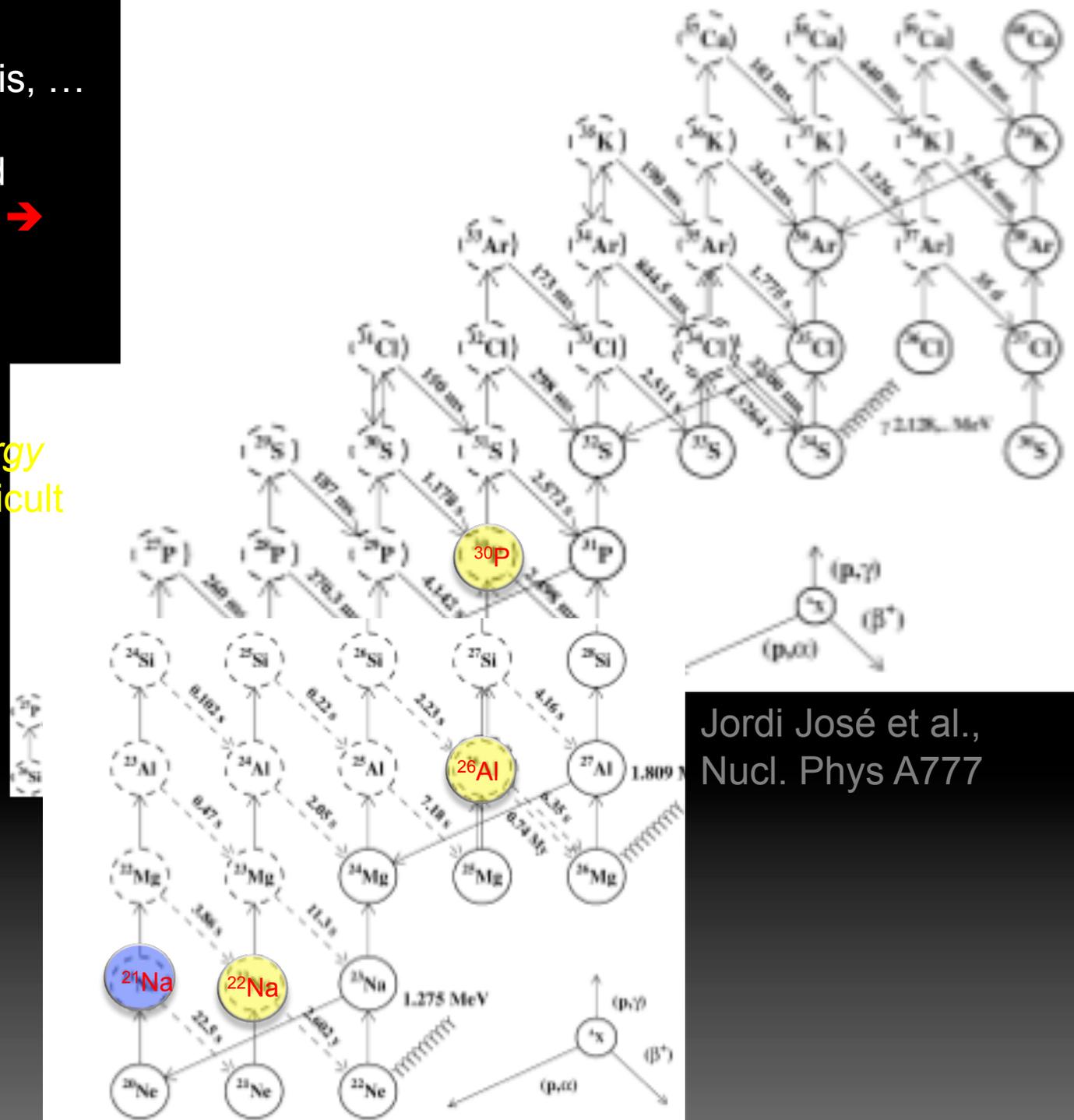
Galactic Activity Signature like ^{22}Na

Hydrodynamic Models
(Explosive Nucleosynthesis, ...
X-Ray bursts ...)

Require a well established
Reaction/decay Networks →

Data

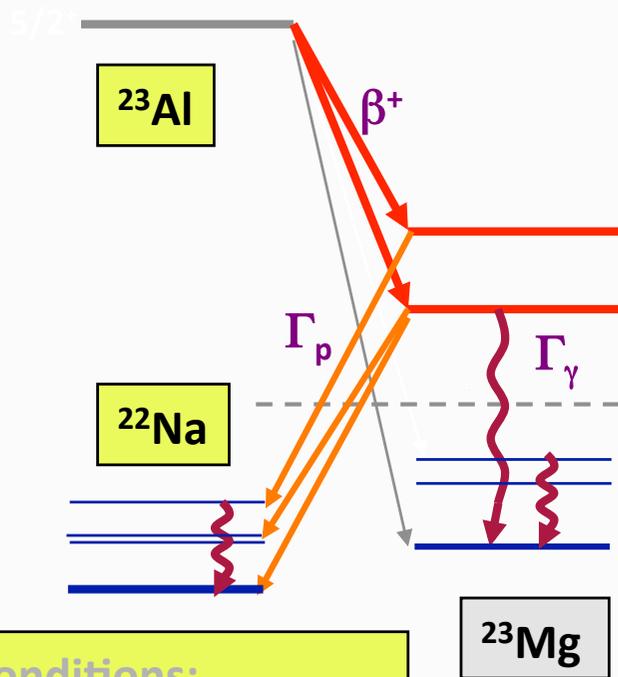
Direct Method – difficult
Gamow window Low Energy
Indirect Method – less difficult
Model Dependent



Jordi José et al.,
Nucl. Phys A777

Fig. 4. Nuclear processes in the NeNa and MgAl regions relevant for nova nucleosynthesis.

Decay spectroscopy

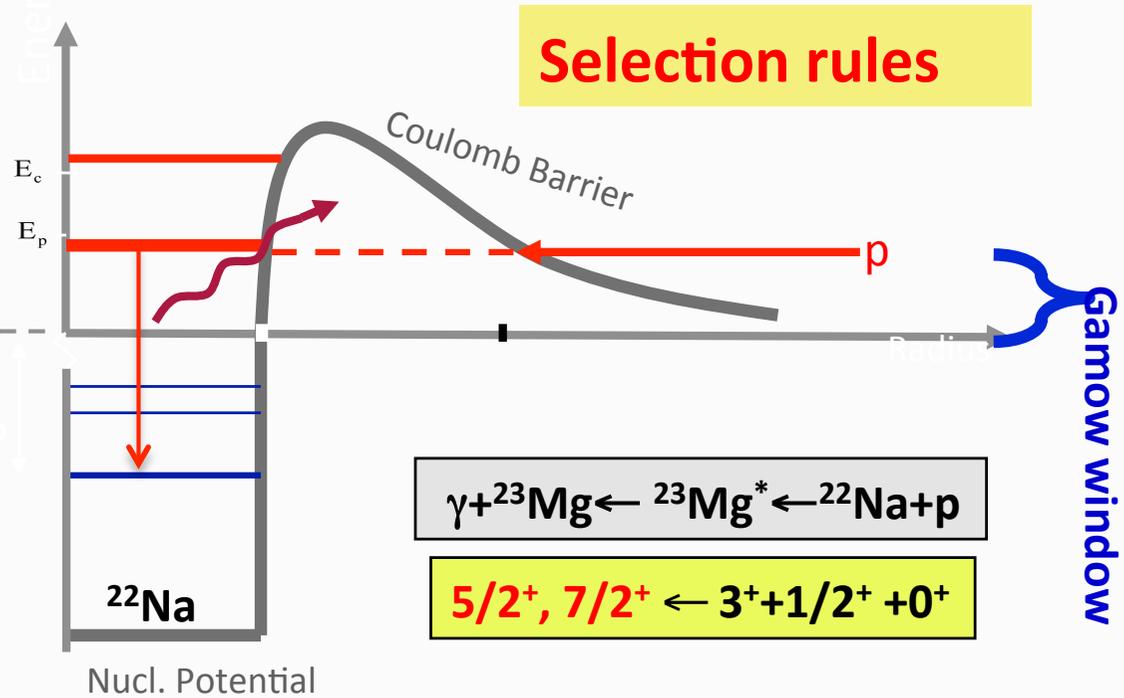


Conditions:
 $Q_{EC} > S_p + 2m_e c^2$
 $J=3/2^+, 5/2^+, 7/2^+$

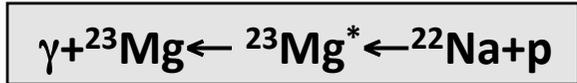
Same compound system: ^{23}Mg

Resonant Capture a two-step process

9



Selection rules



$$5/2^+, 7/2^+ \leftarrow 3^+ + 1/2^+ + 0^+$$

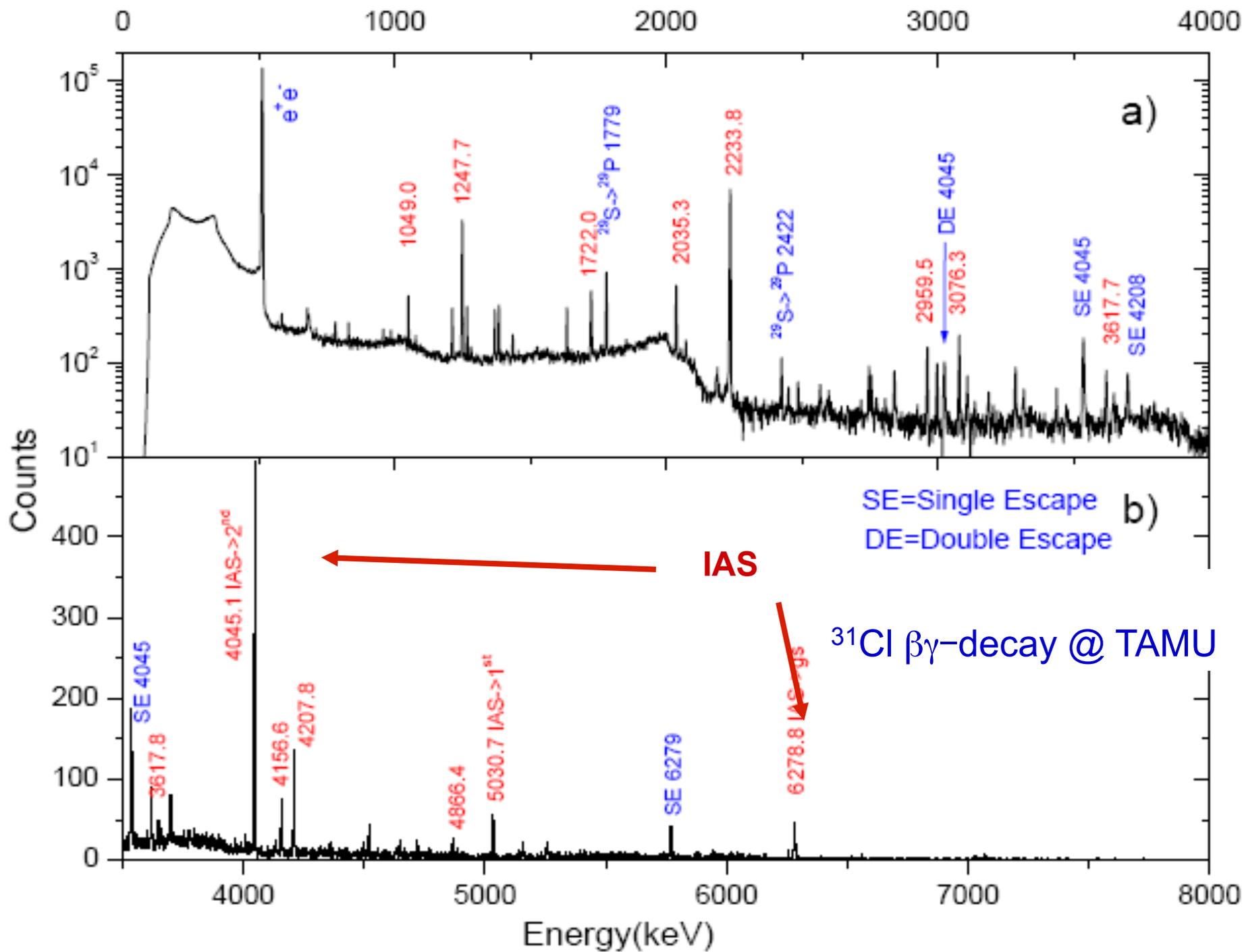
Gamow window

Resonant contributions to the reaction rate:

$$\langle \sigma v \rangle_{res} = \left(\frac{2\pi}{\mu kT} \right)^{3/2} \hbar^2 \omega \gamma \exp\left(-\frac{E_r}{kT} \right)$$

$$\omega \gamma \equiv \frac{2J_r + 1}{(2J_p + 1)(2J_t + 1)} \frac{\Gamma_p \Gamma_\gamma}{\Gamma_{tot}}$$

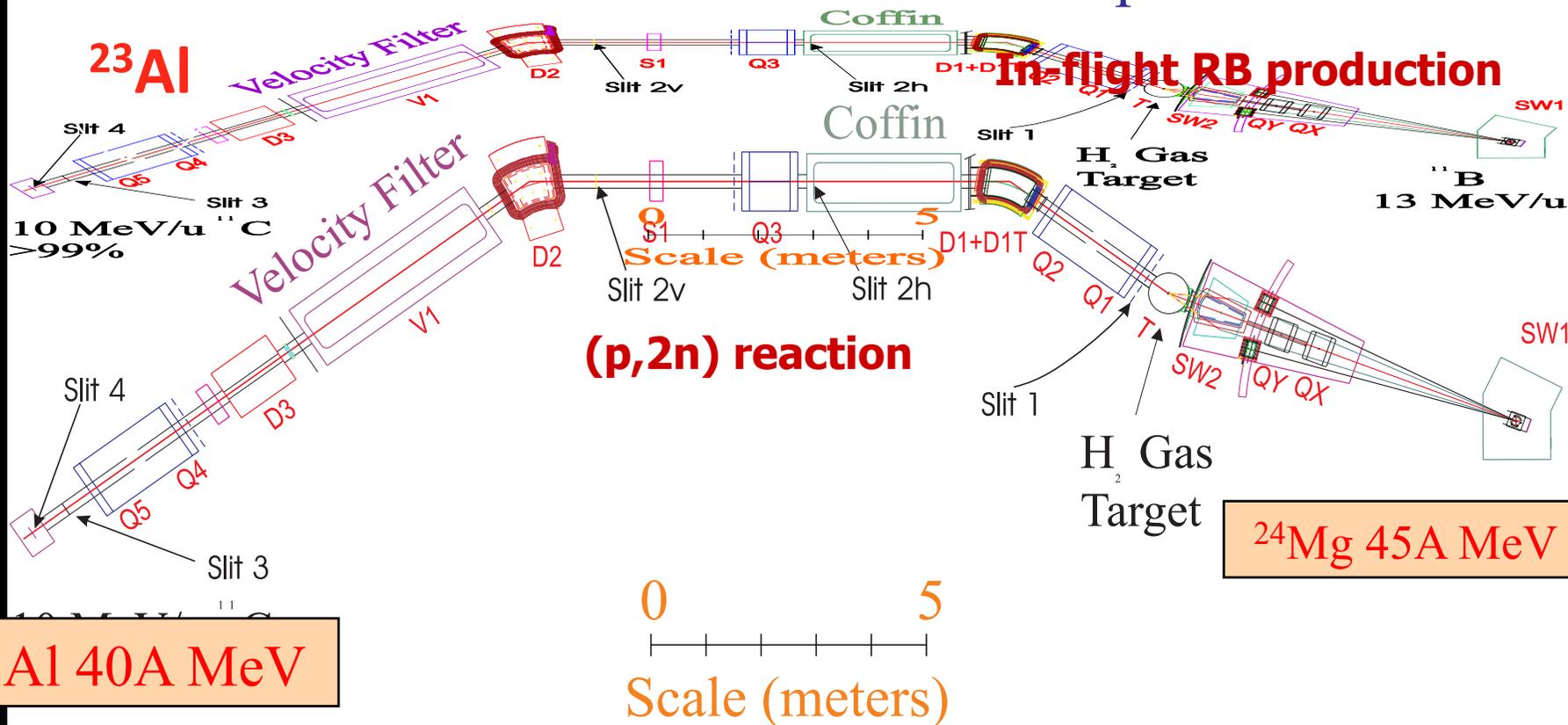
Need energy, J_r , and resonance strength



MARS

Momentum Achromat Recoil Separator

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^{23}Al 40A MeV

^{24}Mg 45A MeV

Purity: 90%, better after degrader
Intensity: ~ up to 4000 pps
First time - very pure & intense ^{23}Al

Primary beam ^{24}Mg @ 45A MeV – K500 Cycl
 Primary target LN₂ cooled H₂ gas p=2.0 atm
 Secondary beam ^{23}Al @ 40.2A MeV

Isotope selection with MARS

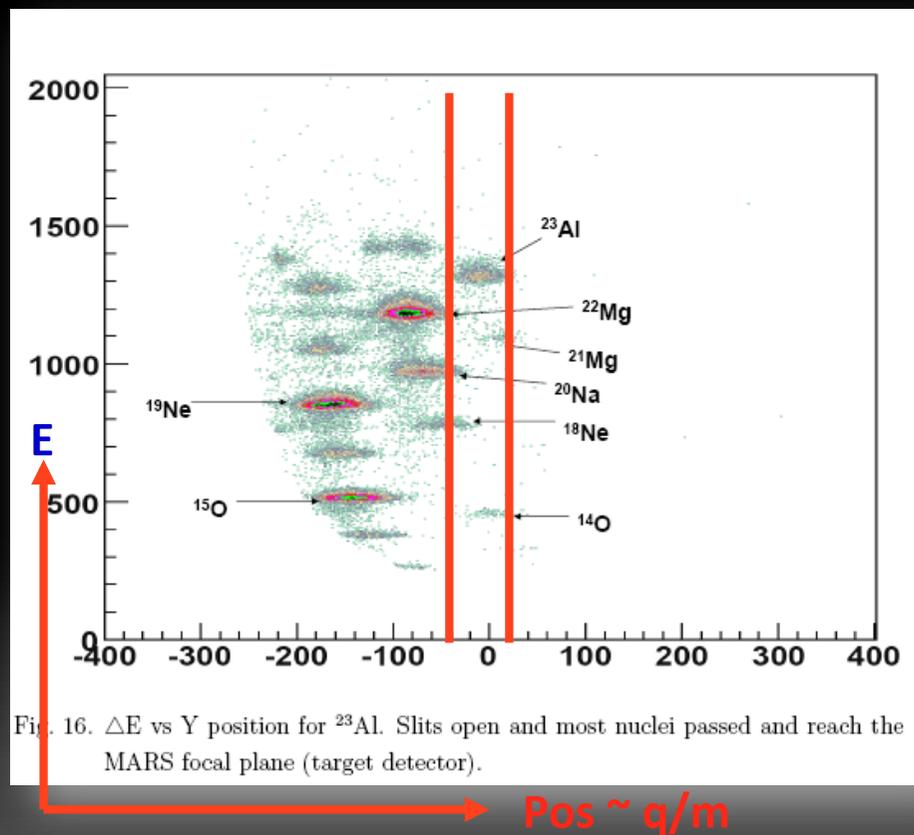
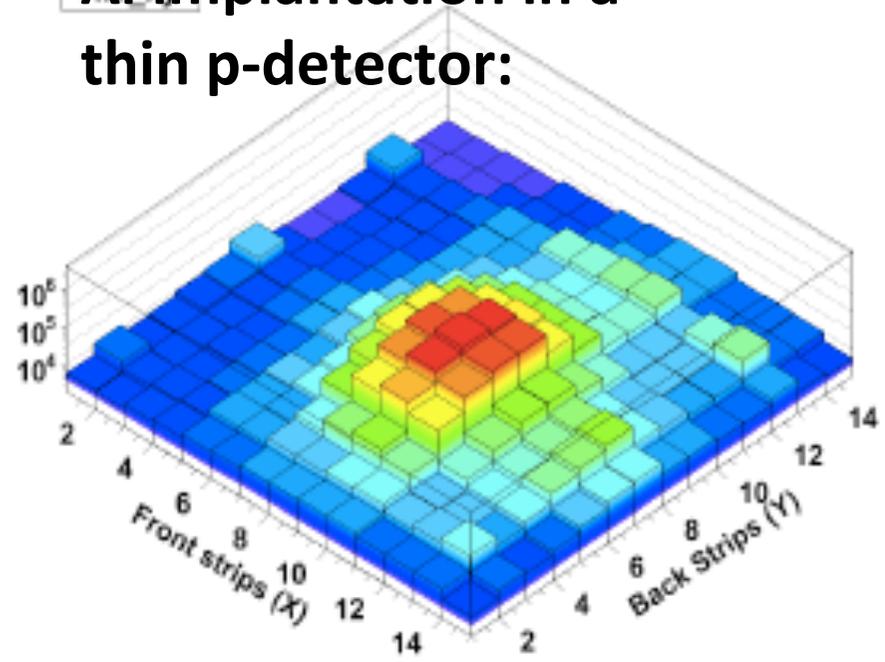


Fig. 16. ΔE vs Y position for ^{23}Al . Slits open and most nuclei passed and reach the MARS focal plane (target detector).

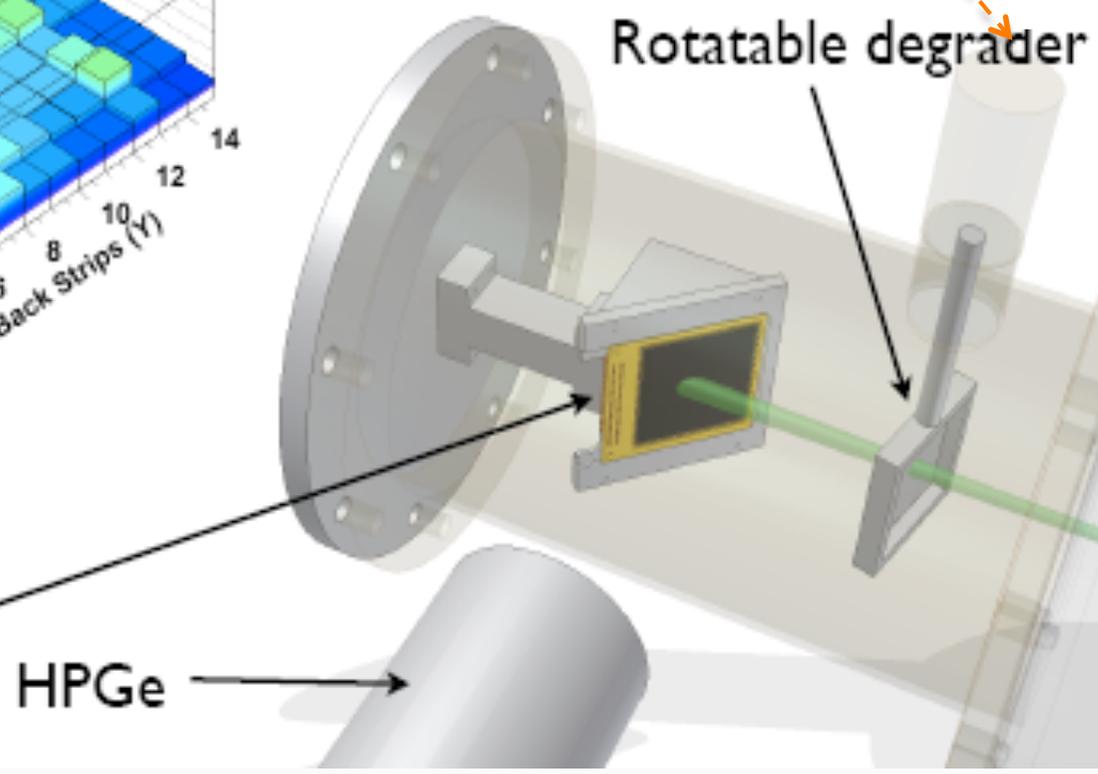
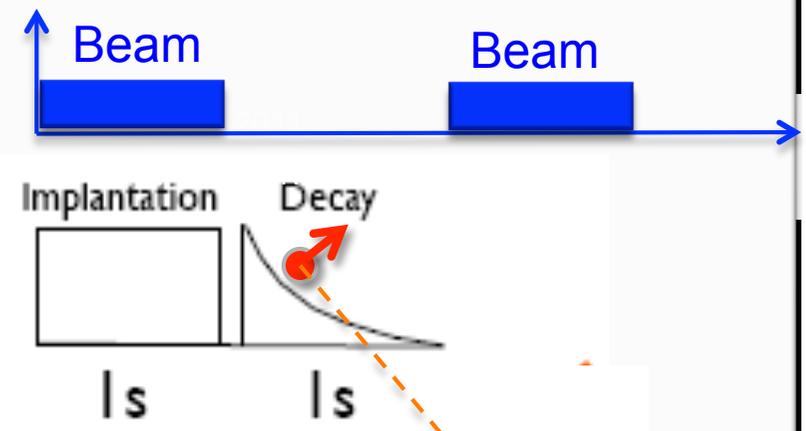
Final cut with focal plane **slits**



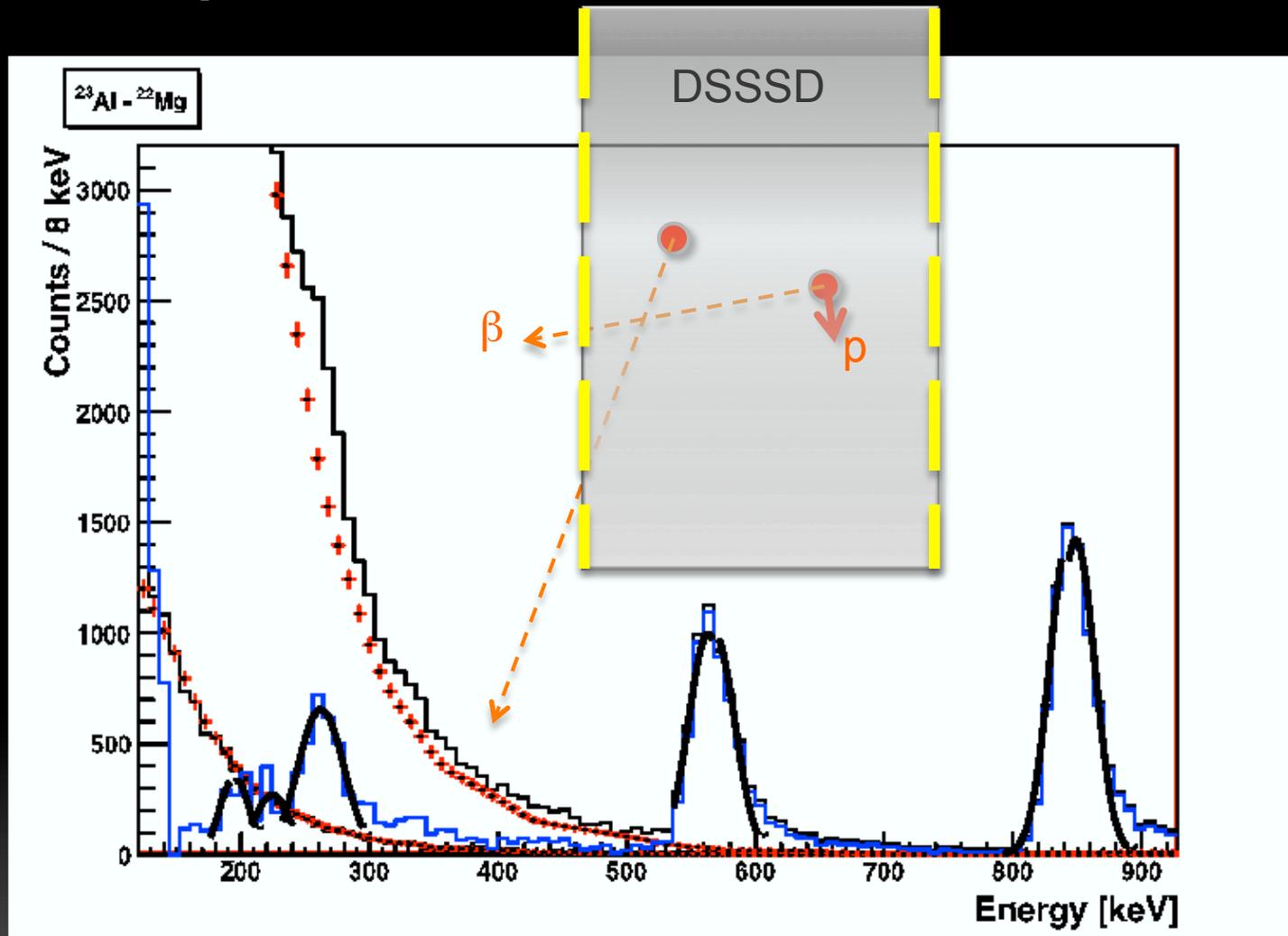
^{23}Al implantation in a thin p-detector:



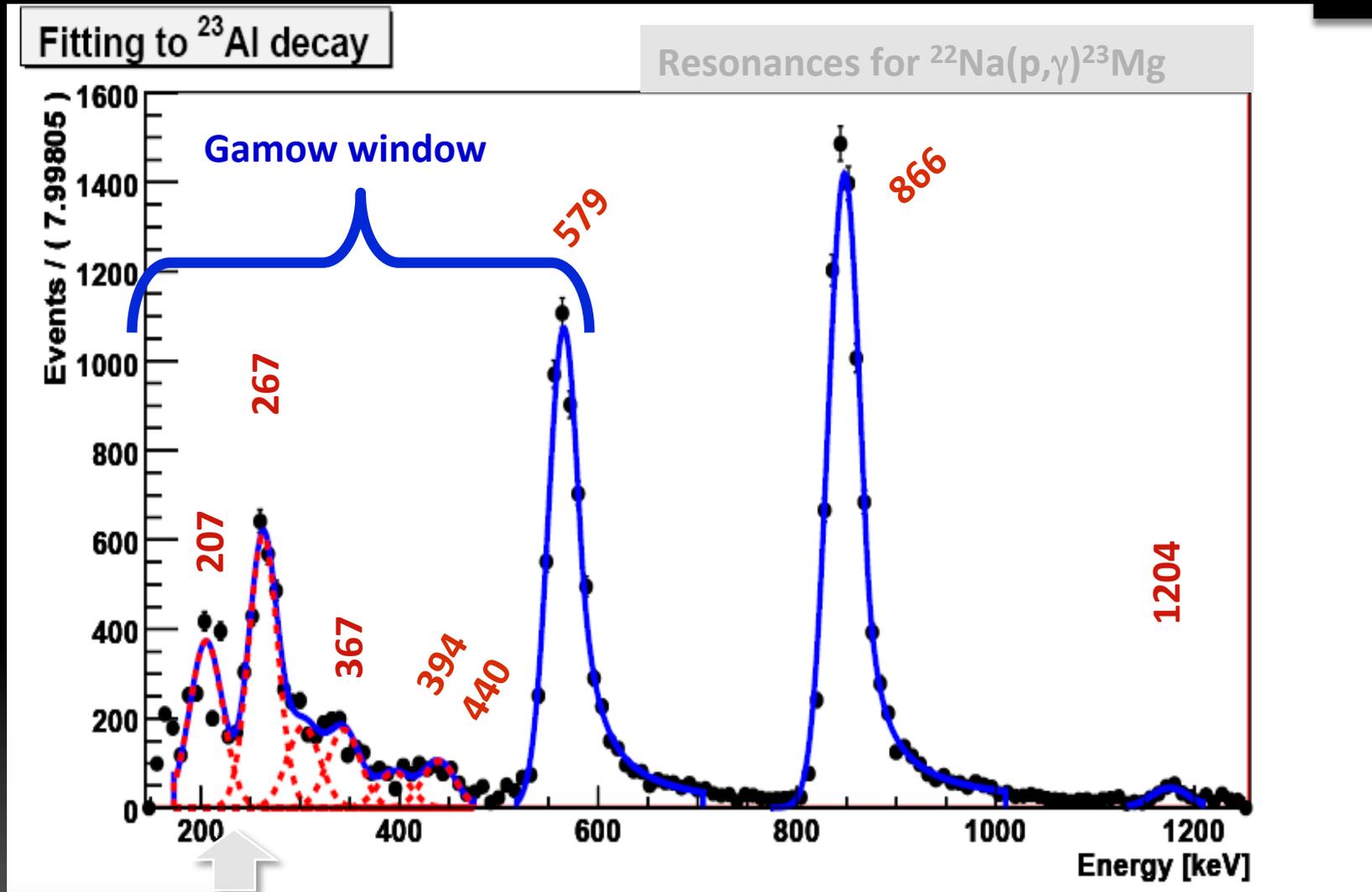
65 μm DSSSD,
16 + 16 strips
(3 x 50 mm²)
+
998 μm Si-pad



^{23}Al β p meas with Si det



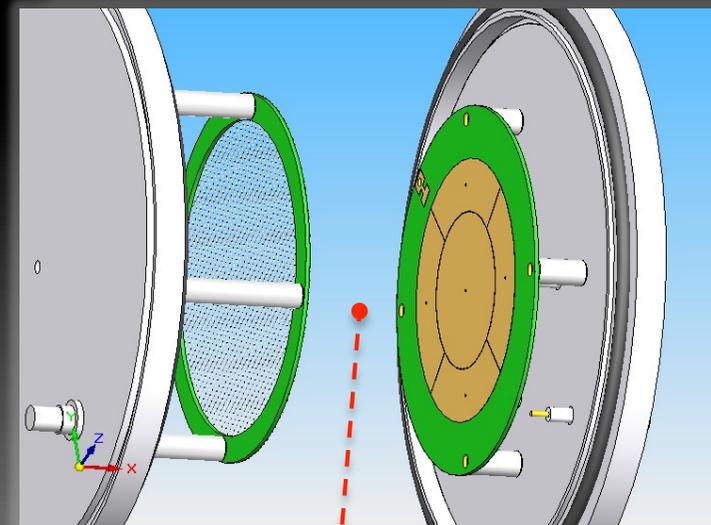
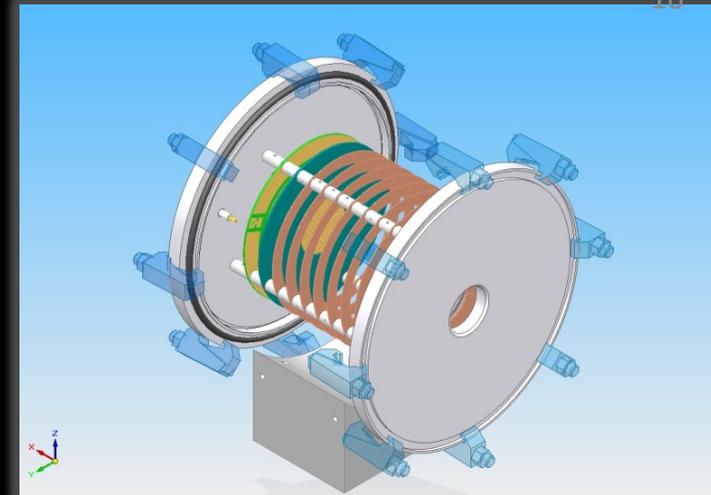
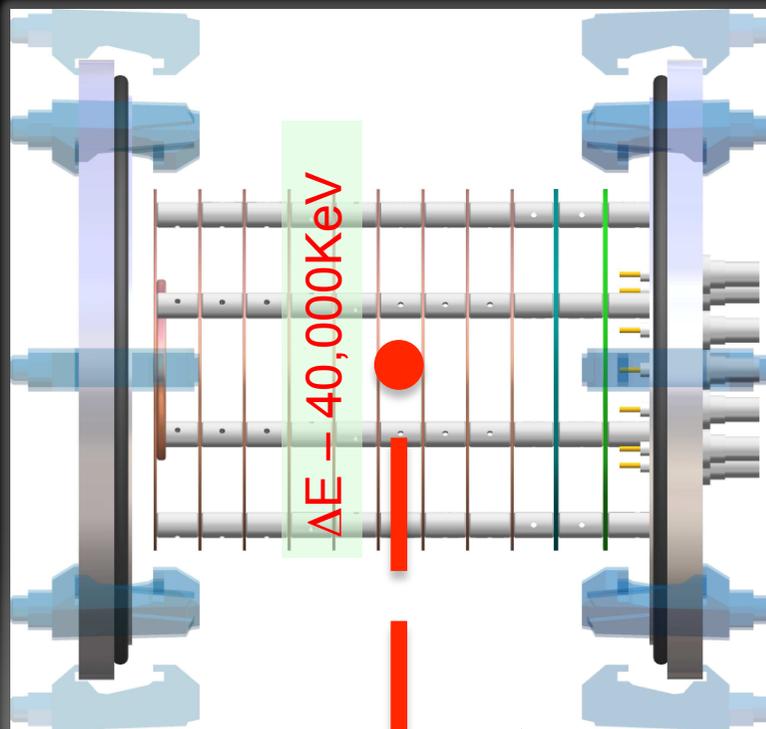
^{23}Al β -delayed p-decay sp – after bkg subtraction



AstroBox-1

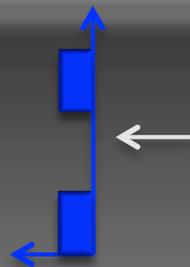
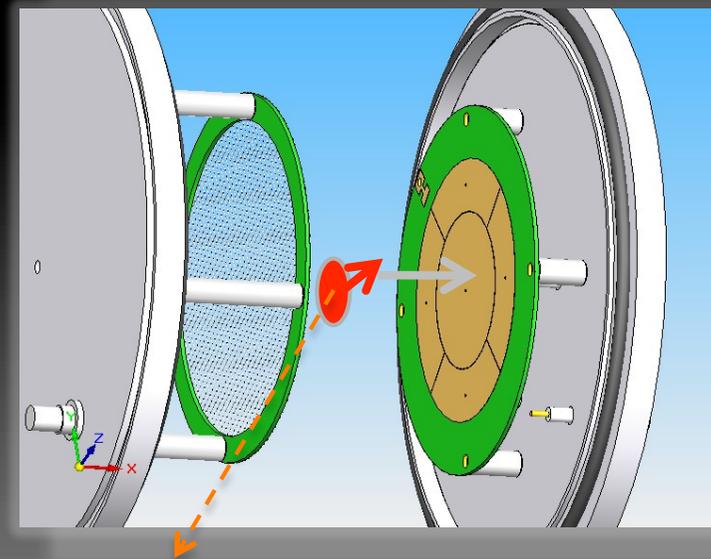
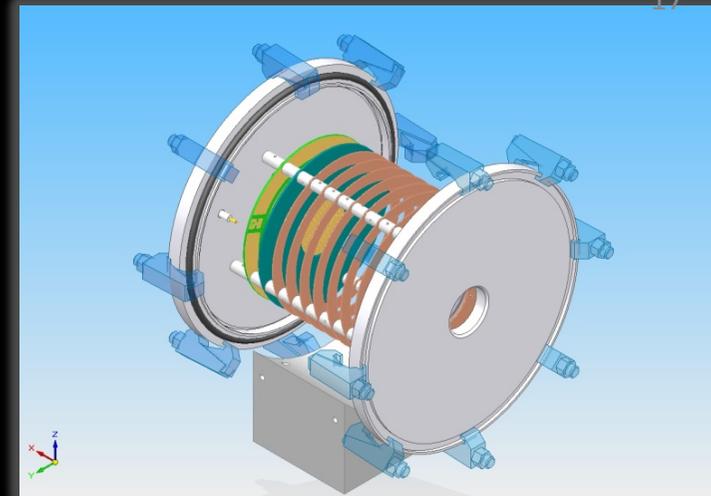
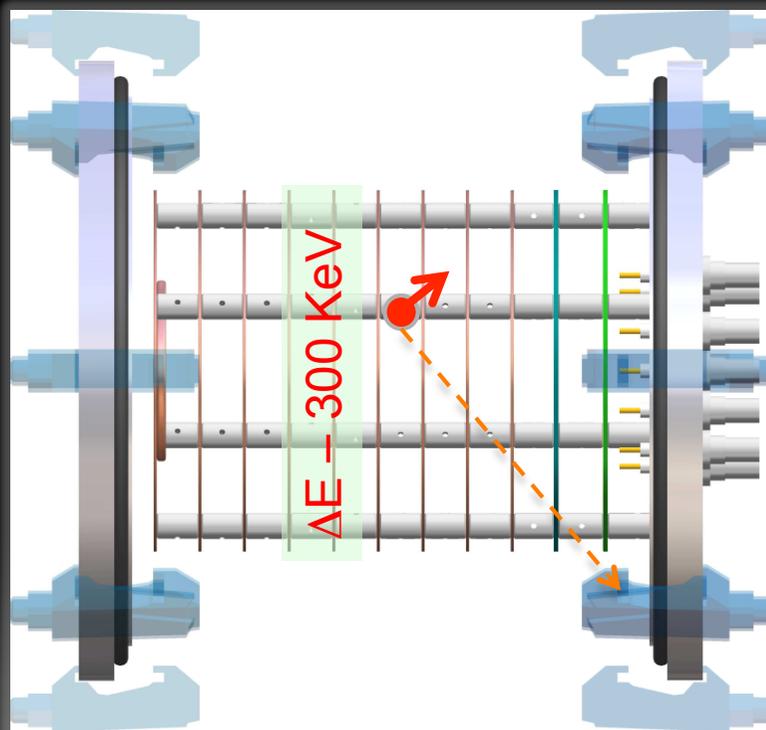
CAO - Marc Riallot, Jean Philippe Mols
Assembly & Tests - Mariam Kebbiri

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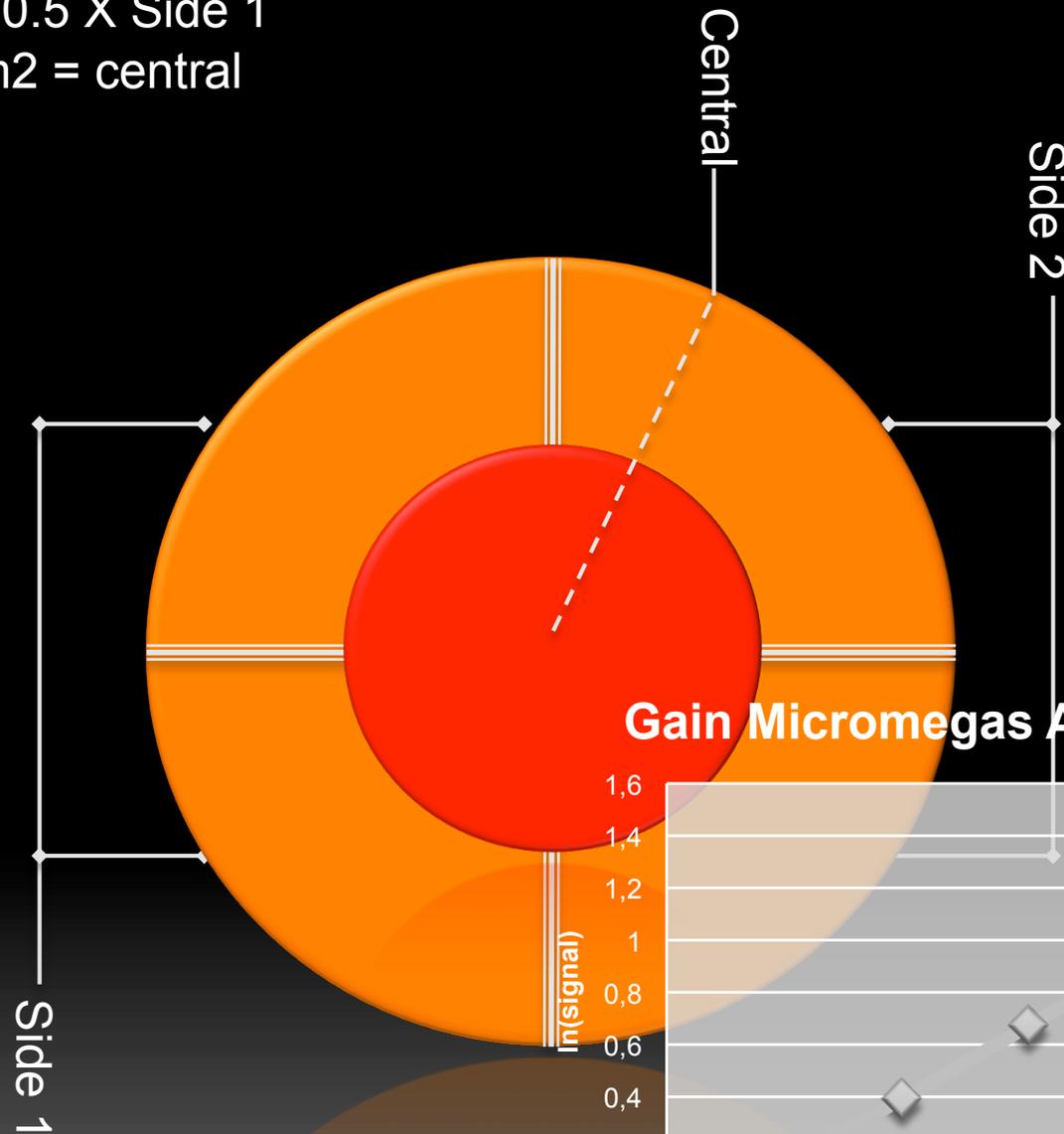
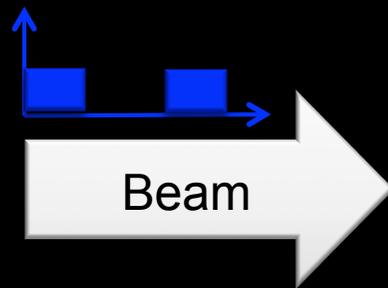


AstroBox-1 CAO - Marc Riallot, Jean Philippe Mols Assembly & Tests - Mariam Kebbiri

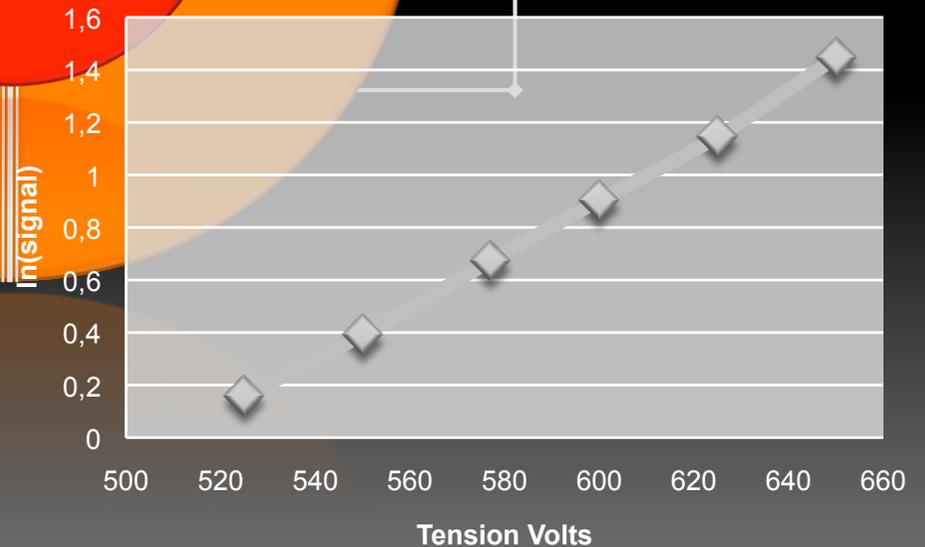
17

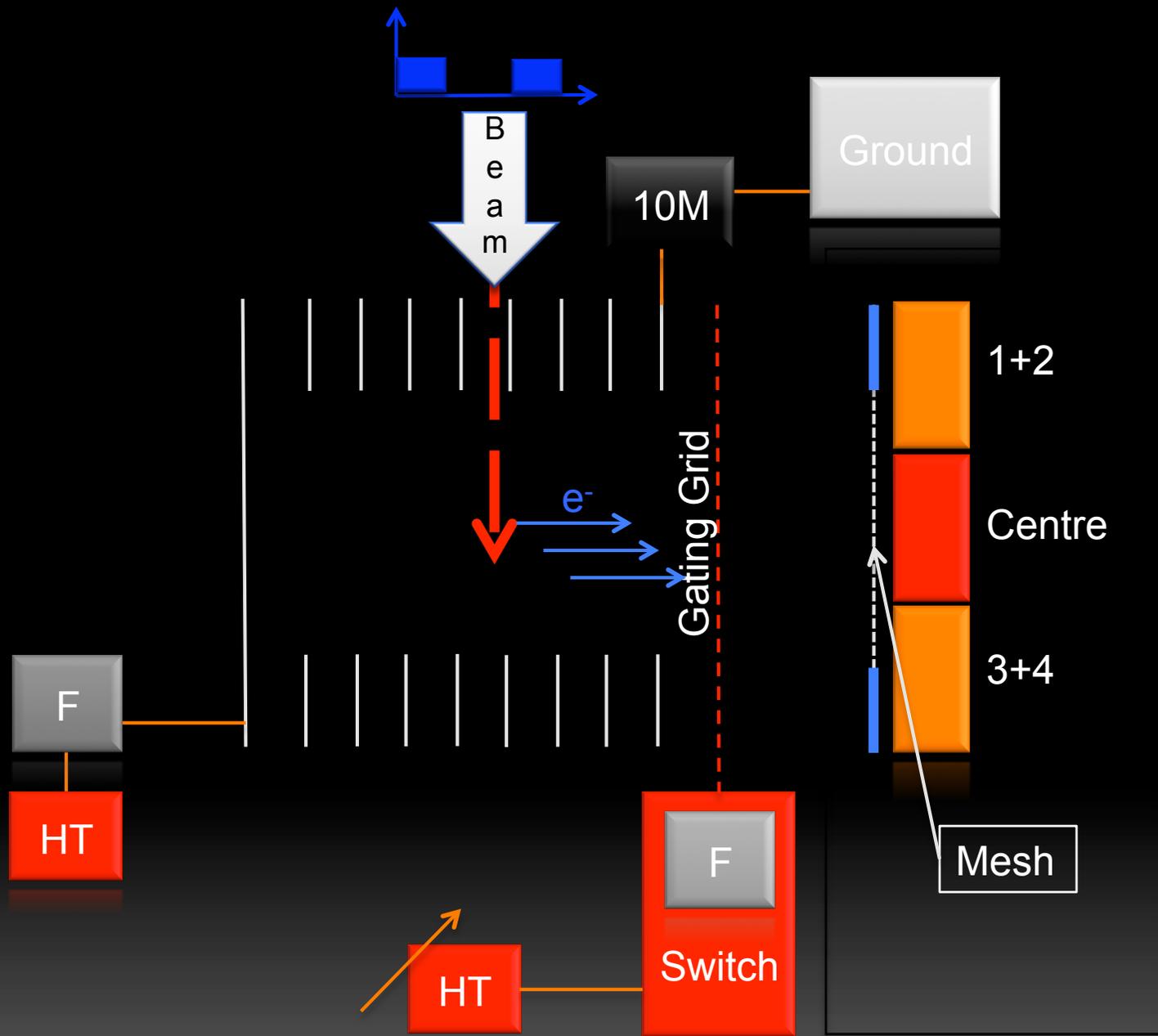


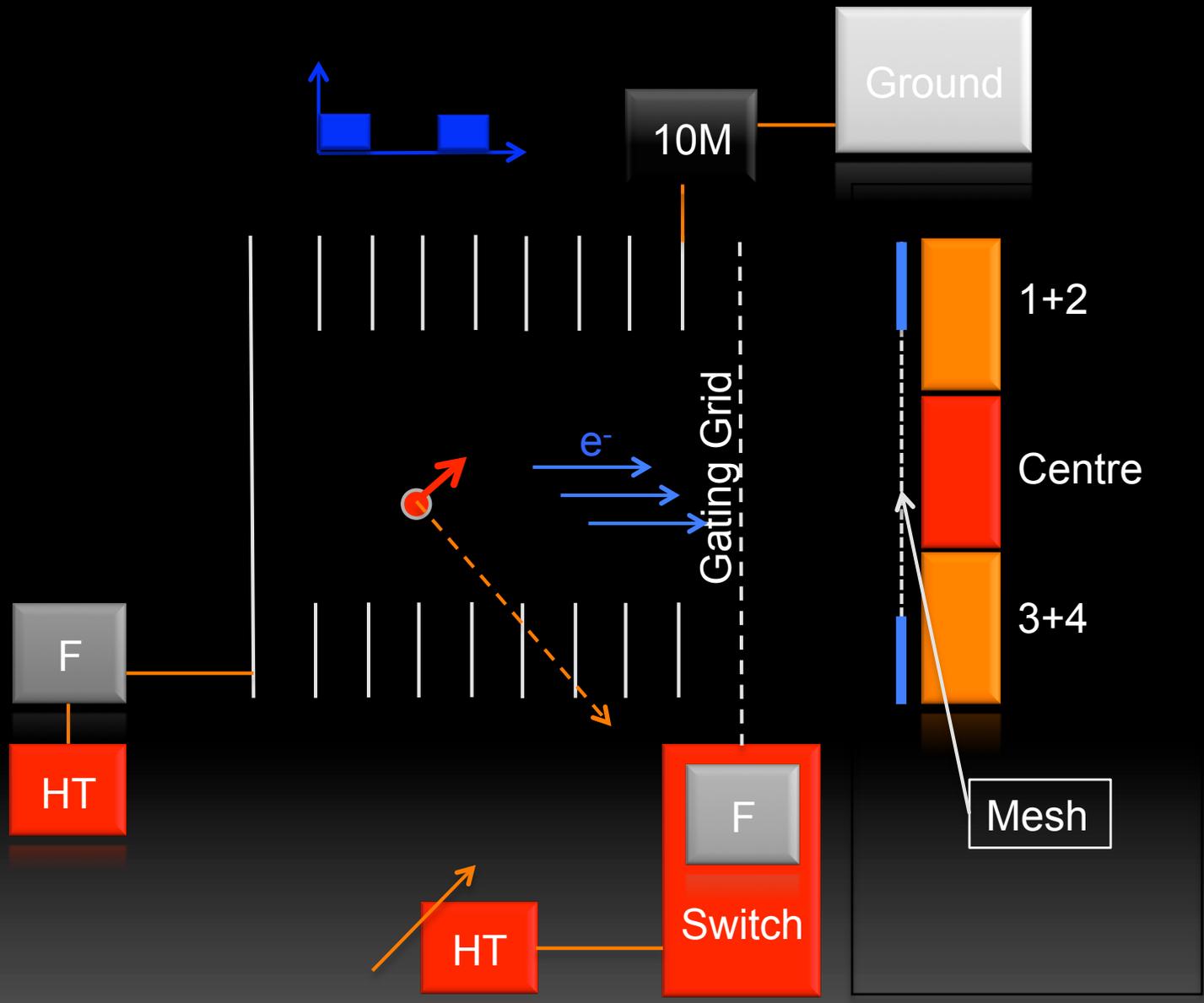
Capa of Central = 0.5 X Side 1
100micron & 12cm² = central
C(central) = 0.1nF
Side 1 (2) = 0.2nF
Mesh = 0.5nF

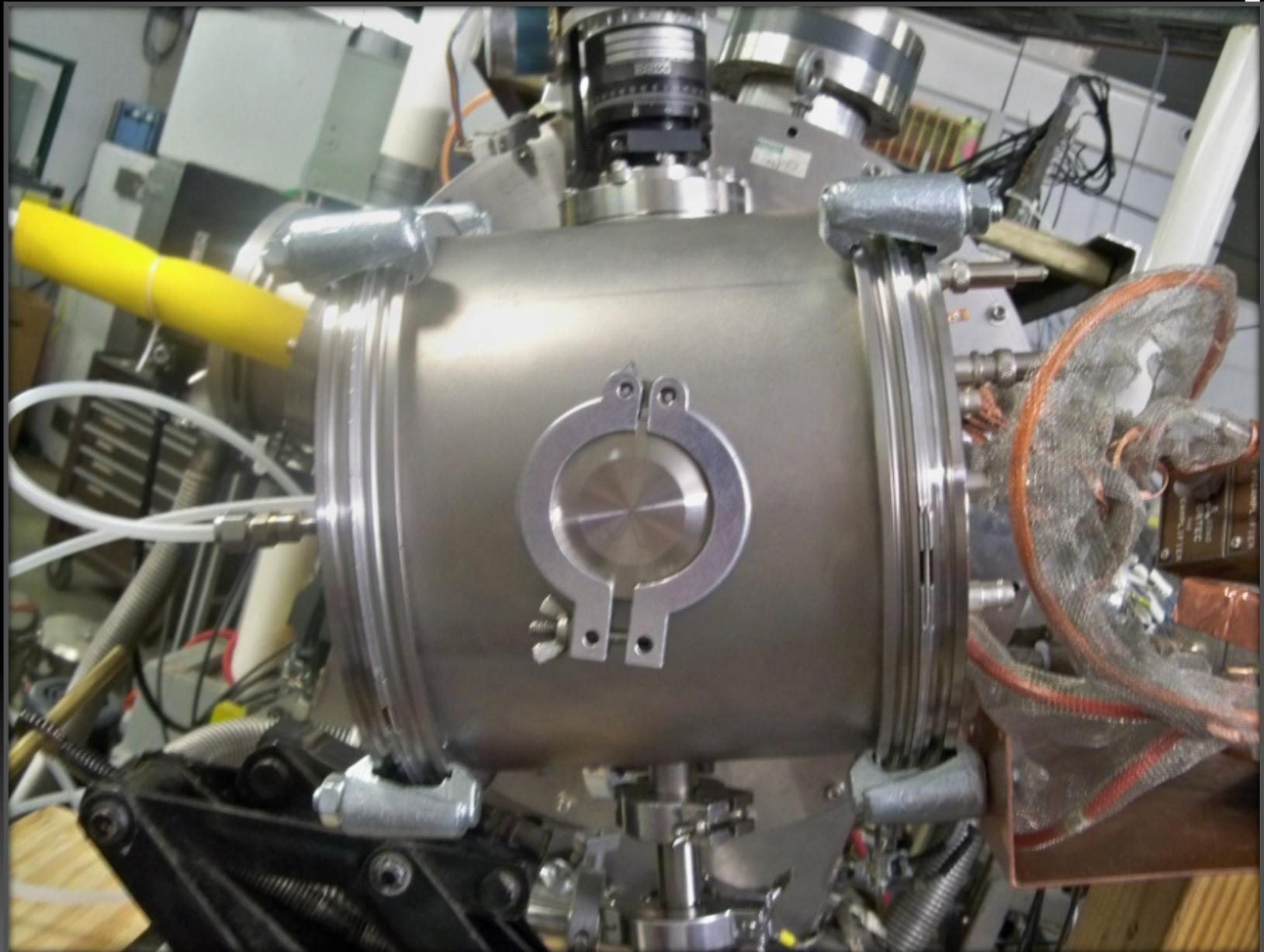


Gain Micromegas Alpha Source

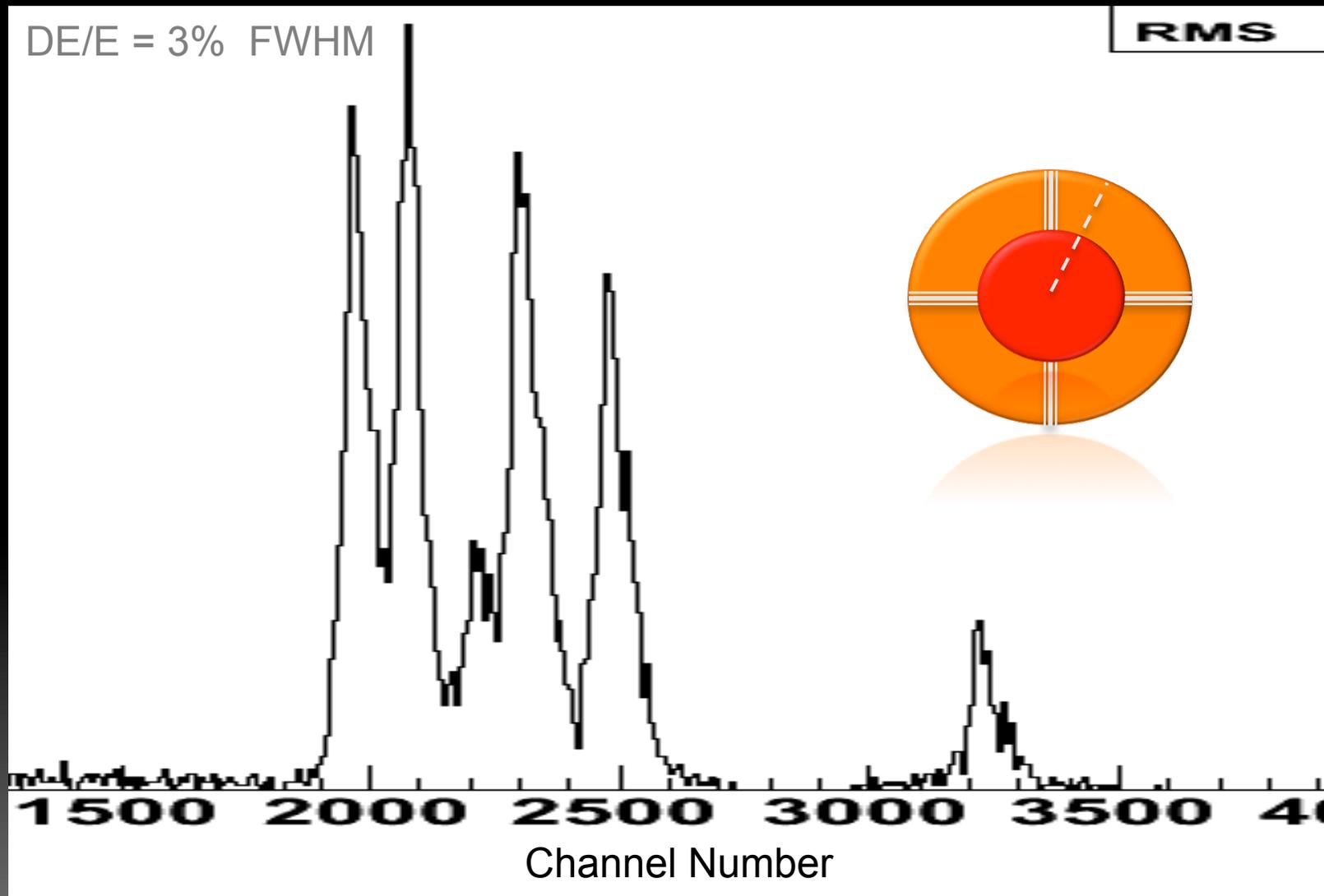




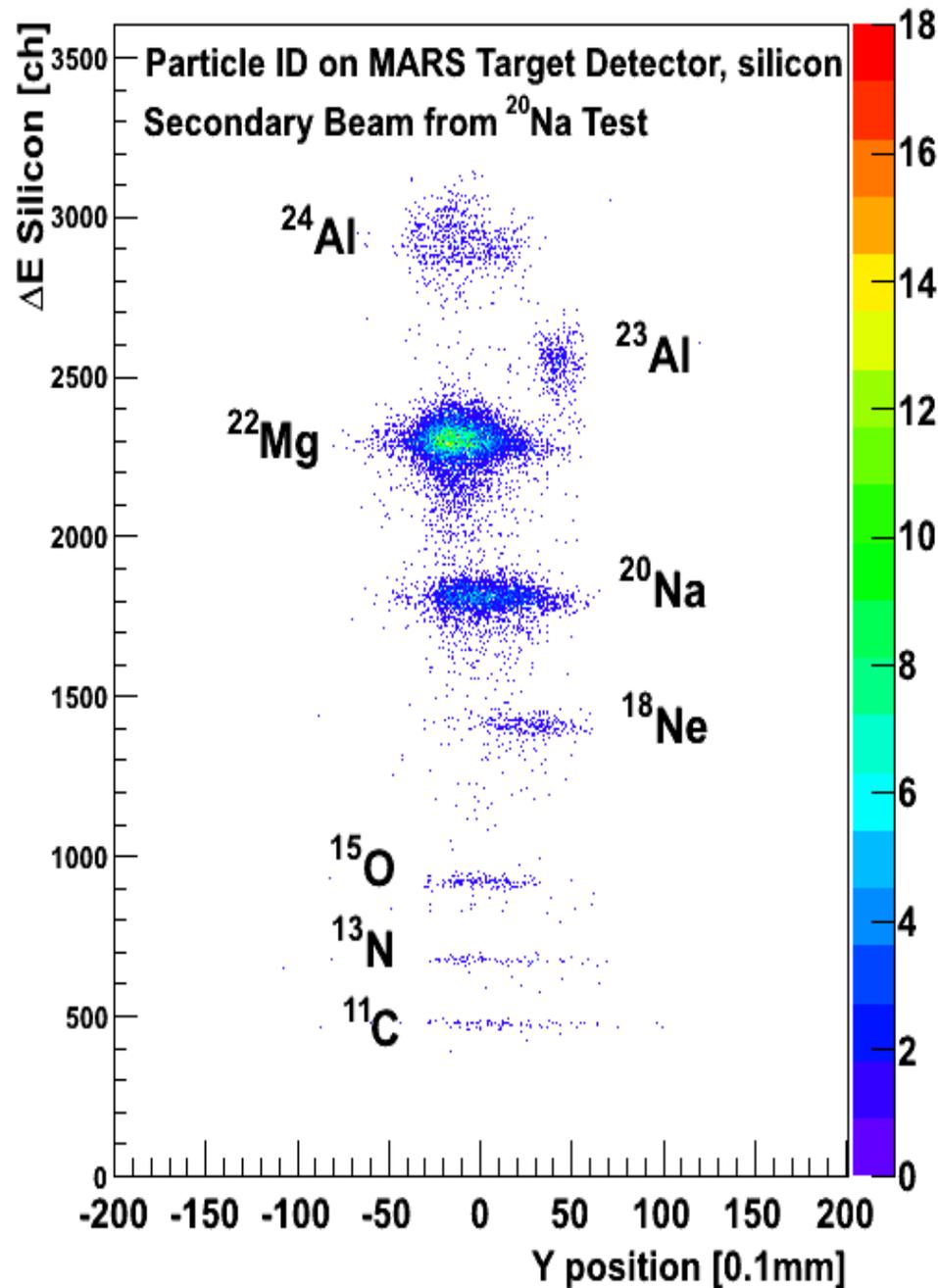




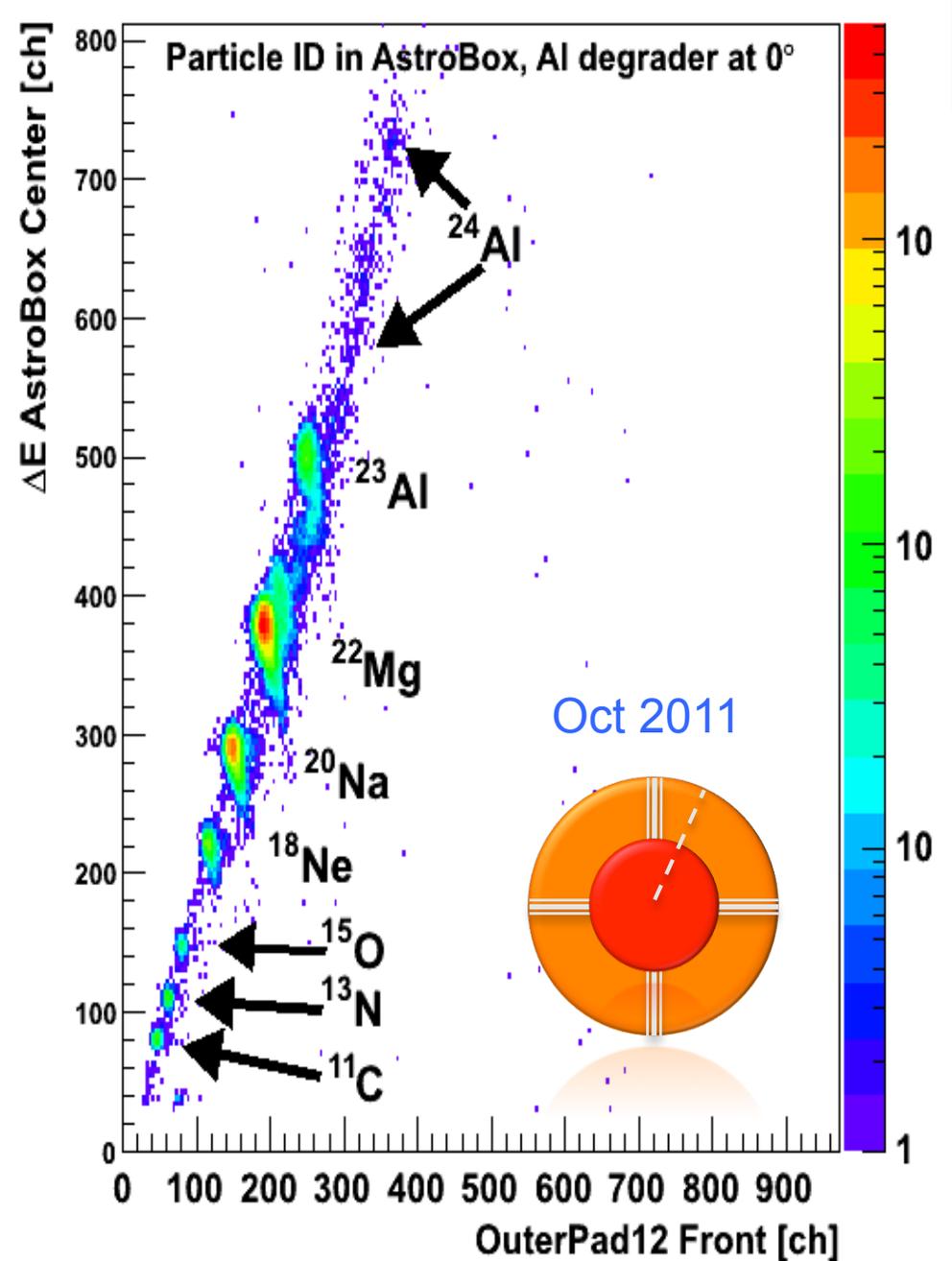
May 2011
Mixed Source
4.5 to 8.5 MeV Alphas

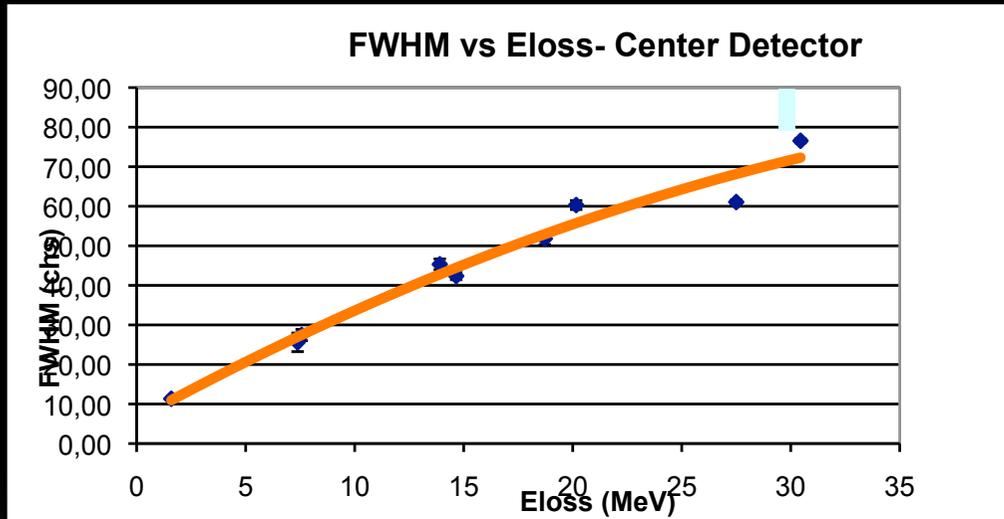
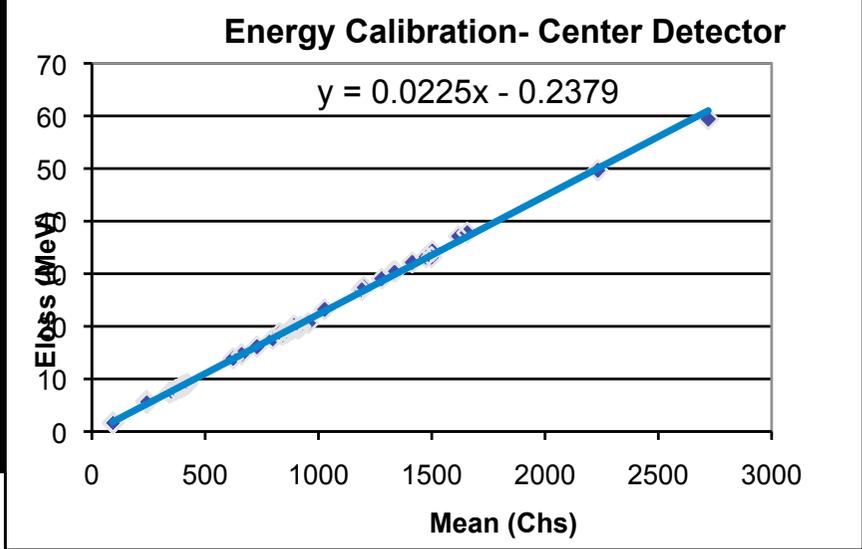
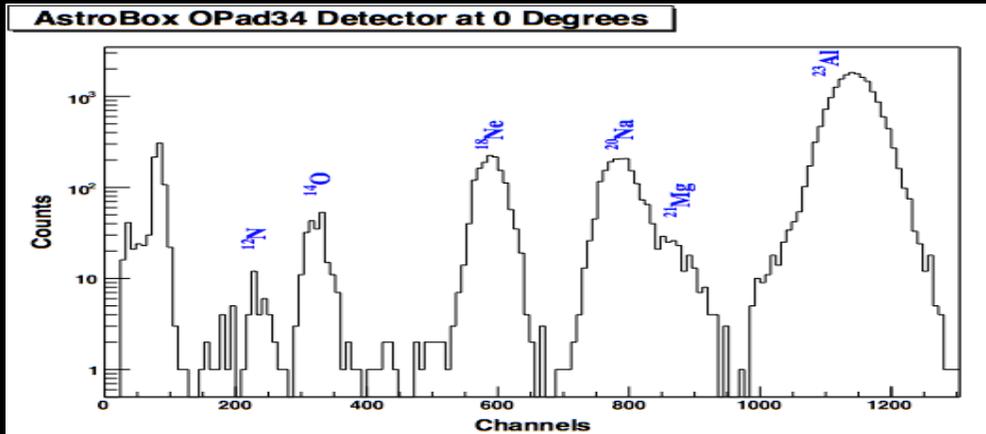


ΔE vs. Y Position - MARS Focal Plane



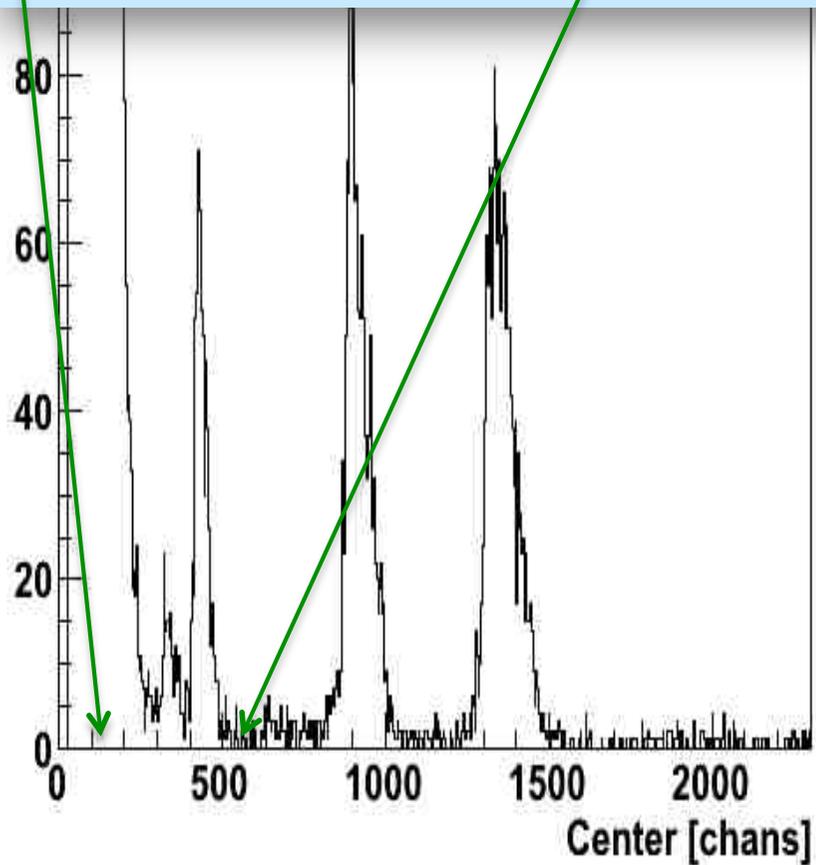
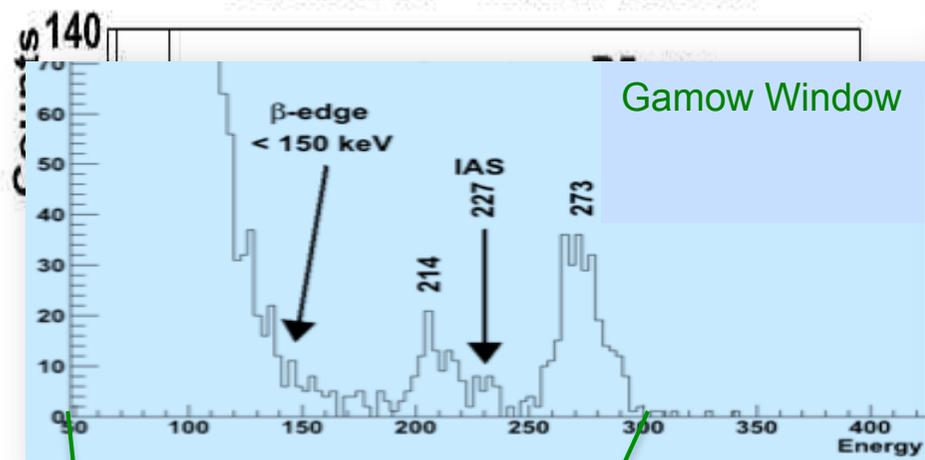
AstroBox Center vs. OPAD12 (Front)



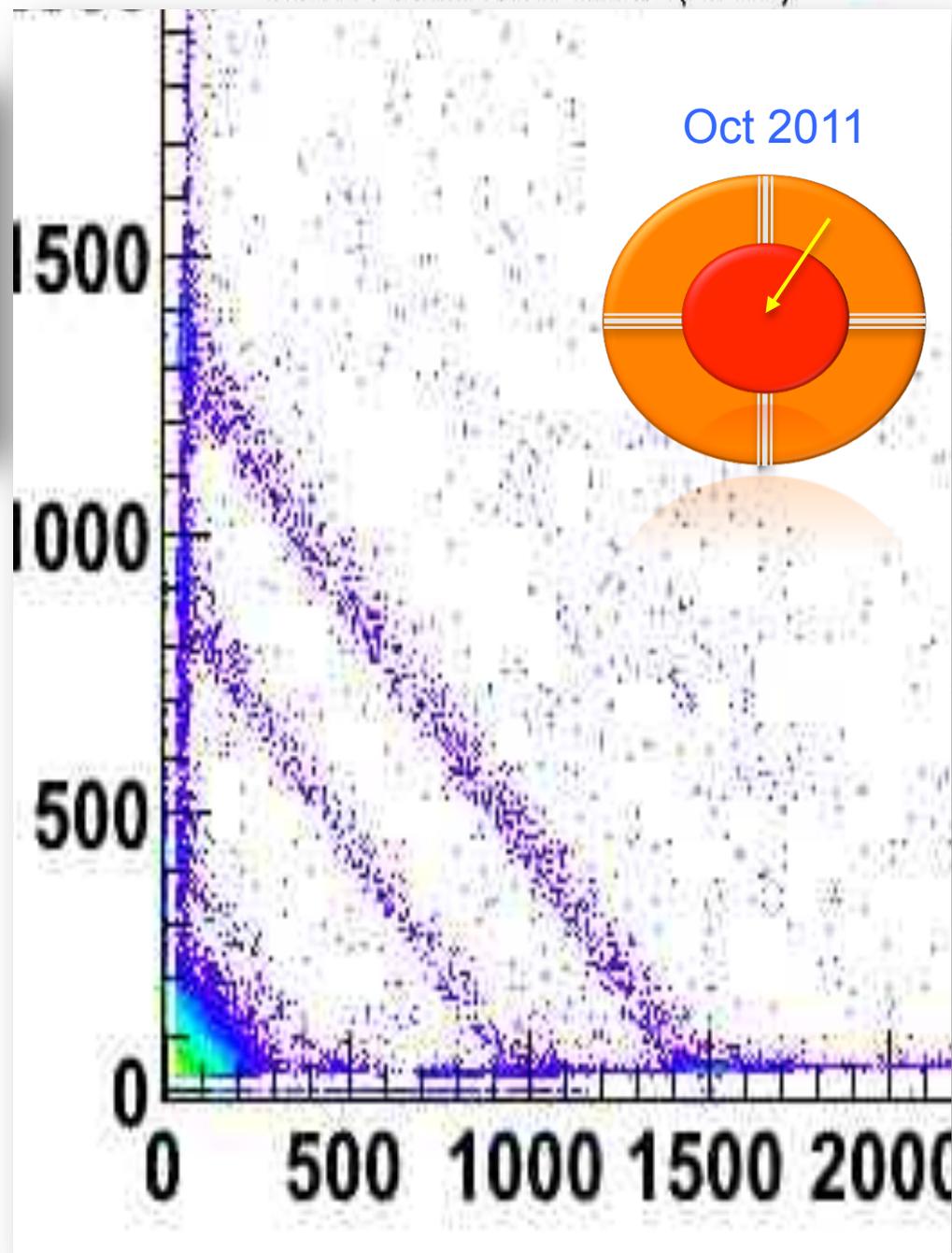


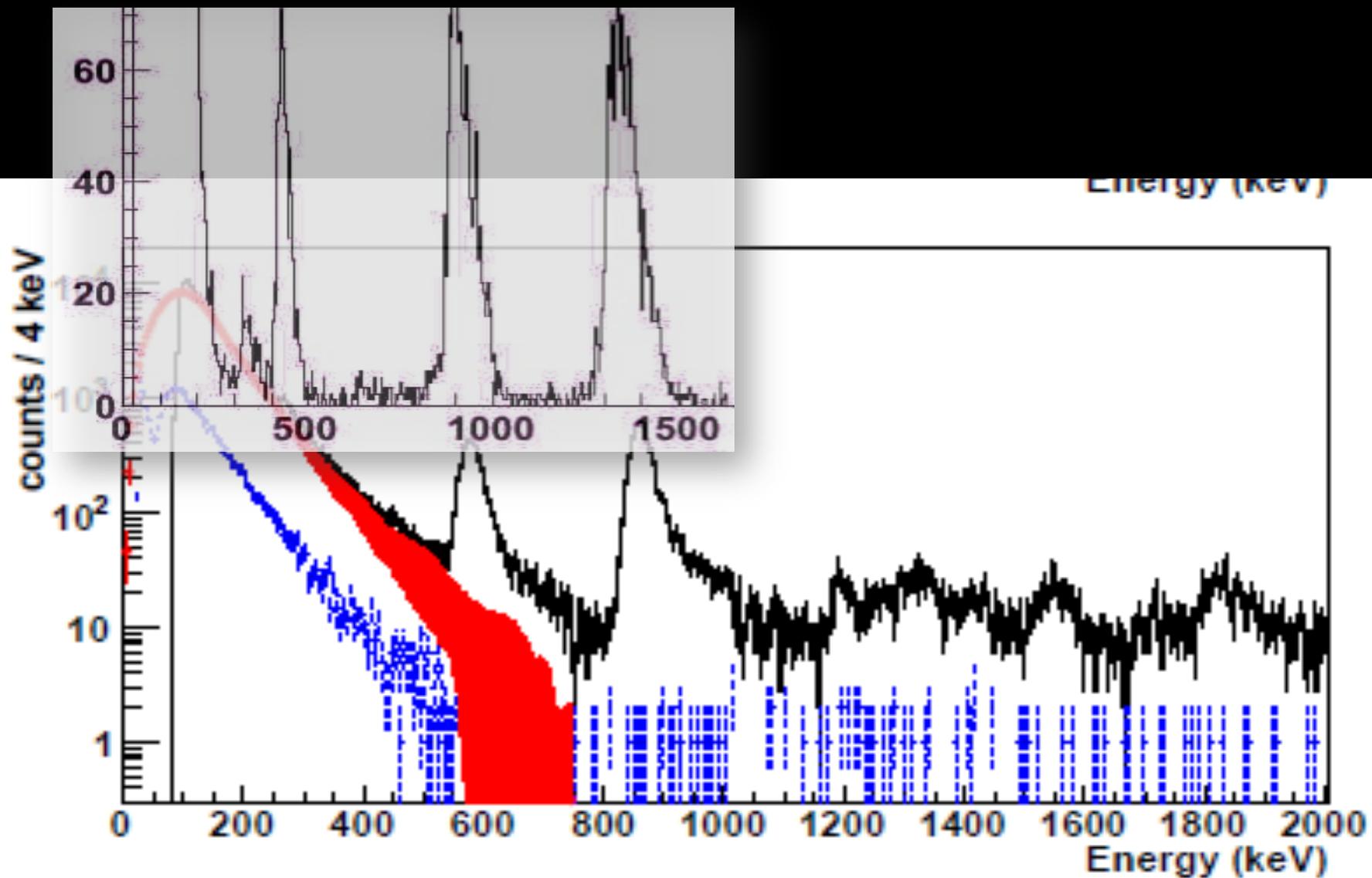
Can develop Beam and Spectrometer Focal Plane Detectors
 Time, Charge & Position readout
 Fast – high counting rates
 Dose can be –very very high ...
 Will save the € zone.

Center Det. - Gated AntiCoin



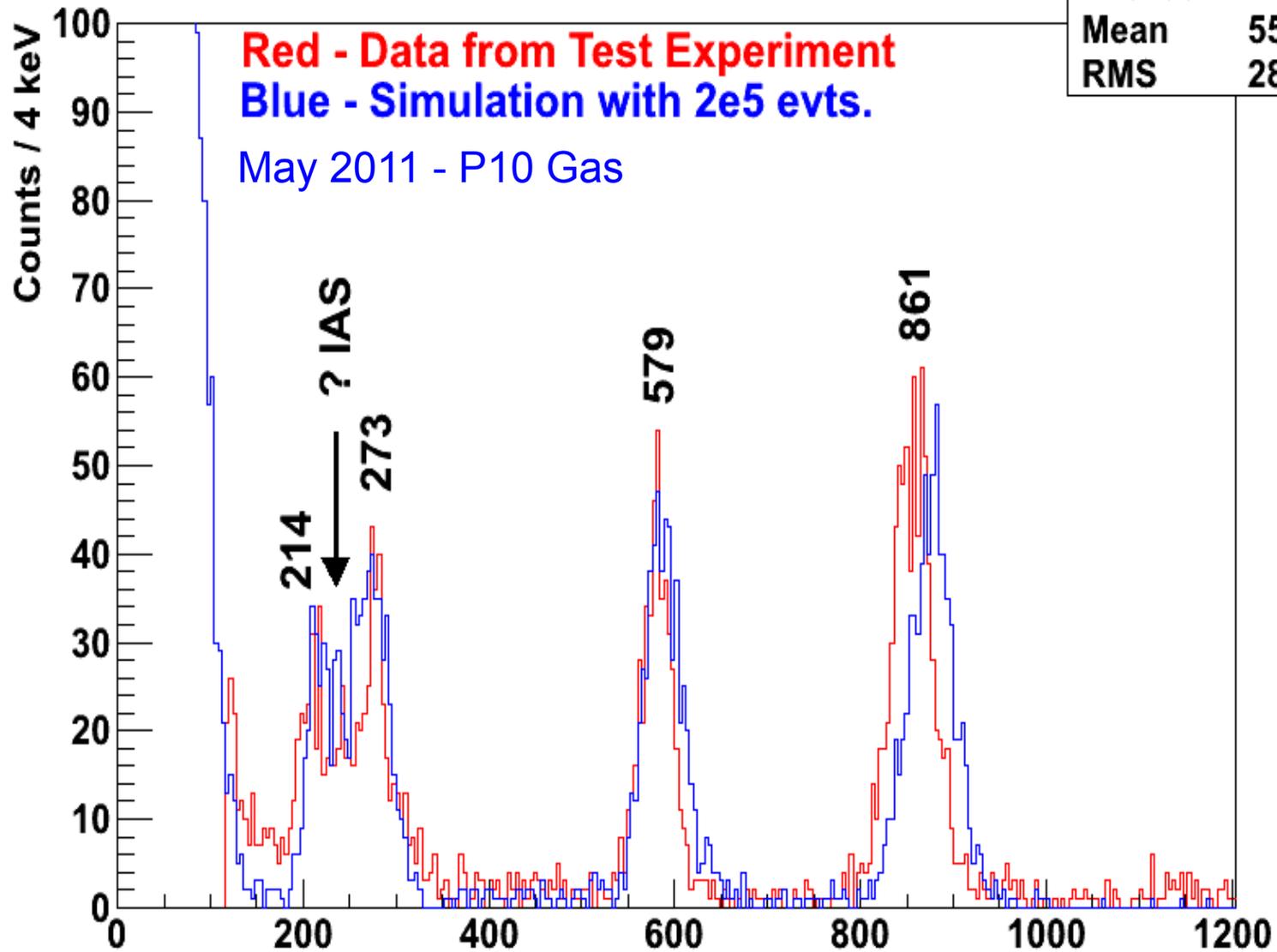
Center vs. OuterPad12 (Front)





^{23}Al in AstroBox1, 800 torr pressure

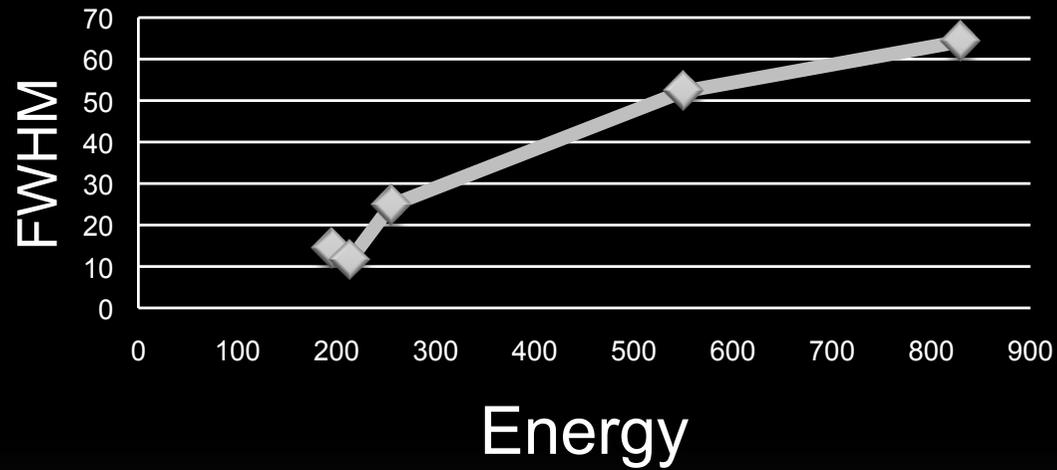
Total_Cal_AntiCoin	
Entries	7126
Mean	555.3
RMS	289.7



For the ^{23}Al $p\beta$ decay spectra

Calibration
Resolution

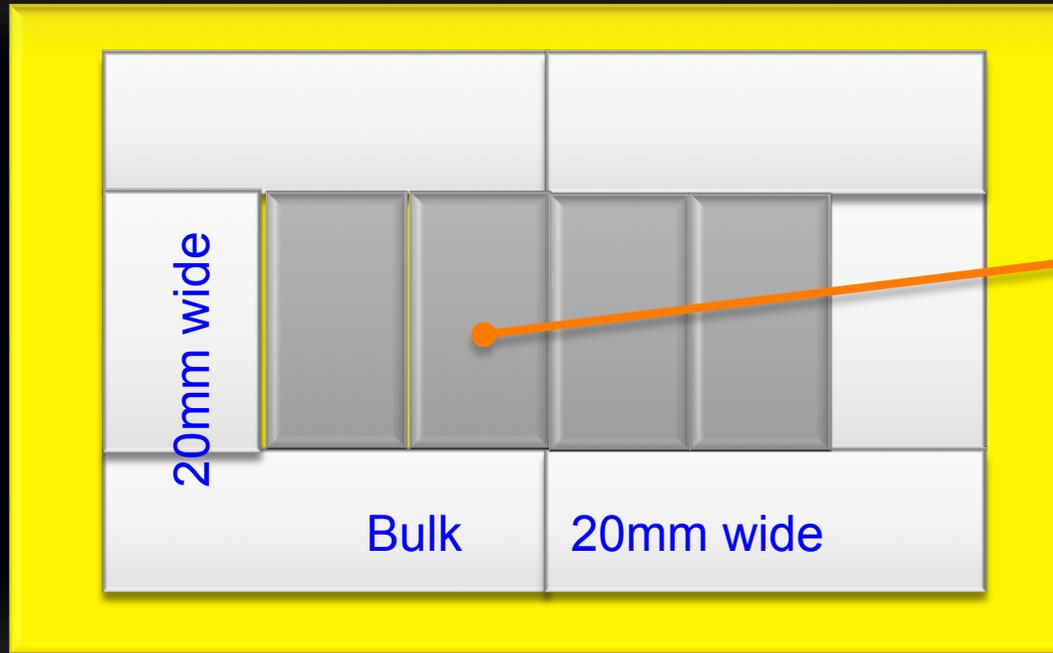
FWHM(KeV) vs Energy(KeV)



AtroBoX-2

- 4 – Central channels
- 6 – 'Escape' channels

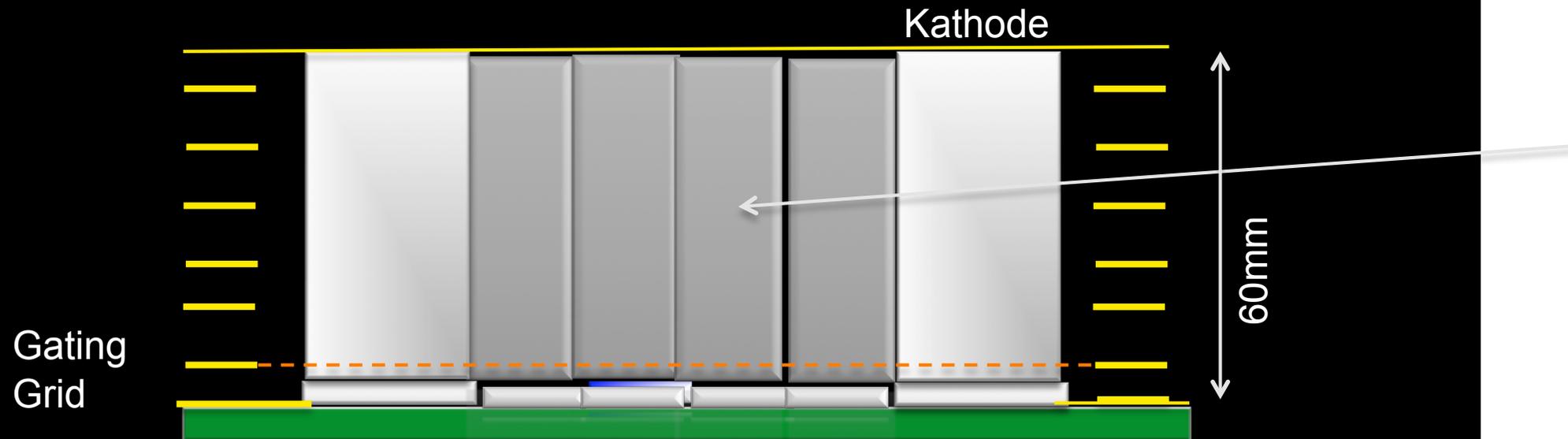
80mm



80mm

130m

Active Volumes



-Reduced Drift height & divided central volume in 4 → less beta

-High Gain pre-amplifiers to cope with high dynamic range
Needed between the decay and beam energy deposits.
Possibly remove the G.Grid.

-Grounding of Mesh & Resistive Micromegas Test

-Sampling ADCs for the central zone to remove low energy betas