

Low channel density MicroMEGAS detectors for decay and reaction studies

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MicroMEGAS based detectors at TAMU

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MicroMEGAS based detectors at TAMU

1. AstroBox — β -delayed particle spectroscopy

MicroMEGAS: 29 ch + aux detectors: 3-16 ch

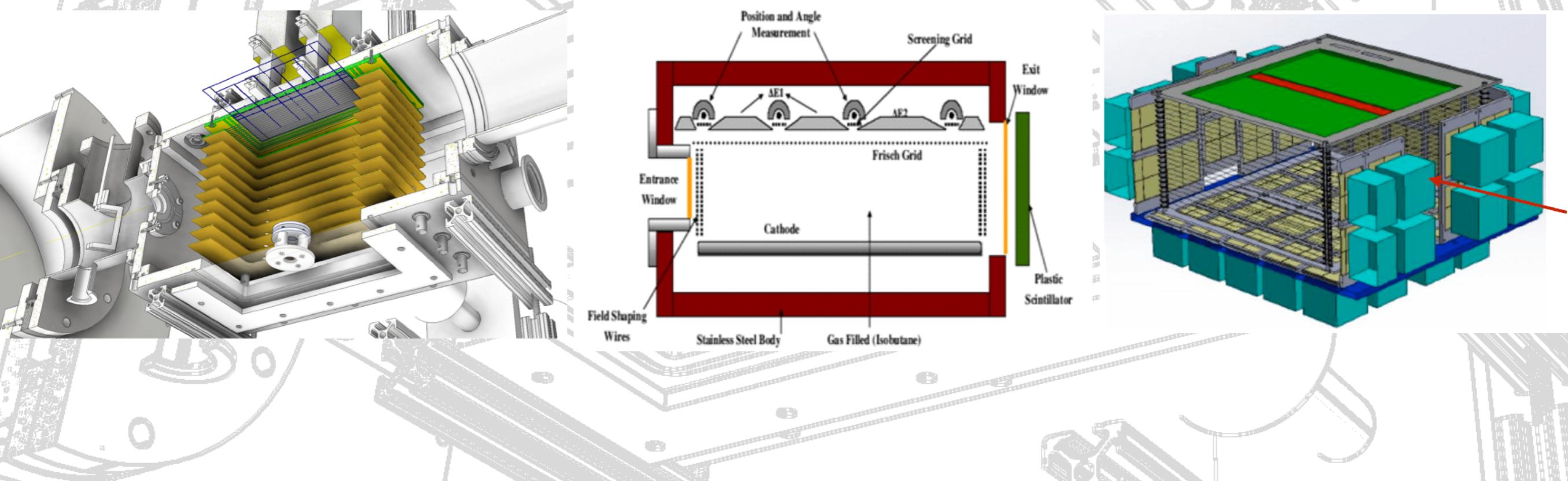
2. MDM / Oxford — FP detector for transfer reactions

MicroMEGAS: 28/56 ch + aux detectors: 12-17 ch (FP)

\sim 200 ch (TIARA + HPGe)

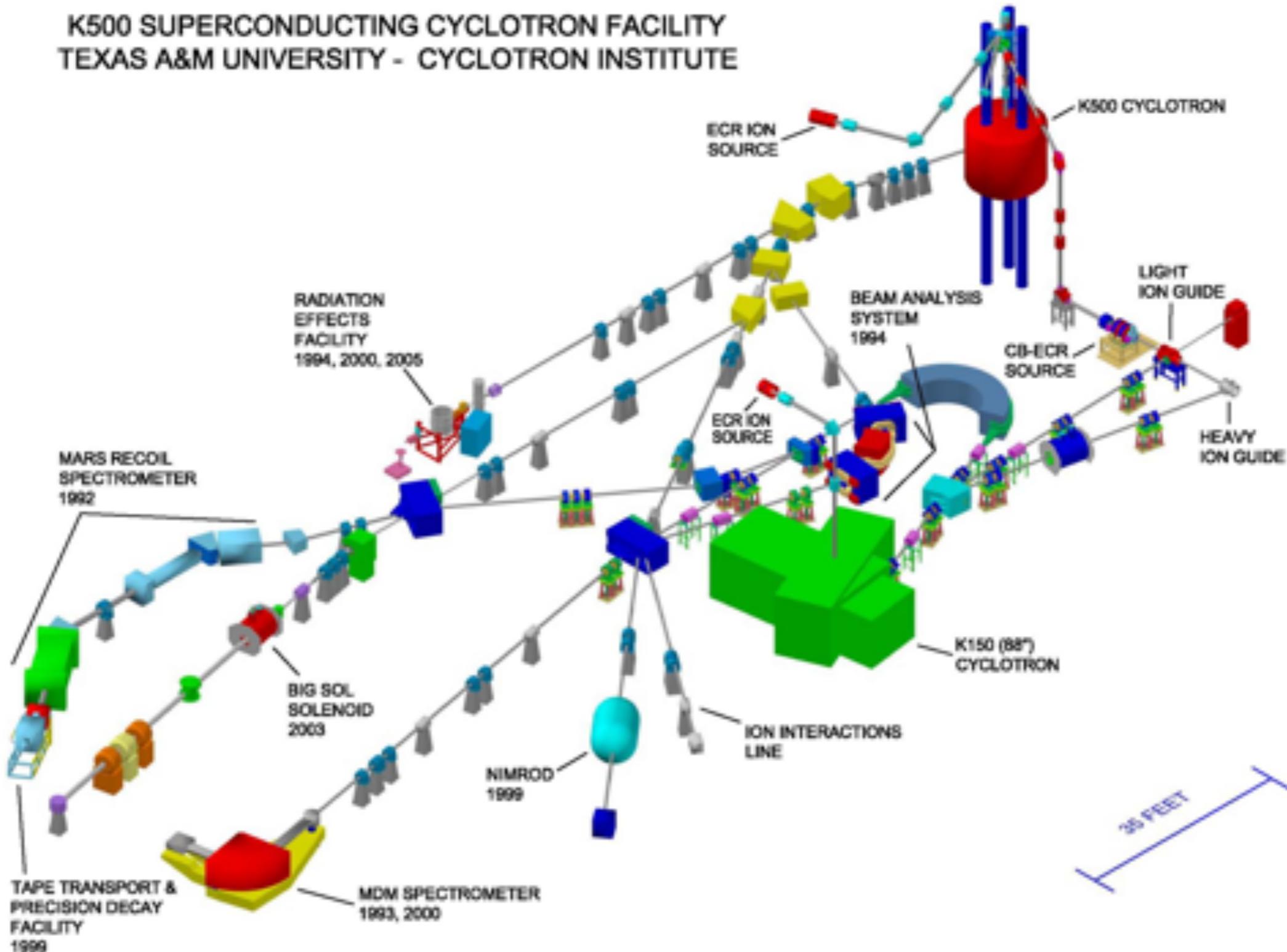
3. TexAT — The Texas Active Target

MicroMEGAS: 1024 ch + aux detectors: 250 ch



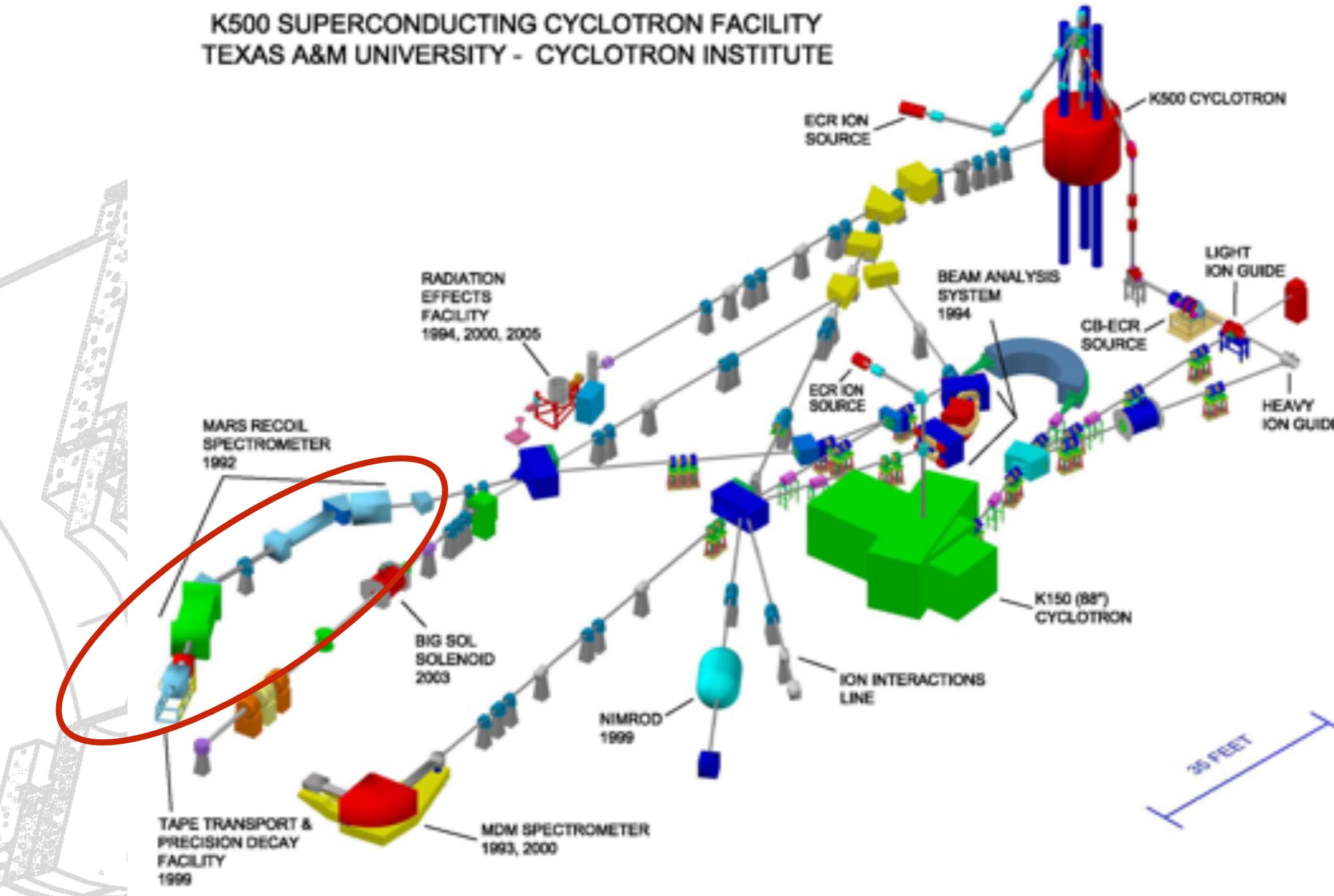
TAMU Cyclotron Institute

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE



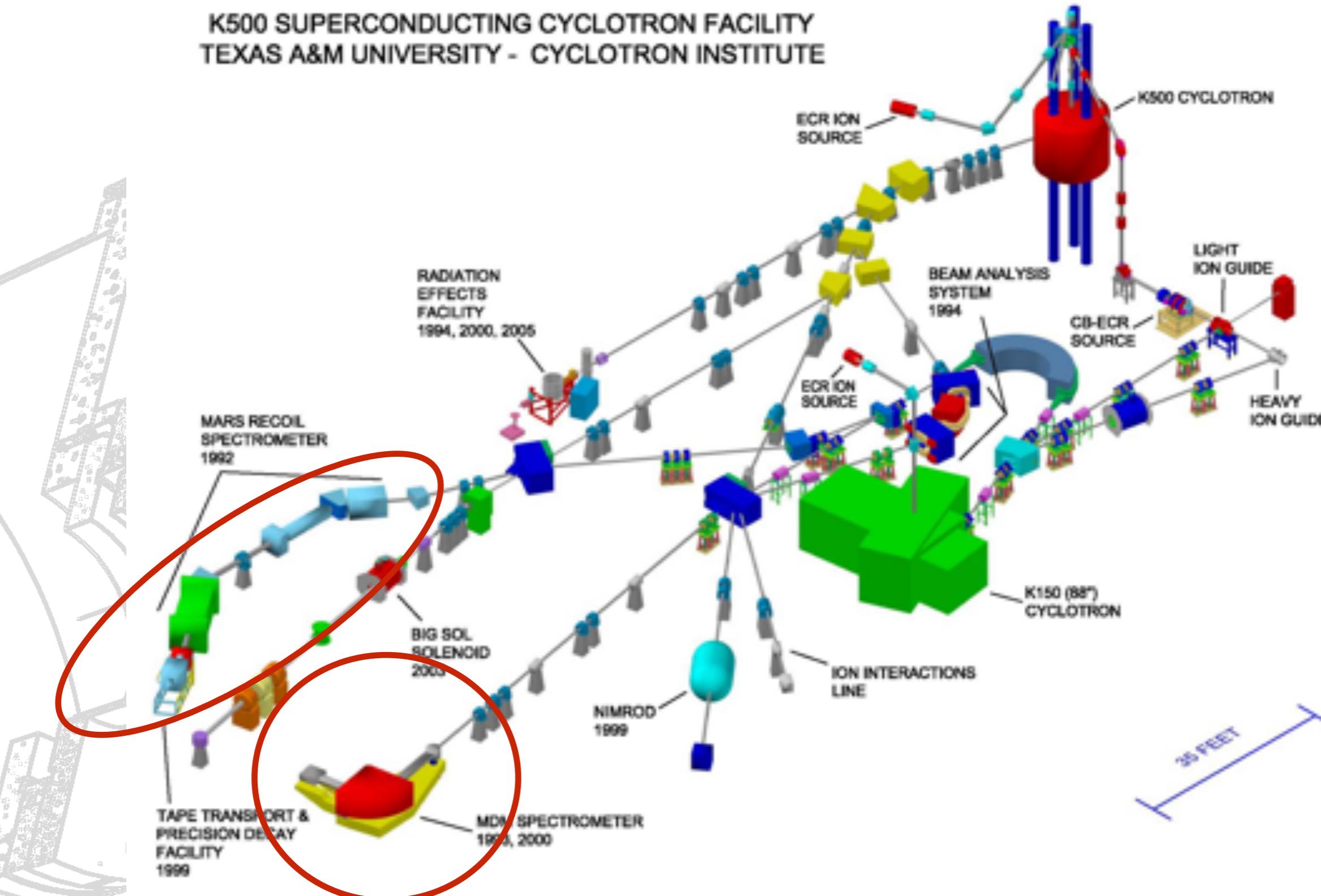
TAMU Cyclotron Institute

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE



TAMU Cyclotron Institute

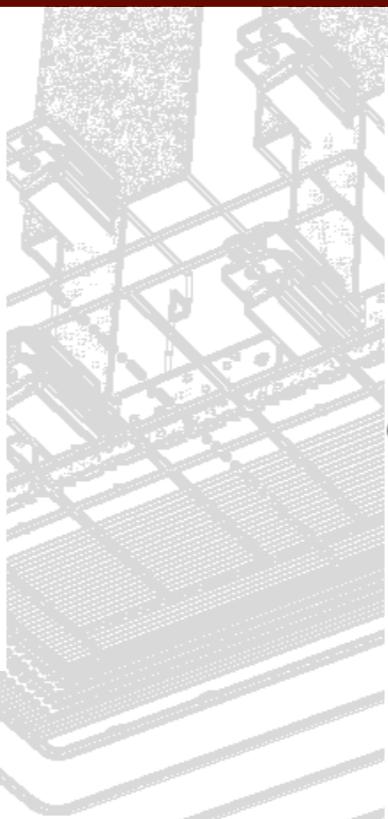
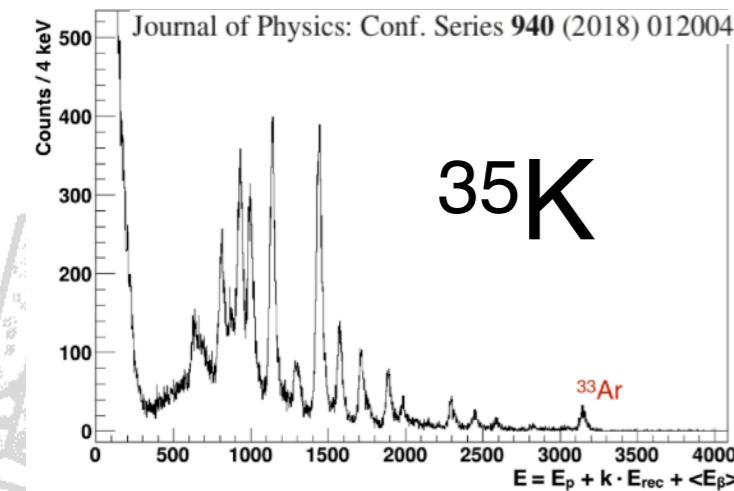
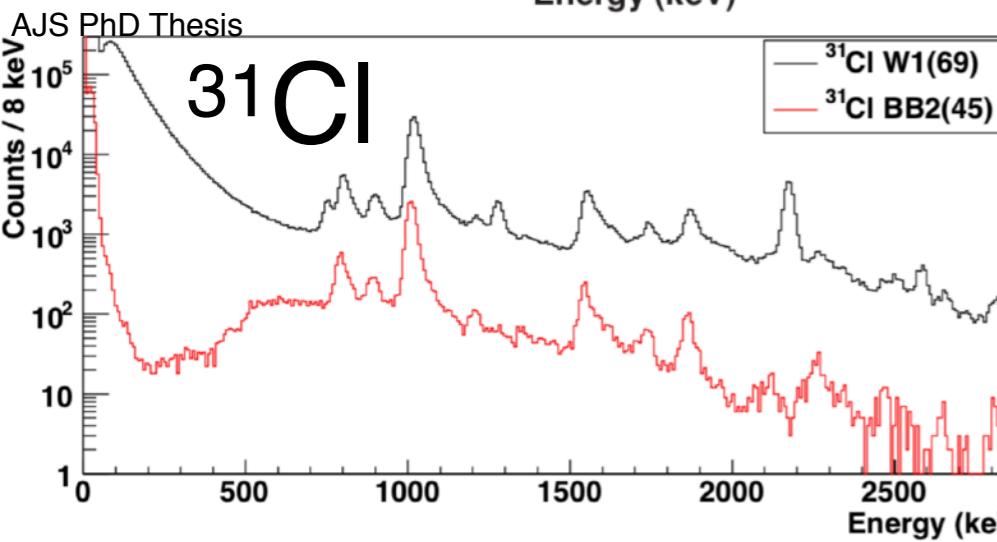
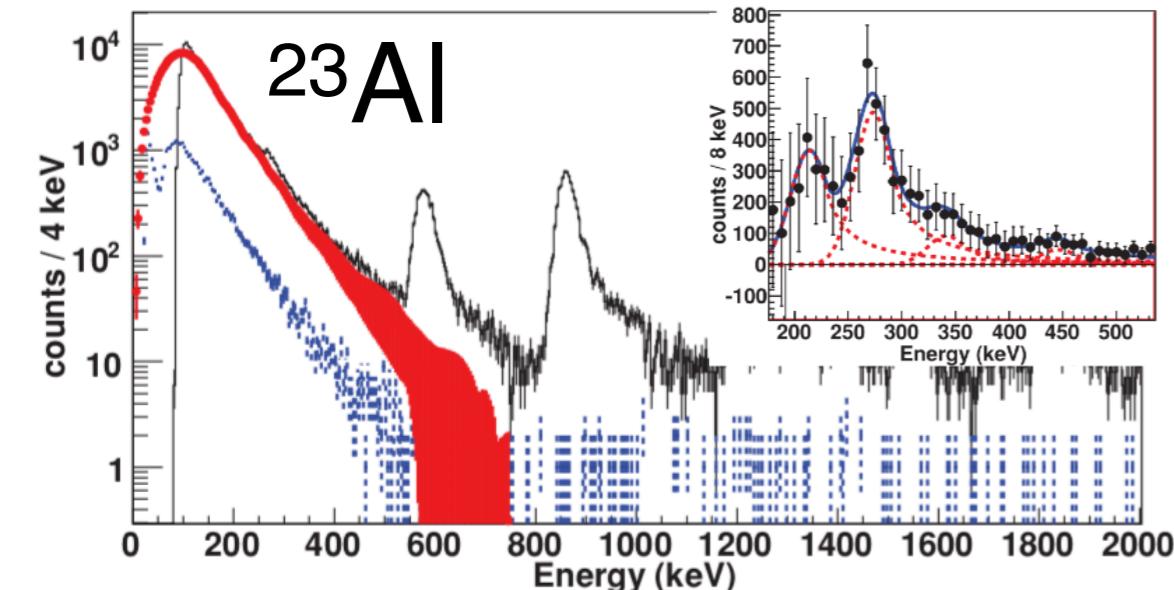
K500 SUPERCONDUCTING CYCLOTRON FACILITY
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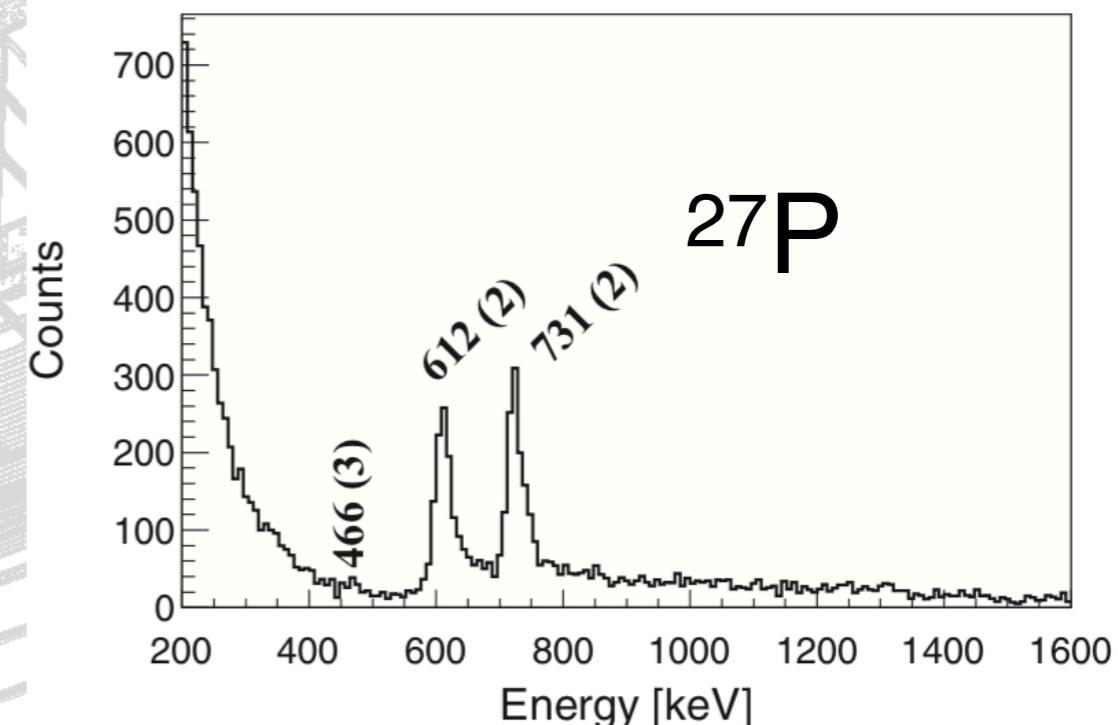
1. AstroBox – β -delayed particle spectroscopy

β p-decays for nucleosynthesis at TAMU

A. SAASTAMOINEN *et al.* PHYSICAL REVIEW C 83, 045808 (2011)

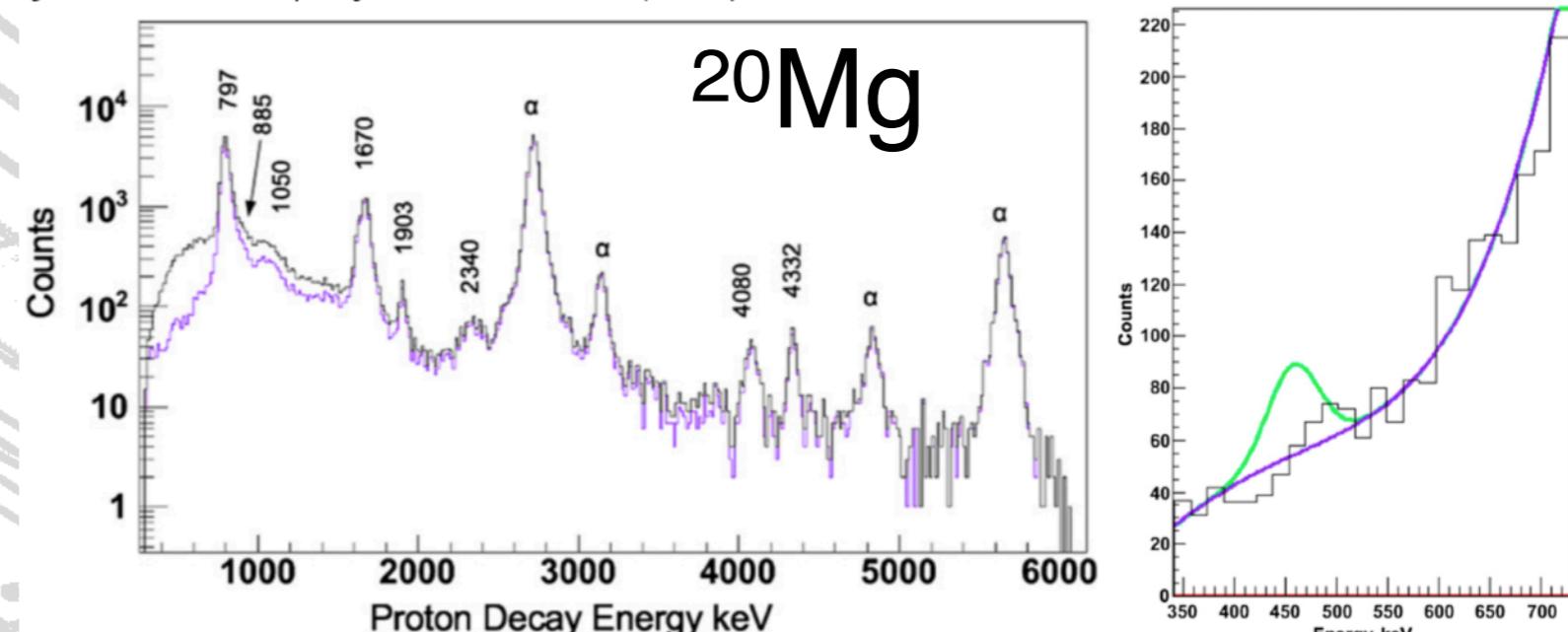


E. MCCLESKEY *et al.* PHYSICAL REVIEW C 94, 065806 (2016)

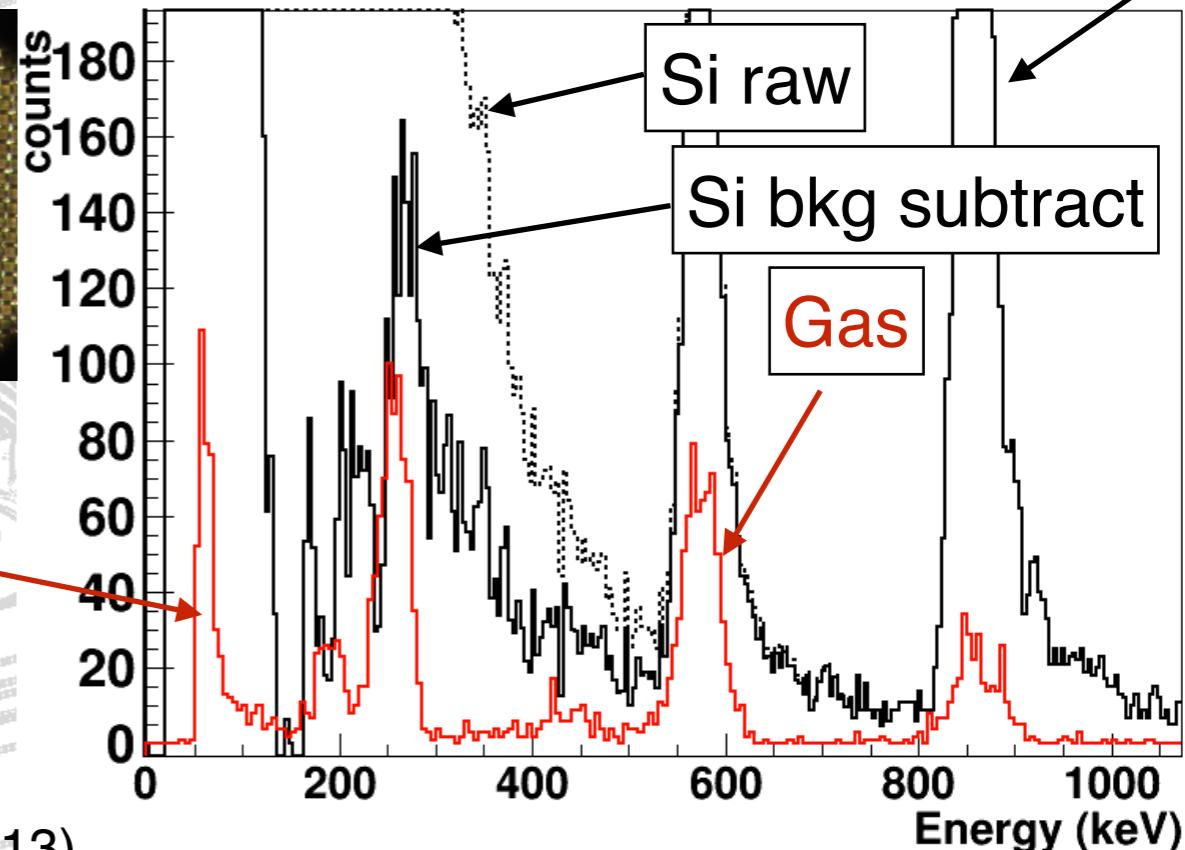
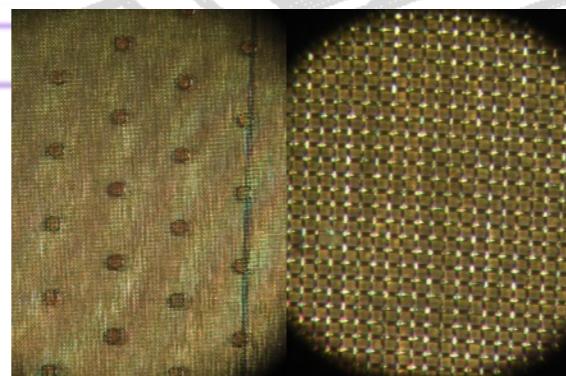
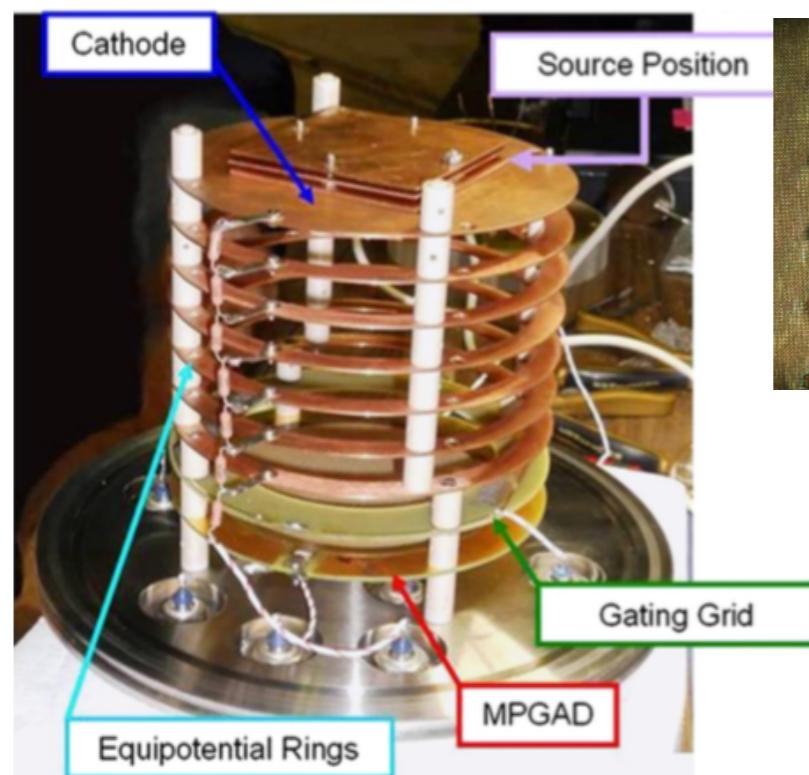
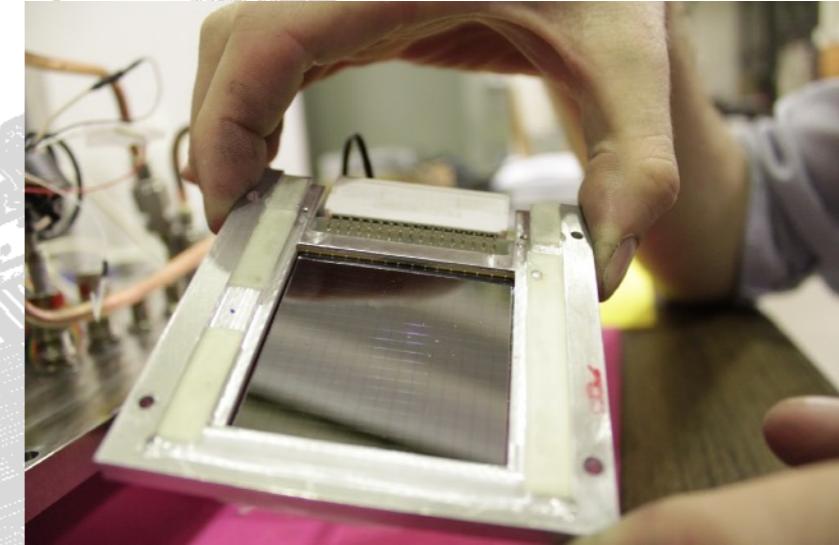
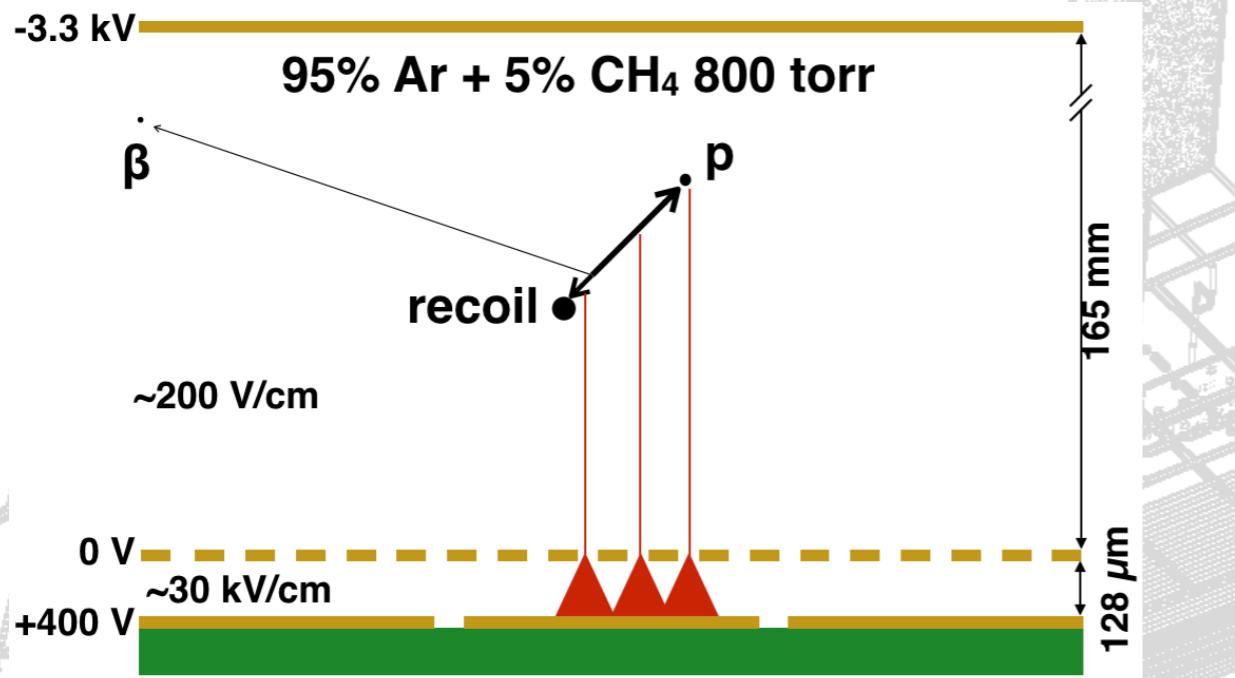


Common problem with Si-detectors: β & escape background, impurities, sensitive to noise!

J.P. Wallace *et al.* / Physics Letters B 712 (2012) 59–62



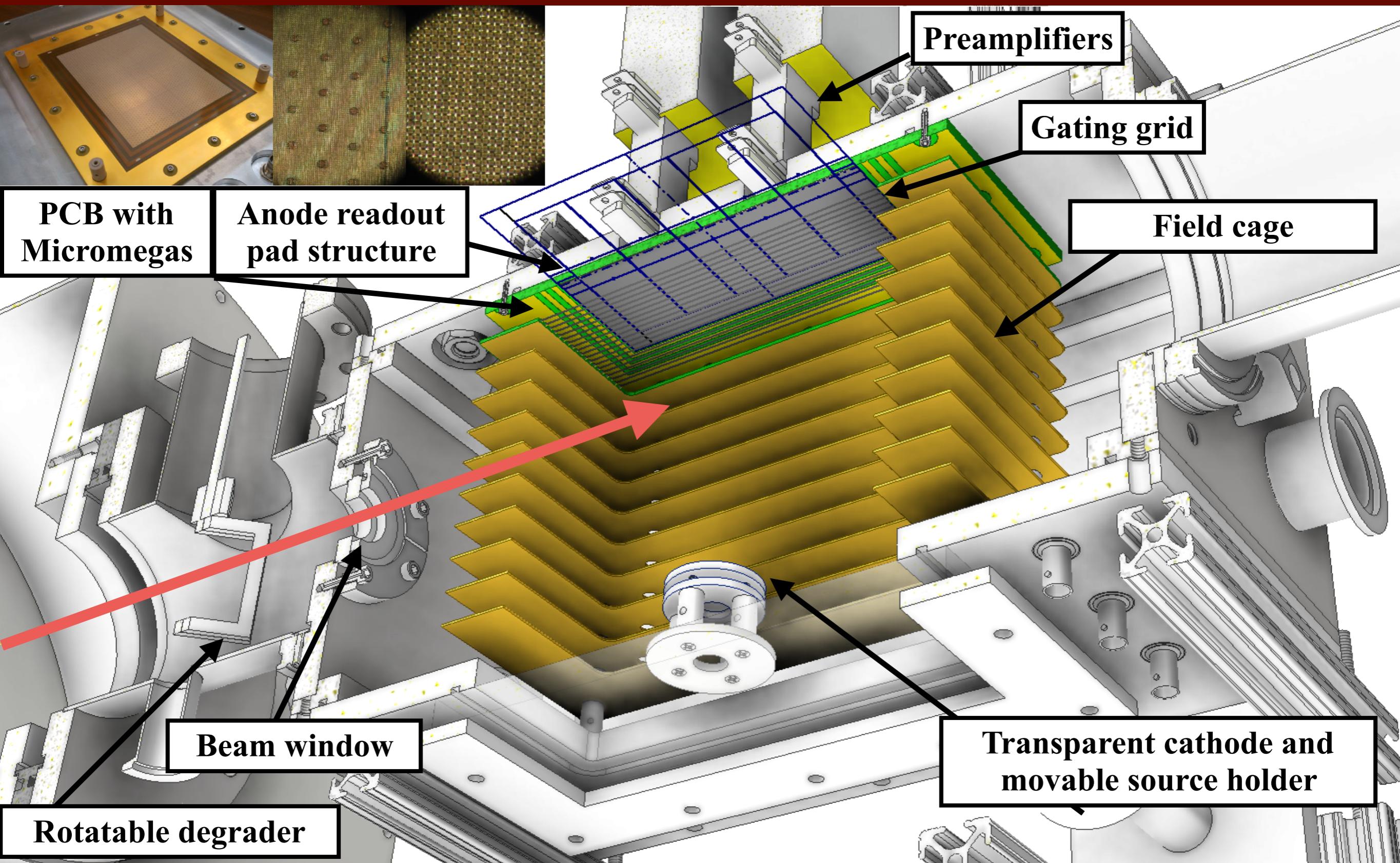
From Si to gas as detection medium



AstroBox (2009-2012): E. Pollacco et al., NIM A723, 102 (2013)

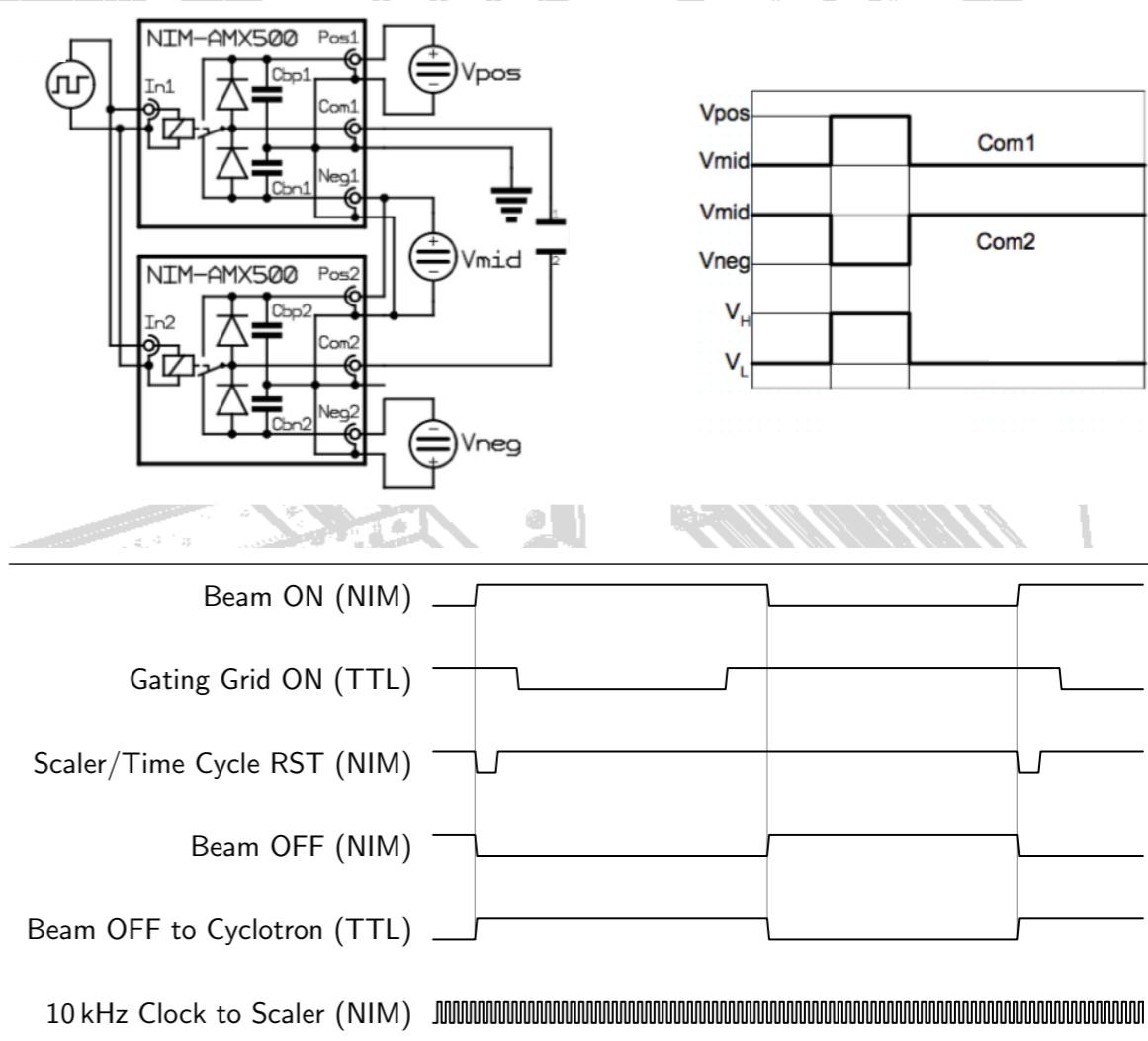
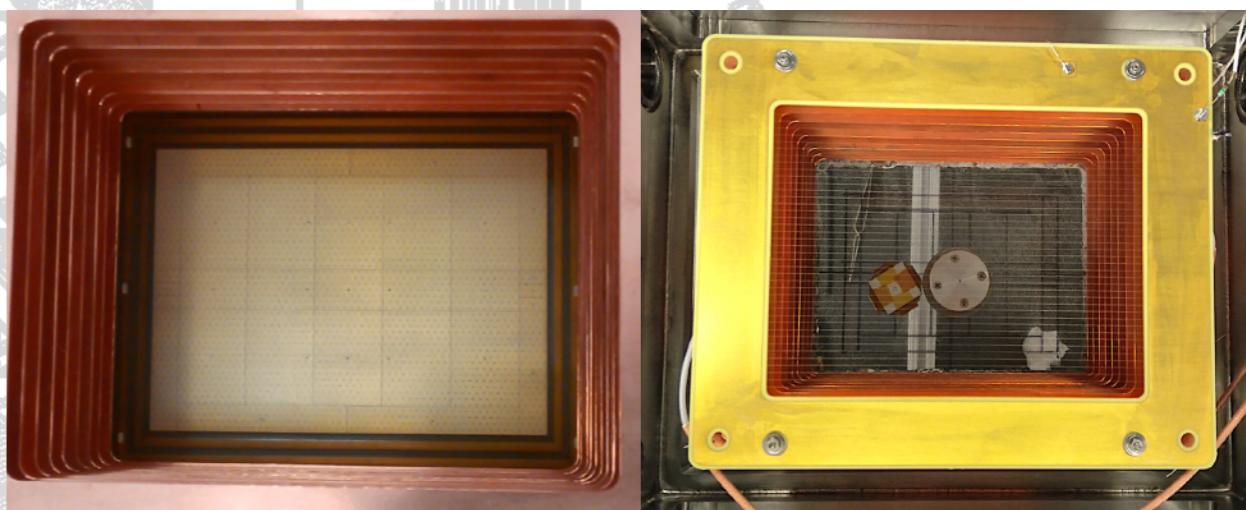
AstroBox2 (2014-): A. Saastamoinen et al. NIM B376, 357 (2016)

The AstroBox2 detector

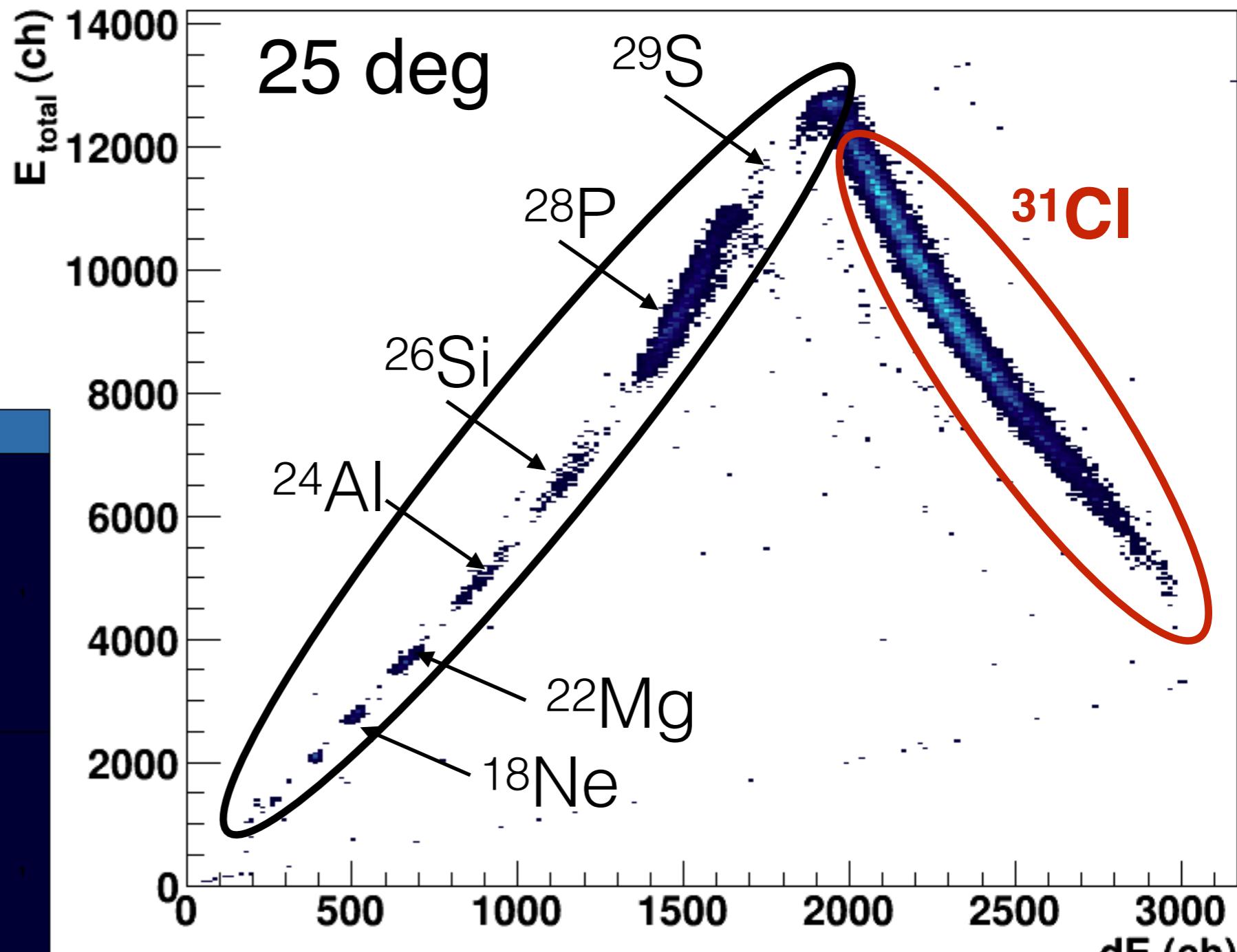
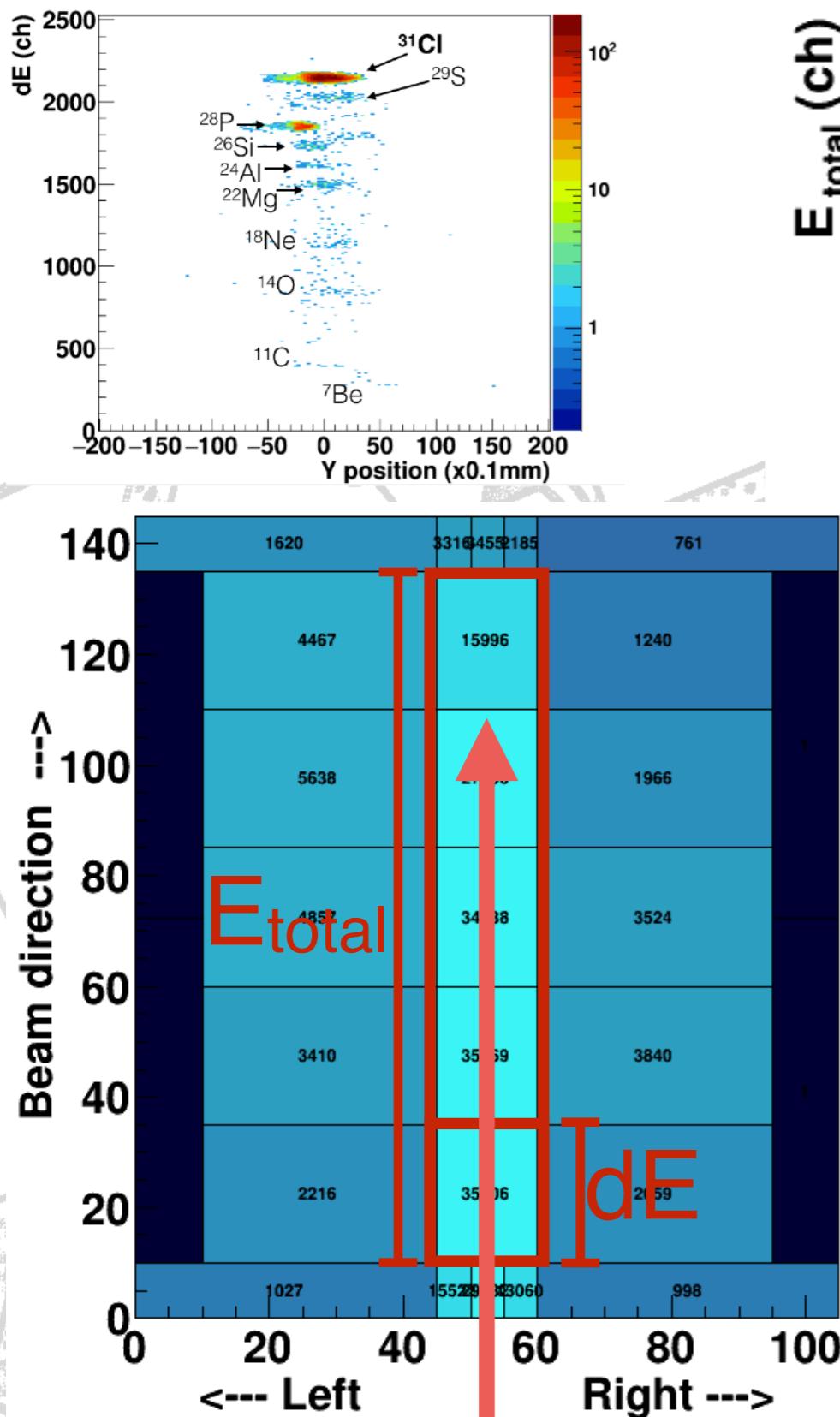


AstroBox2: Basics

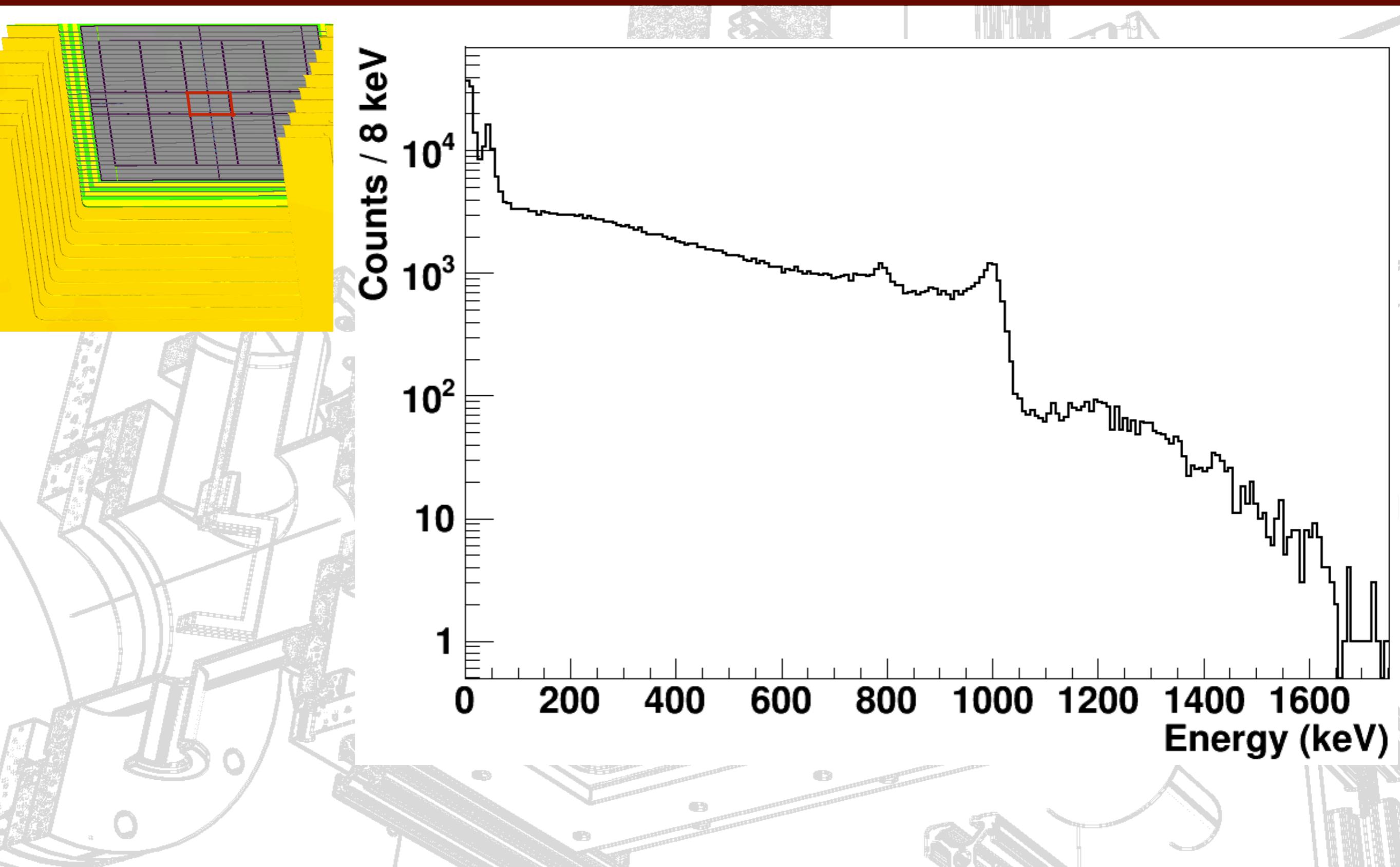
- Total 29 pads, $105 \times 145 \text{ mm}^2$ total area
- 128 μm gap (also 256, but not in use)
- “Classical” collect/decay scheme
- Analogue electronics (mesytec)
- Typically ~ 1 atm P5 (UHP)
- Drift field $\sim 200 \text{ V/cm}$ ($v_e \sim 3 \text{ cm/us}$)
- Mesh in ground
- *Beam off*: anode HT fixed
fixed electronics gain
 $\rightarrow \sim 1.6 \text{ MeV f.s. (10V ADC)}$
- *Beam on*: Gating grid transparency few %
 $\rightarrow \sim 50\text{-}60 \text{ MeV f.s. (10V ADC)}$
- Typical RMS noise $< 10 \text{ mV}_{\text{pp}}$
- Typical resolutions
 - ^{55}Fe , 5.9 keV X-ray: 14-16% FWHM,
 - ^{241}Am , 5.5 MeV α : ~2% FWHM
 - (source outside the active volume),
 - ^{25}Si βp , 400-1000 keV: 4-5% FWHM $\rightarrow \sim 100/\sqrt{E_p}$ (estimate for micro bulk $90/\sqrt{E_p}$)



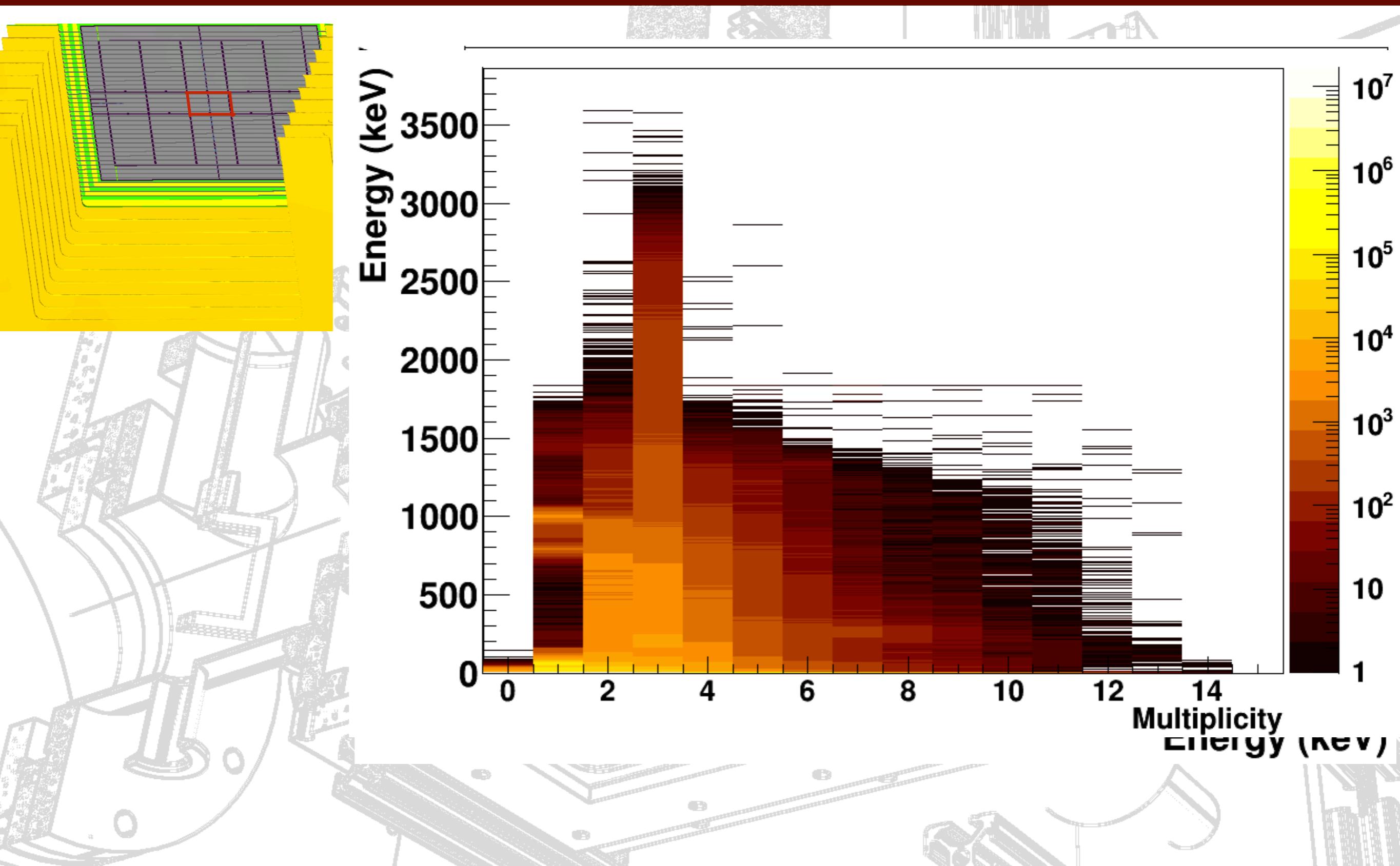
Rejecting of impurities



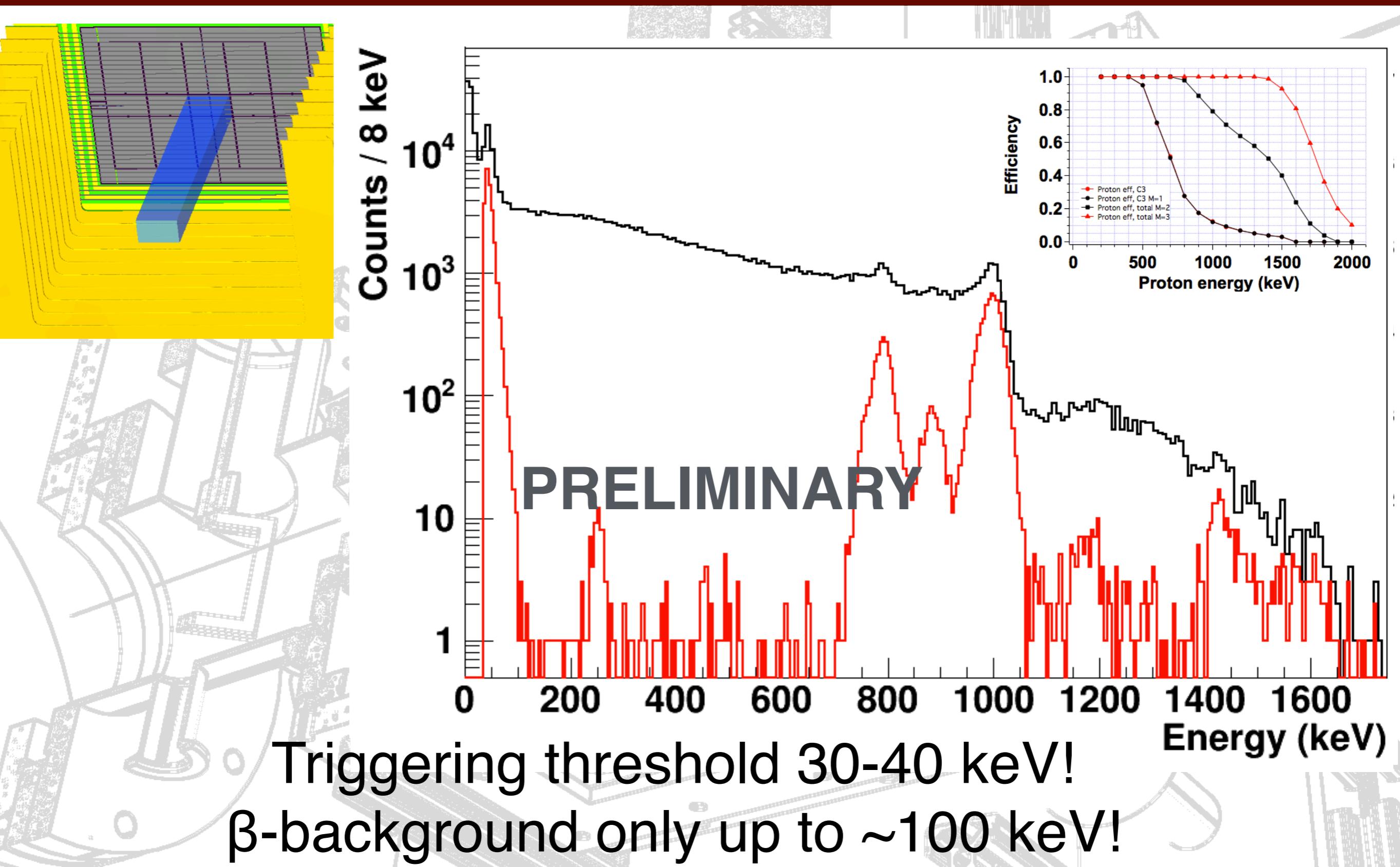
Background free β -delayed protons: Example case ^{31}Cl



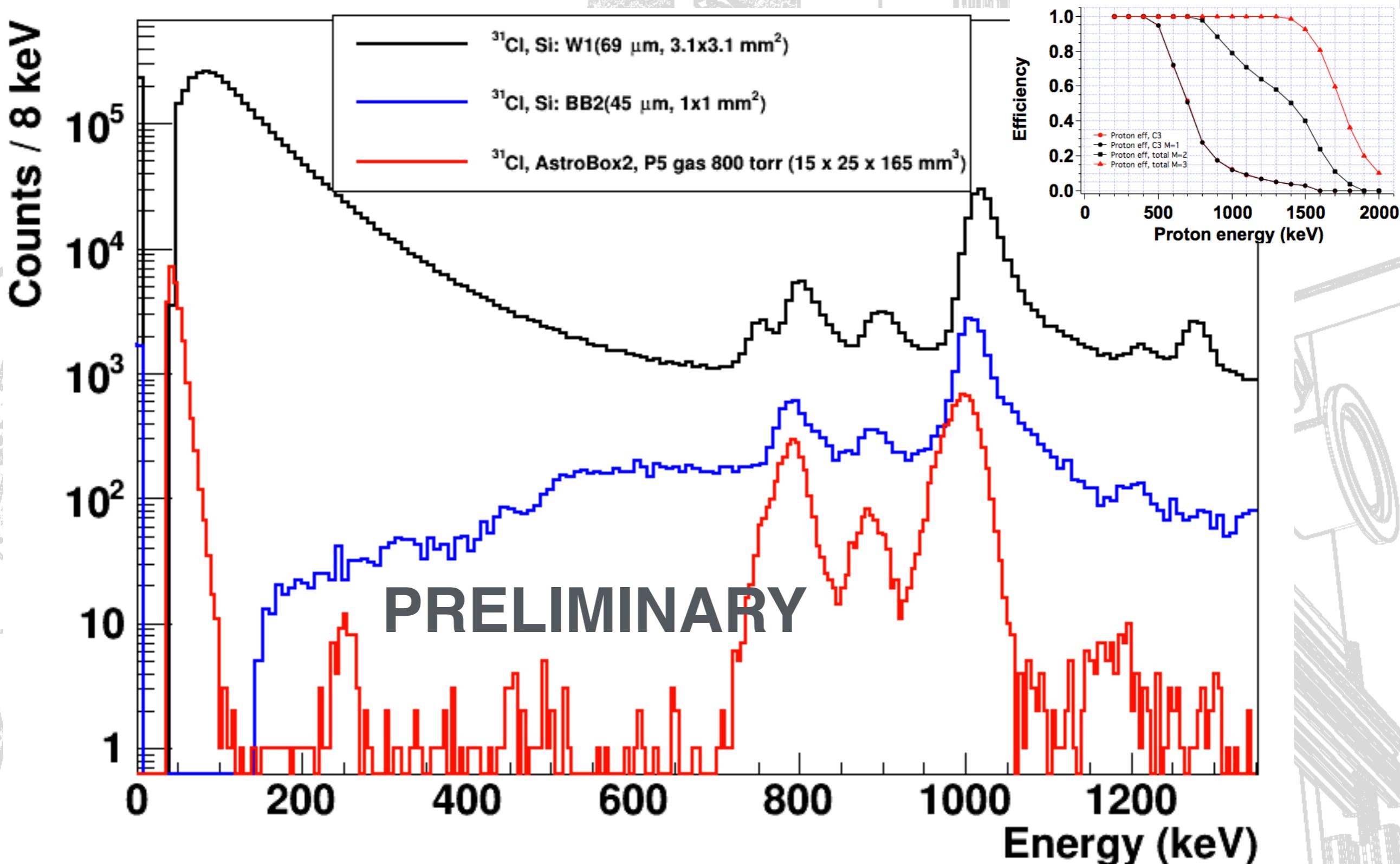
Background free β -delayed protons: Example case ^{31}Cl



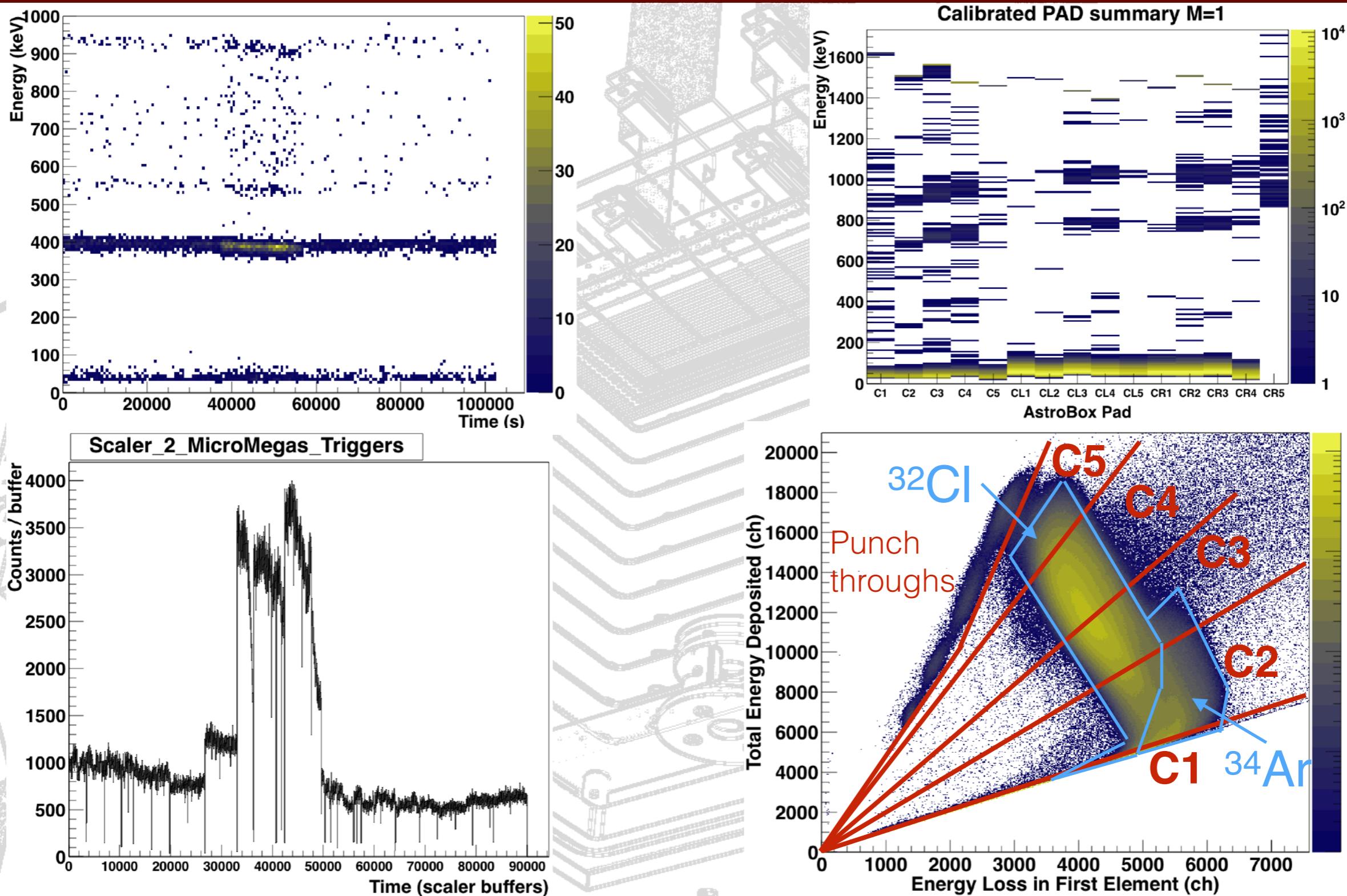
Background free β -delayed protons: Example case ^{31}Cl



^{31}Cl - Comparison to Si data

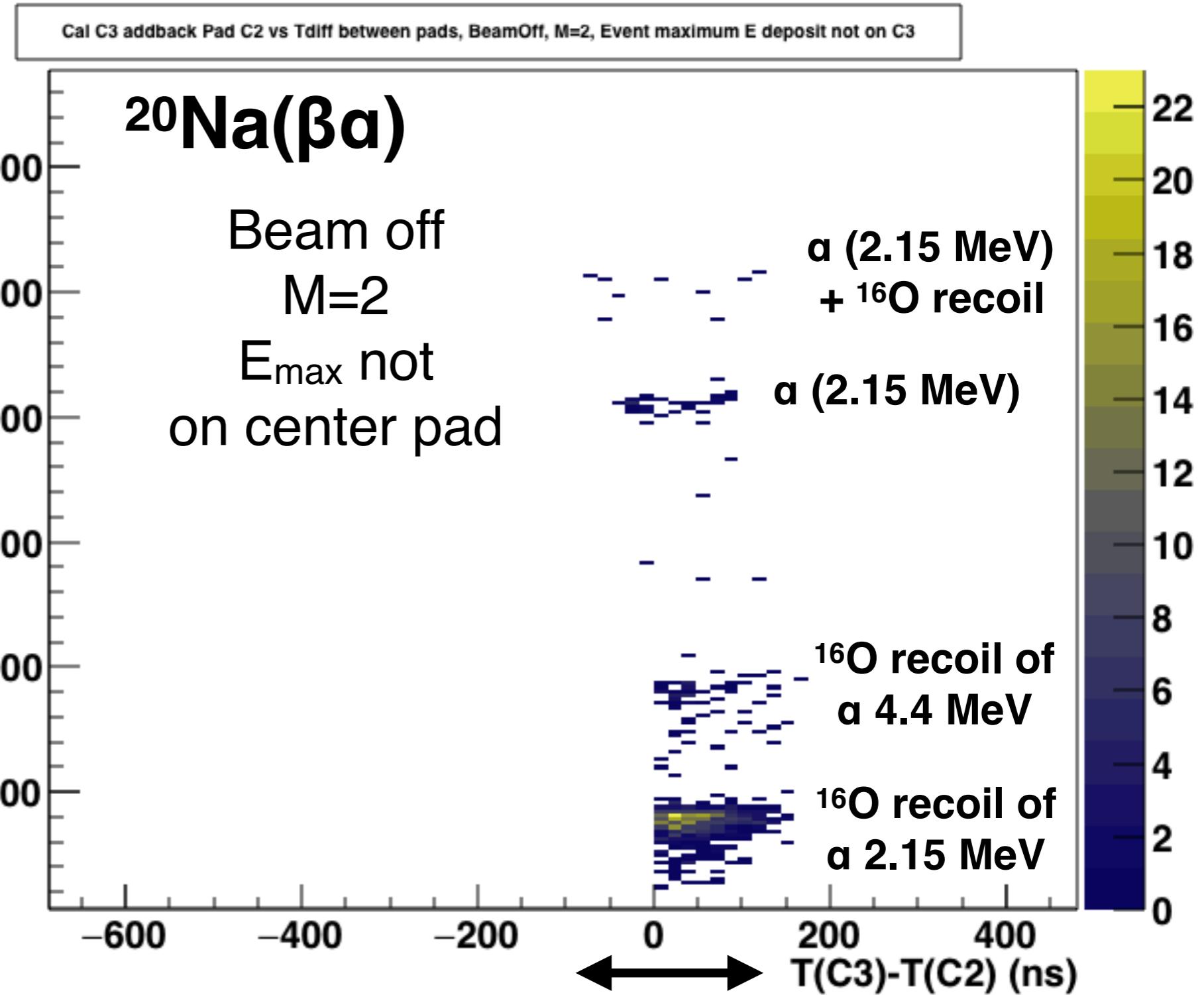
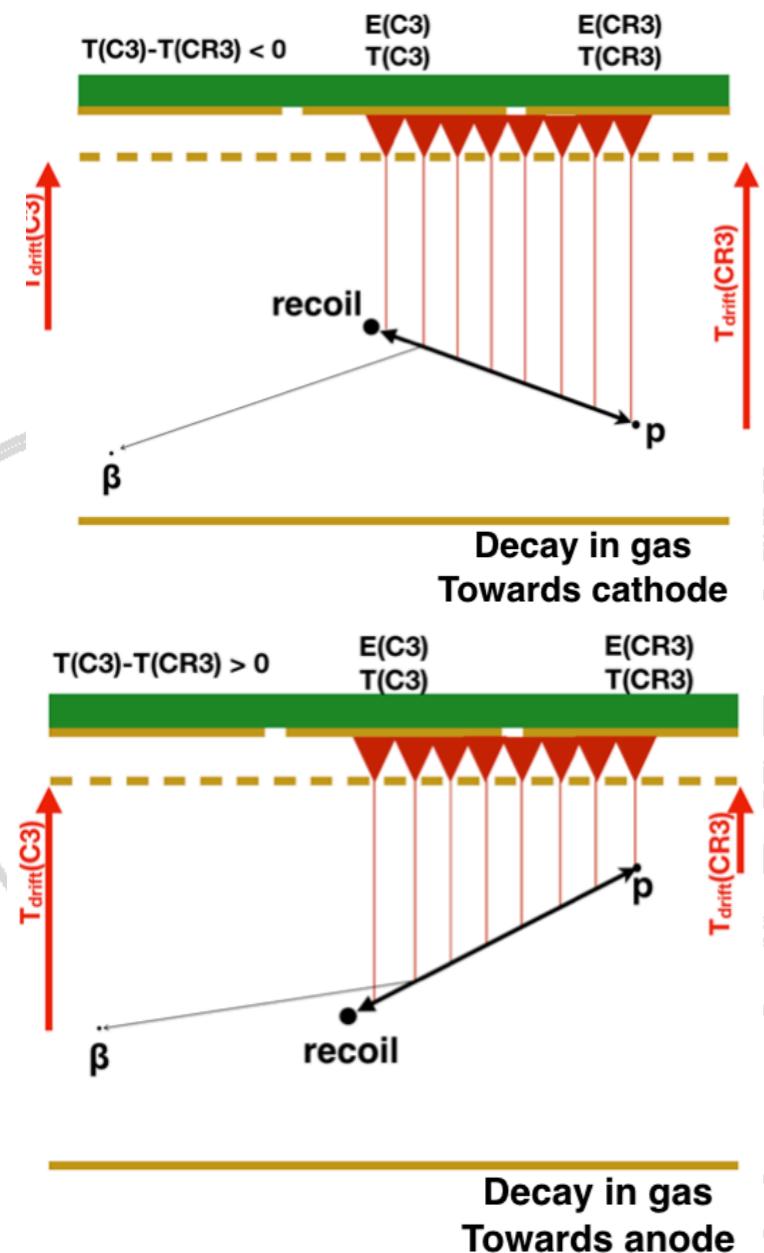


Rate effects during β -decay?



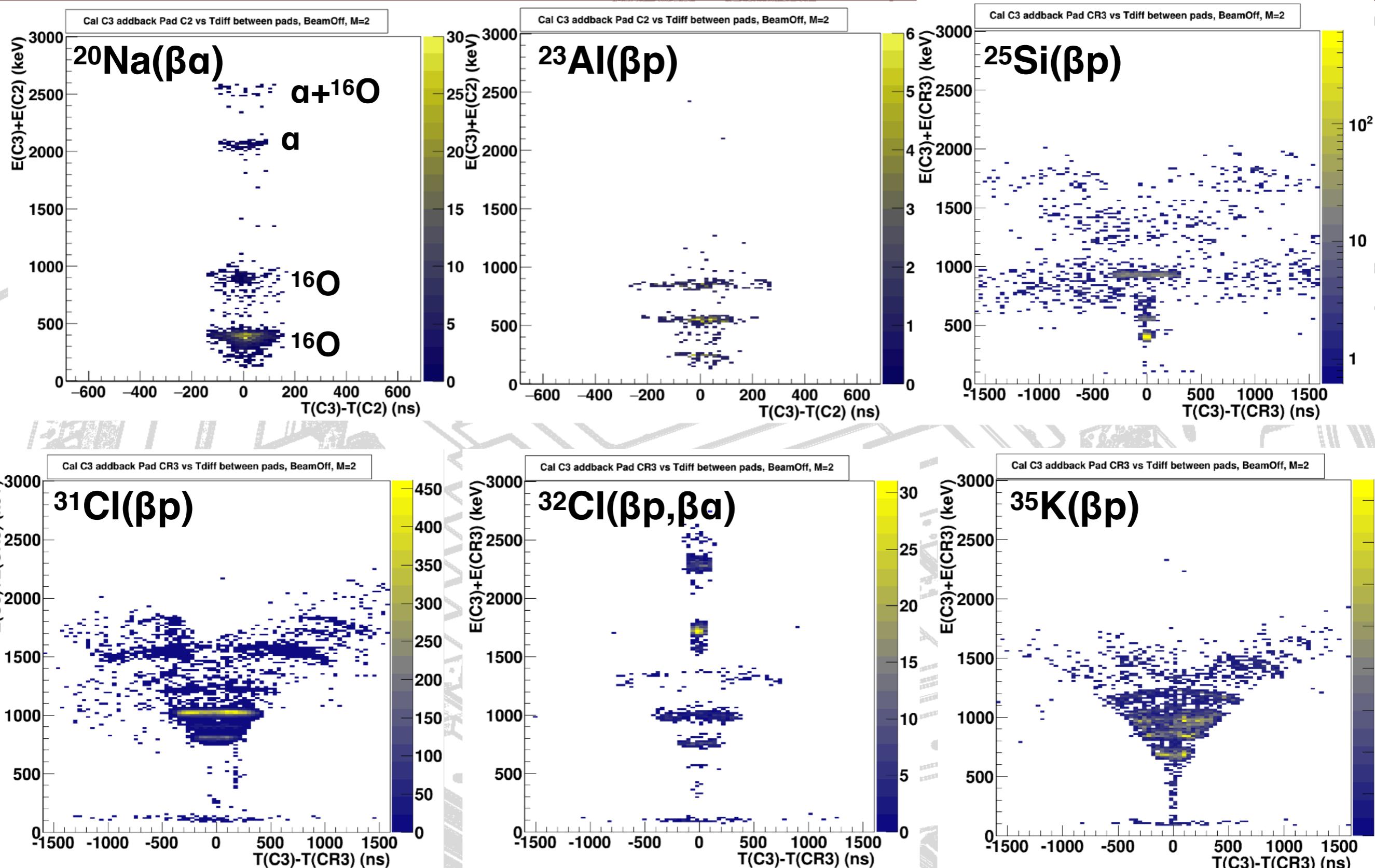
$I_{\beta p} \sim 0.1\text{-}10\%$, $I_{\beta s} = 100\%$ — β s multi-scatter, ionize throughout the volume over pad

(Gas/plasma) Chemistry in play?



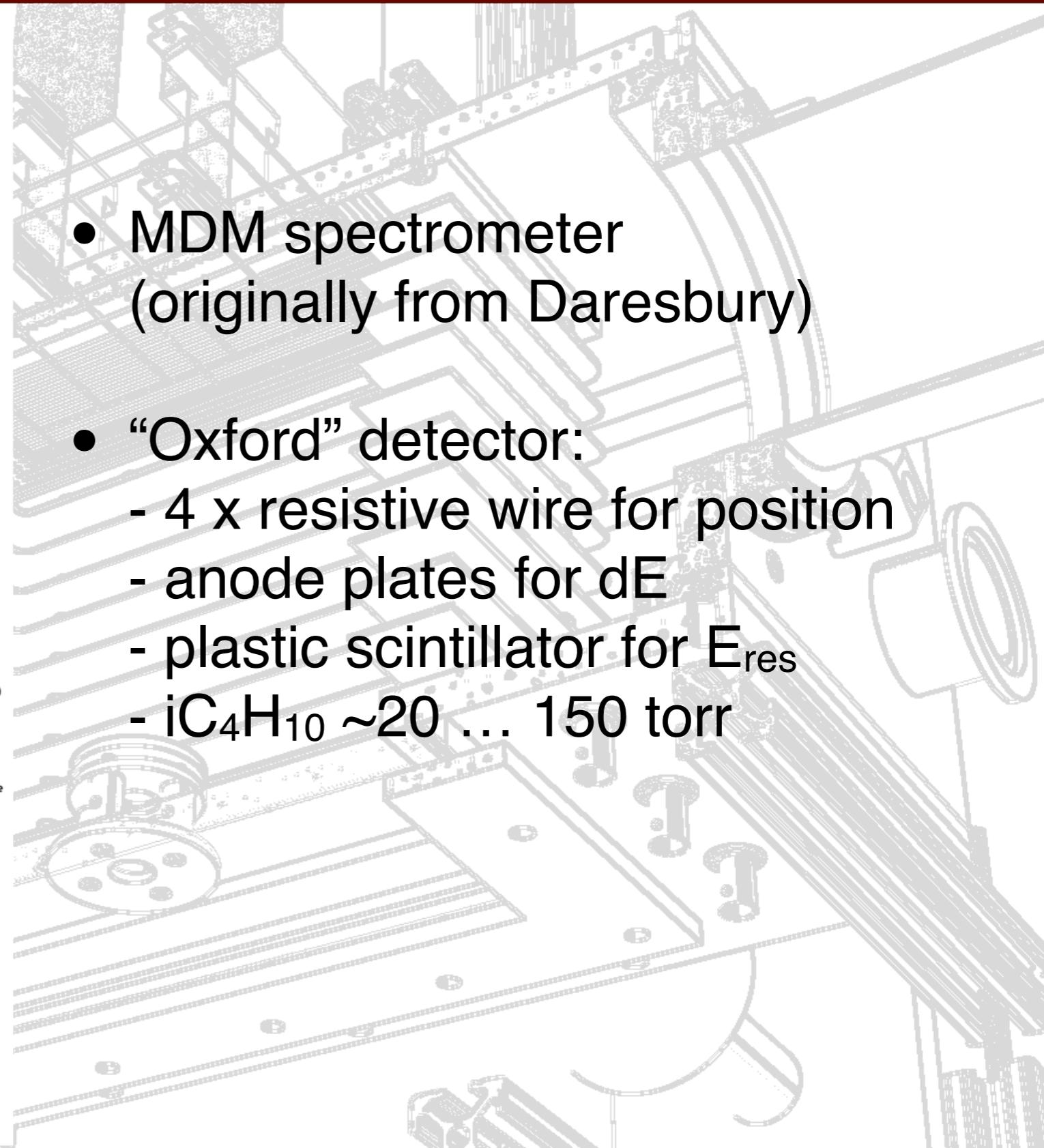
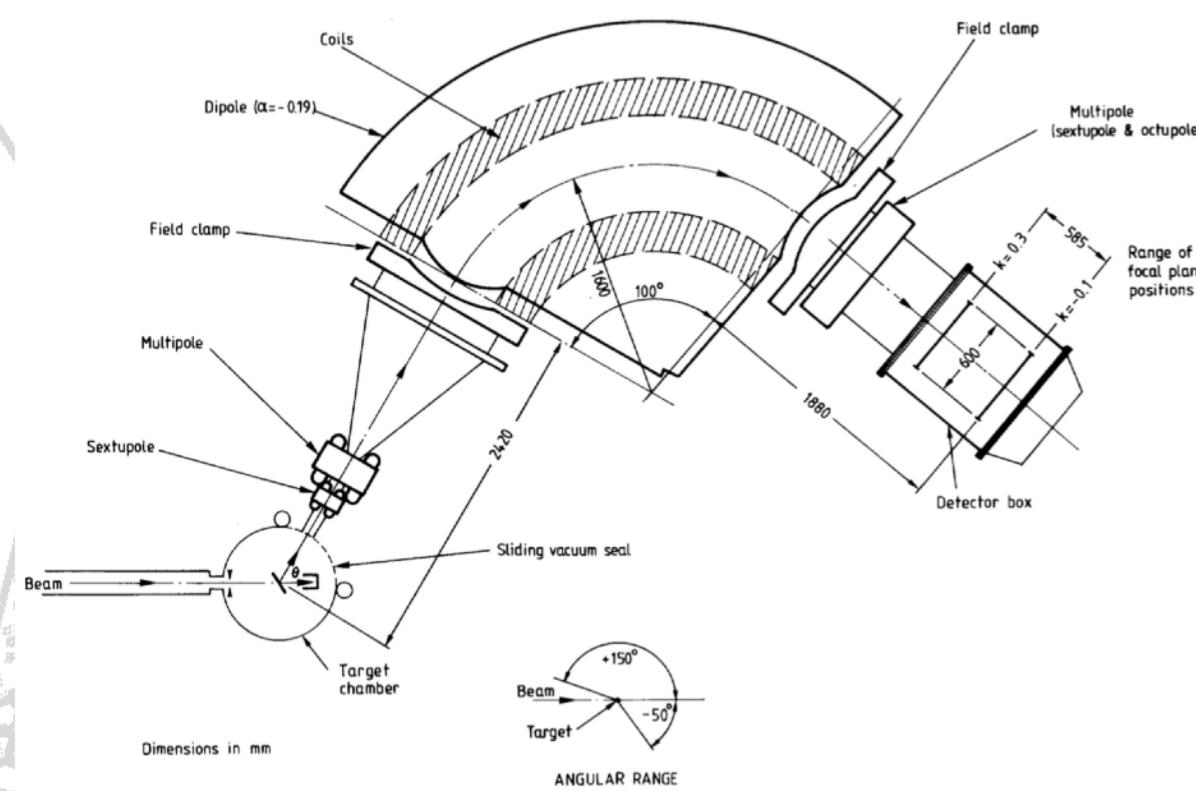
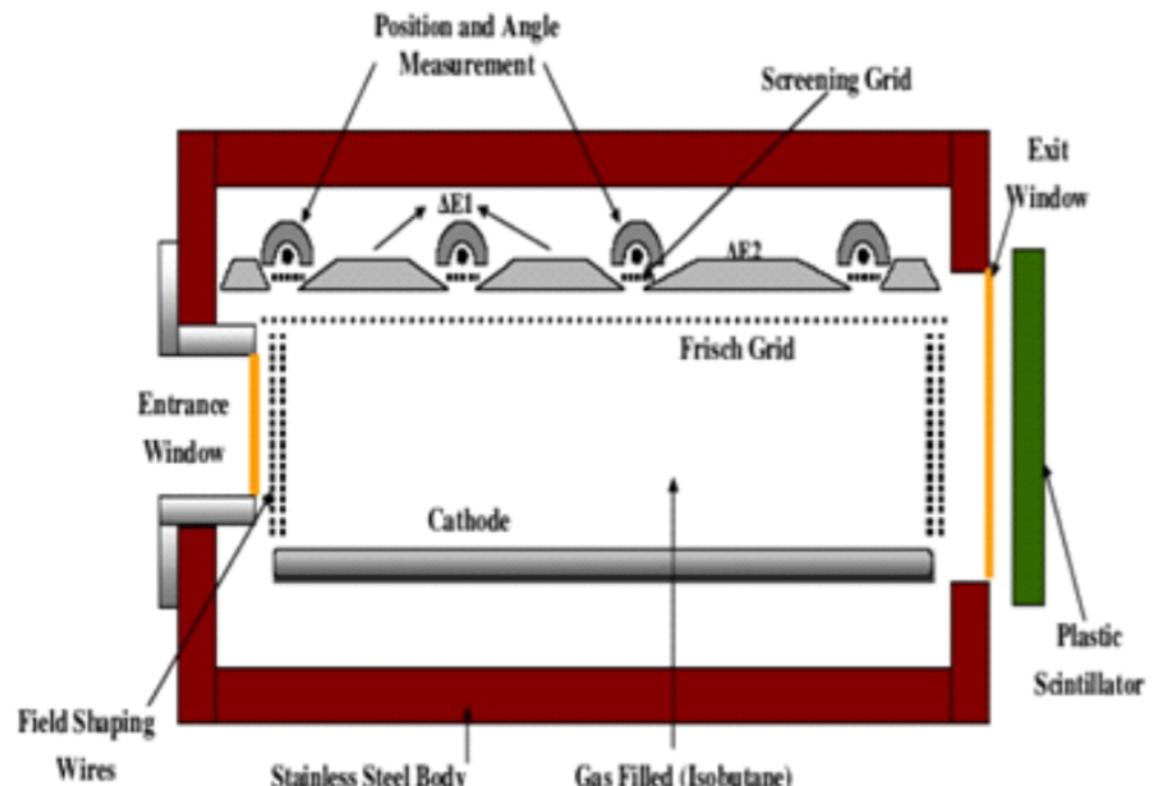
Can we do better with waveforms / digital?

(Gas/plasma) Chemistry in play?



2. MDM/Oxford – FP detector for transfer reactions

MDMFocal Plane Detector

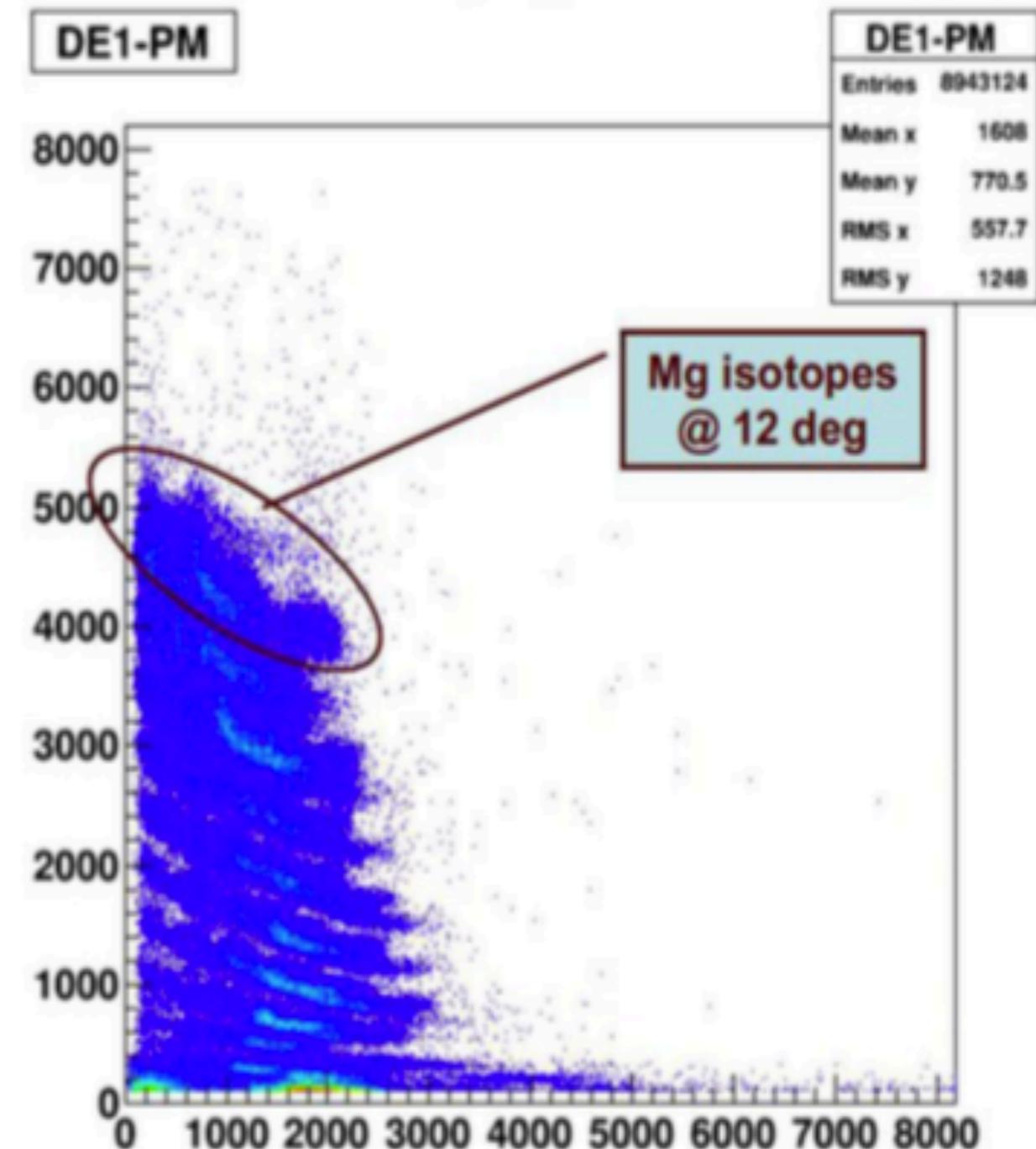
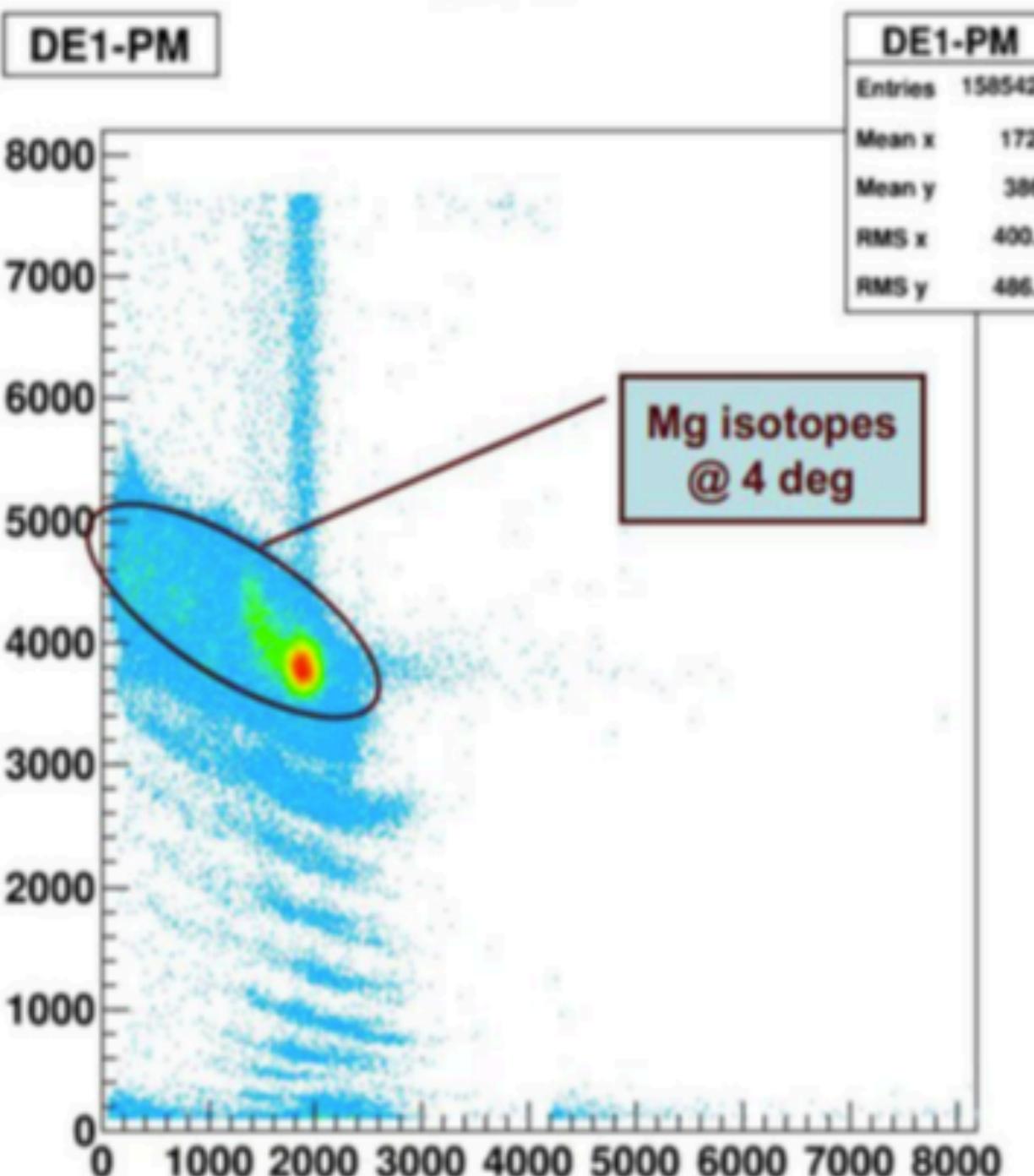


- MDM spectrometer
(originally from Daresbury)
- “Oxford” detector:
 - 4 x resistive wire for position
 - anode plates for dE
 - plastic scintillator for E_{res}
 - $iC_4H_{10} \sim 20 \dots 150$ torr

$^{26}\text{Mg} + ^{13}\text{C}$ transfer, 2009

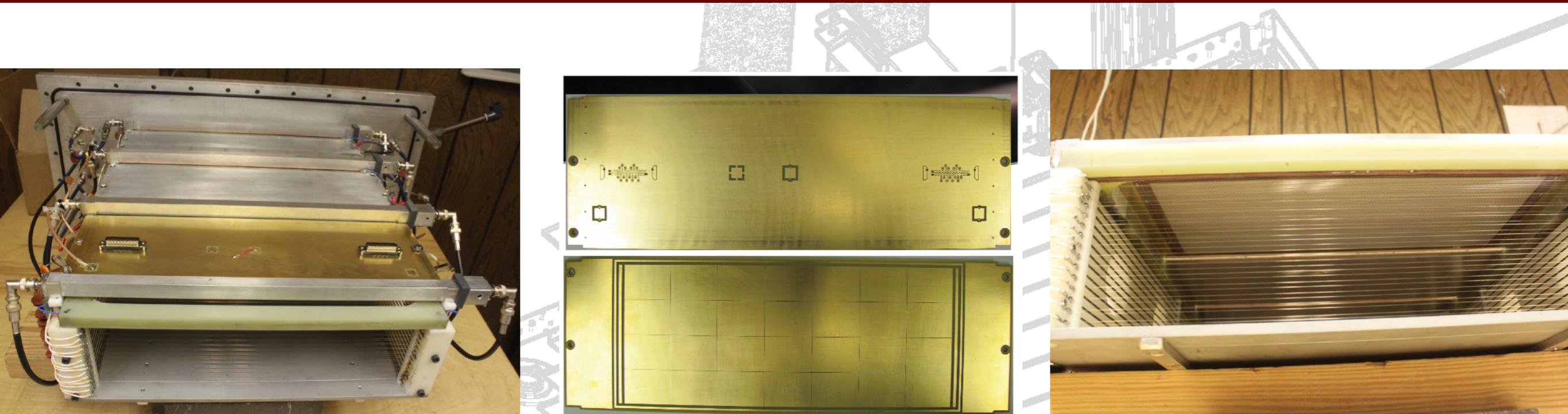
Pre-Upgrade limit: A=26,27

$\Delta E / E \approx 9 \%$



Courtesy of Alexandra Spiridon

MICROMEGAS Detectors for dE measurement



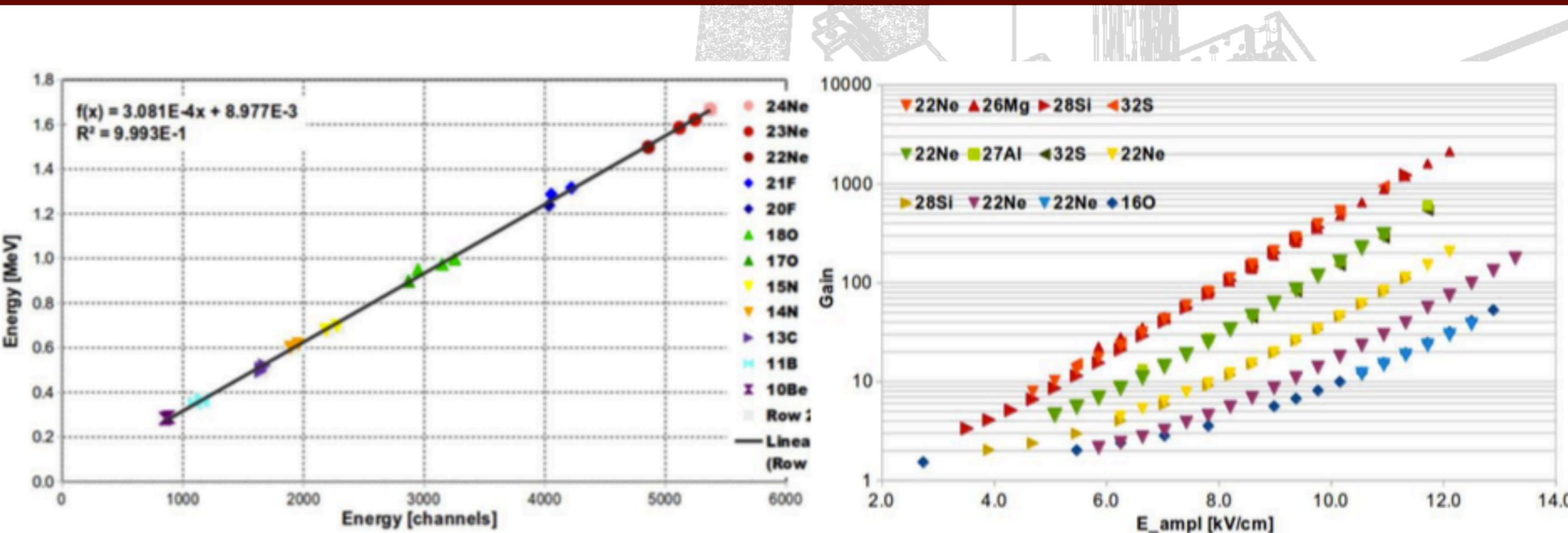
Initial upgrade:

- Replaced least useful dE anode plate
- 4 x 7 pads, total 28 ch, easy to instrument
- Otherwise, operate the rest of the detector as before
(easy to go back if things do not work)

Further upgrades:

- Replaced one more anode plate with Micromegas (8 rows total)
- Replaced plastic scintillator + window with CsI array in gas (Rogachev group)
- Digital readout with CAEN V1730 (Christian group)

Characterization with elastic scattering on Au target



Multisampling of several pads!

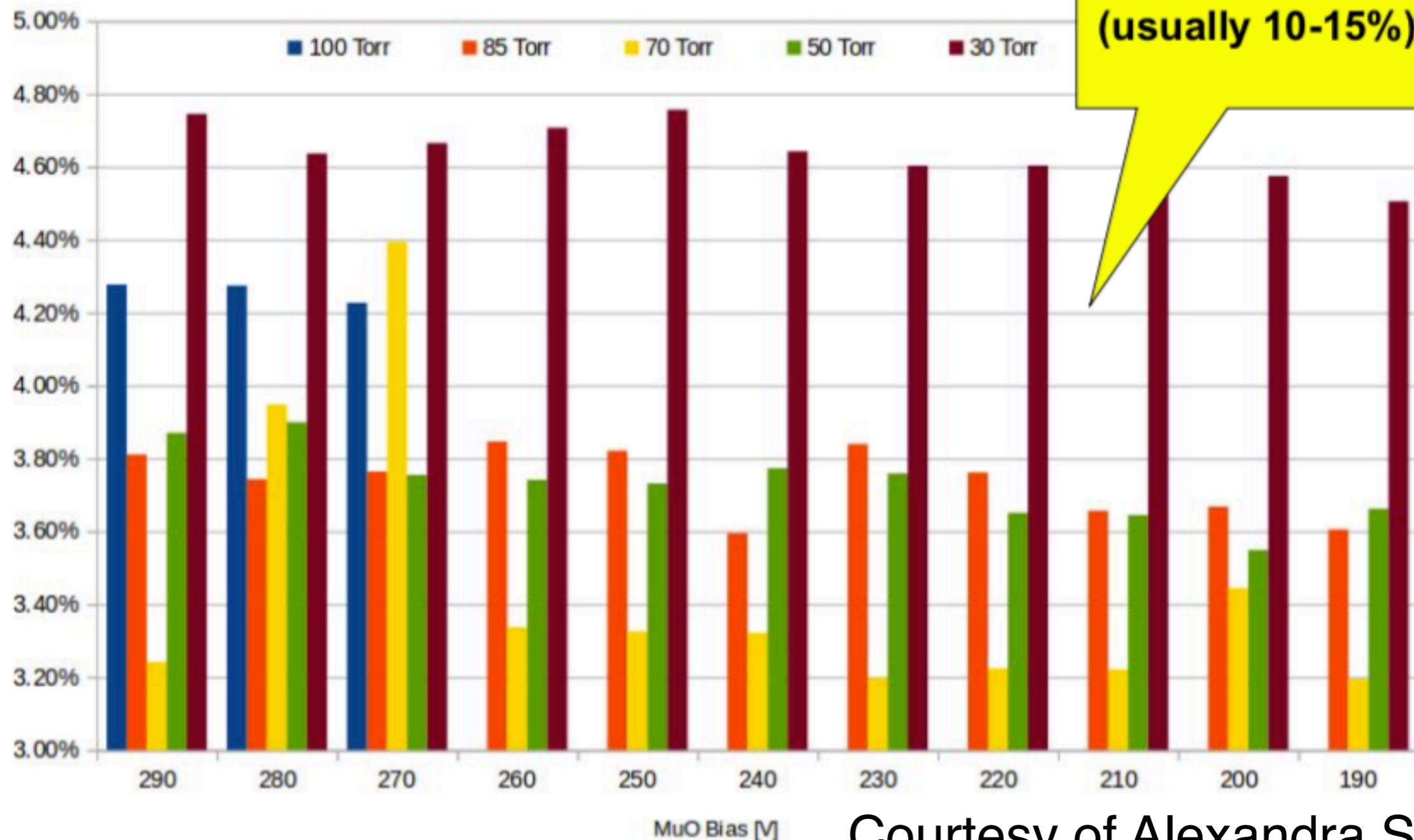
Beam	R[dE1]	R[Row]	R[SumR]	R[AvgR]	R[WAvg]	R[EMuO]	R[dEtot]
^{22}Ne	12.2%	7.4%	5.0%	5.1%	5.2%	4.7%	6.1%
^{26}Mg	7.5%	7.7%	5.1%	5.0%	4.9%	4.4%	4.3%
^{28}Si	7.9%	8.8%	6.5%	6.4%	6.4%	6.1%	4.6%
^{32}S	14.9%	11.0%	7.2%	7.2%	7.1%	6.9%	7.0%

Courtesy of Alexandra Spiridon

Characterization with elastic scattering on Au target

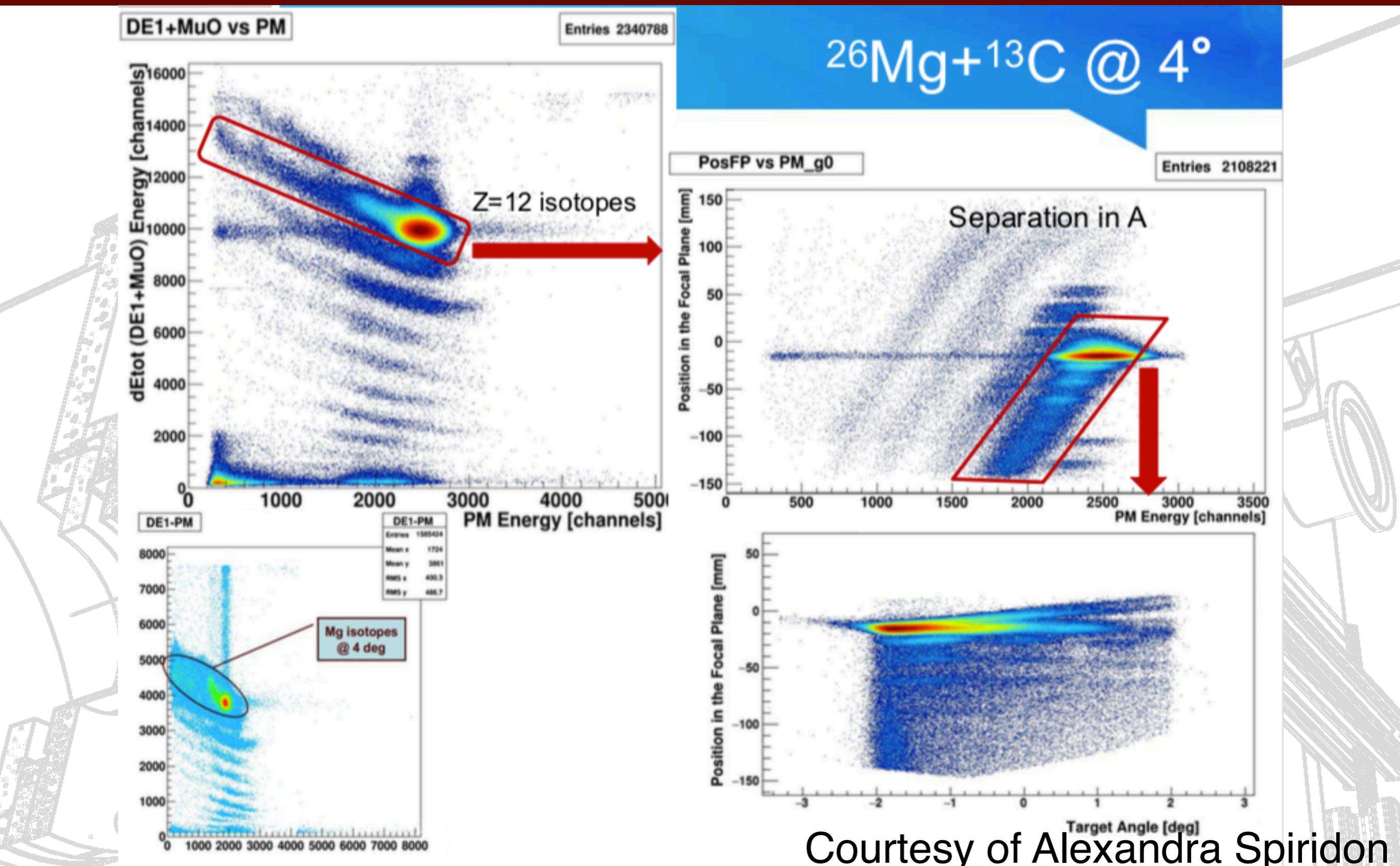
Variation of the MuO resolution with bias and pressure

Note that dE1 has resolutions of 8% at best (usually 10-15%)



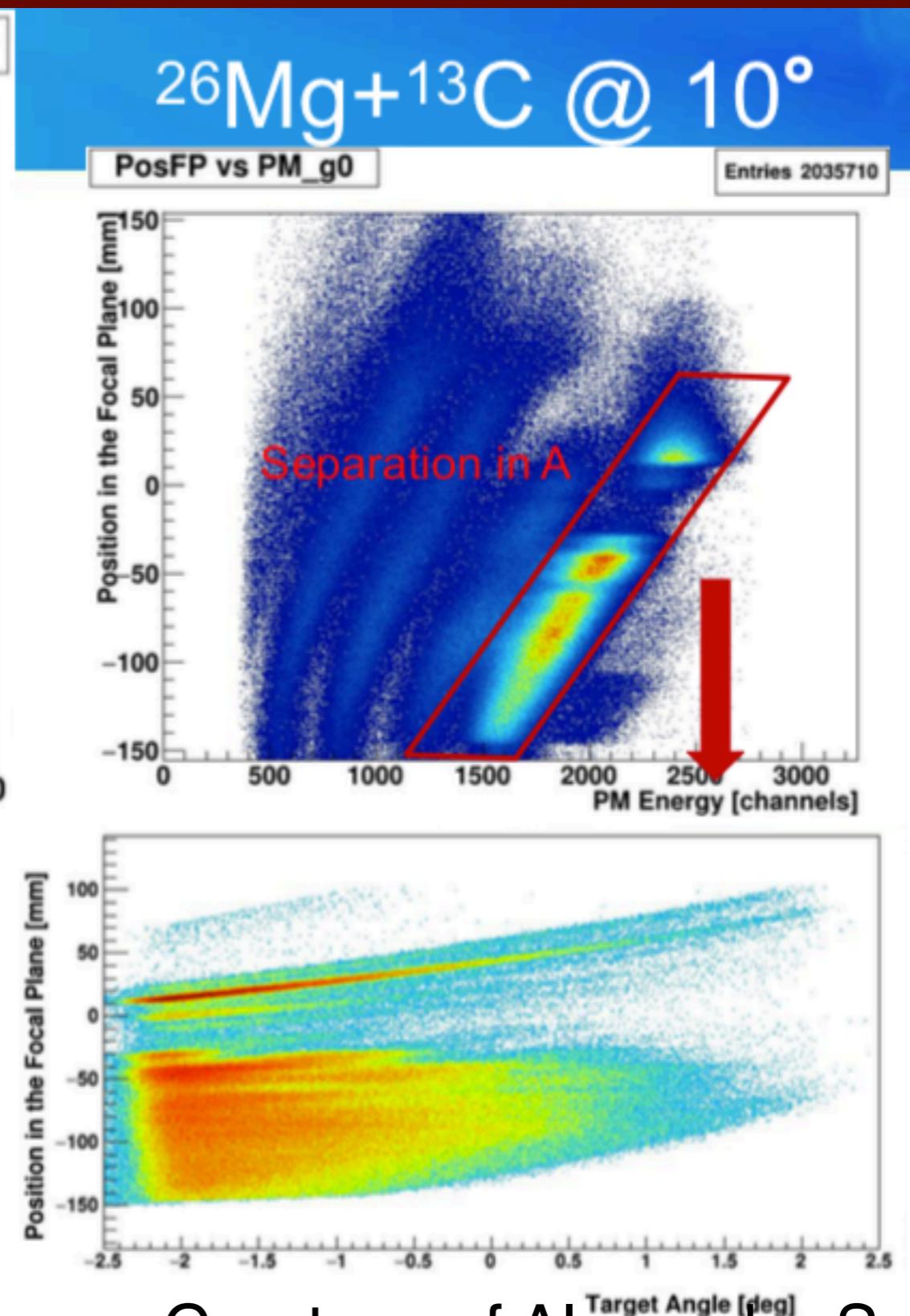
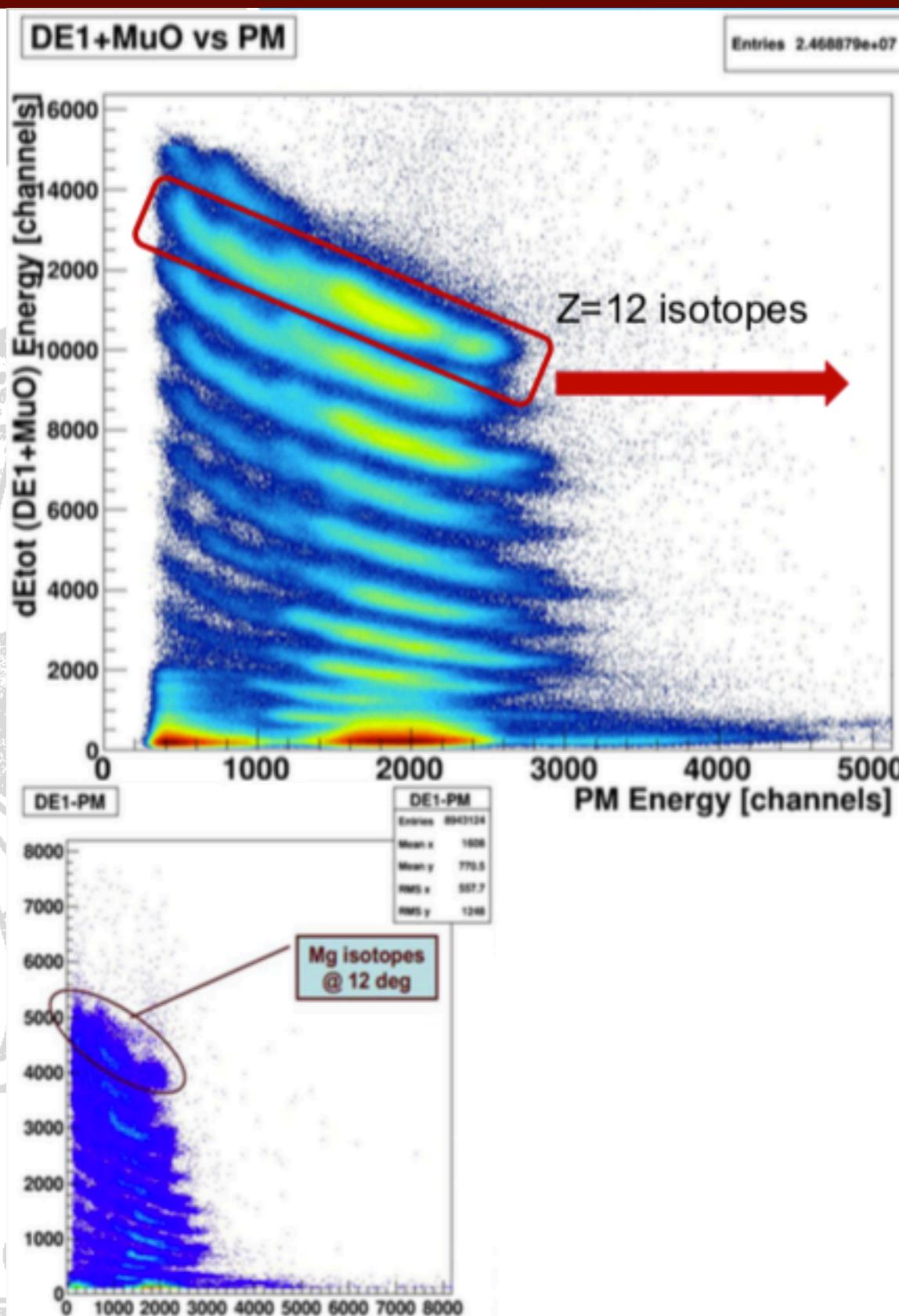
Courtesy of Alexandra Spiridon

$^{13}\text{C}(^{26}\text{Mg}, ^{27}\text{Mg})^{12}\text{C}$ @ 12 MeV/u



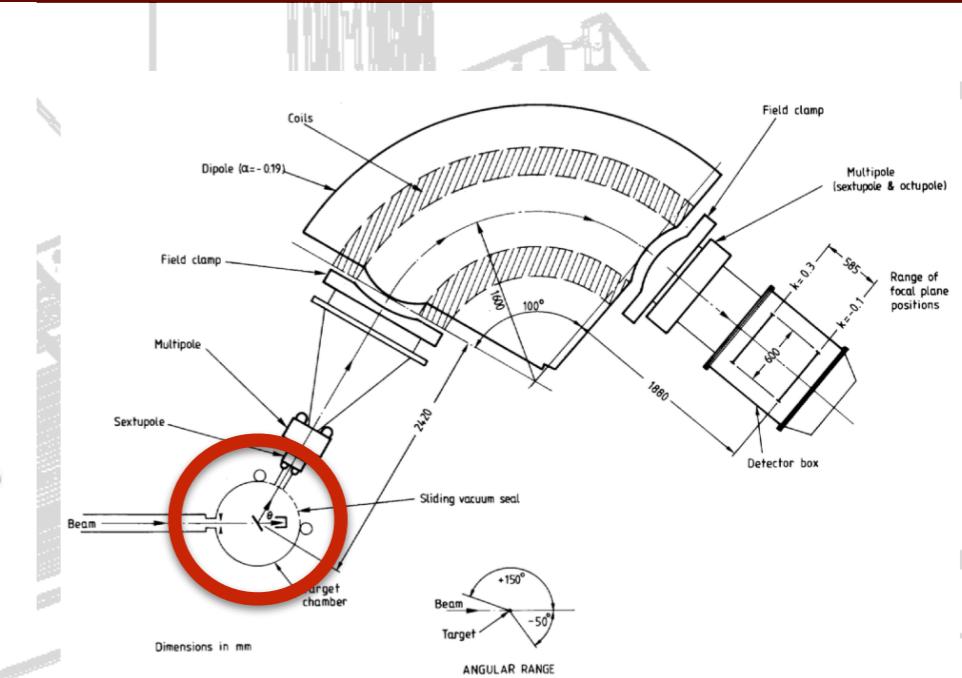
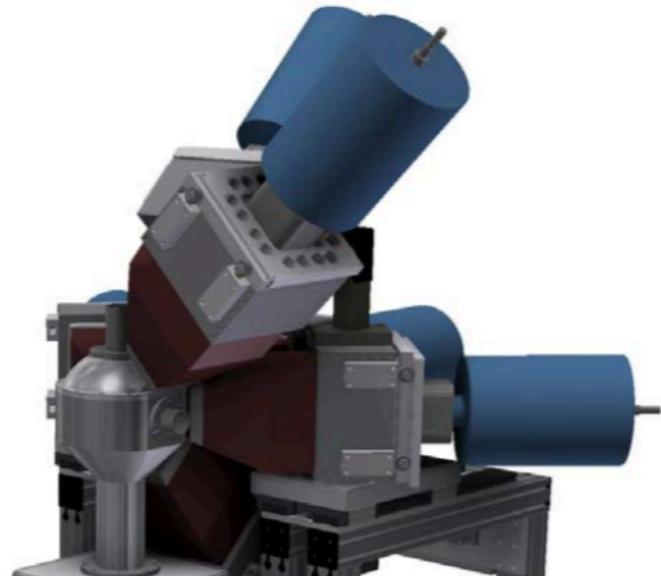
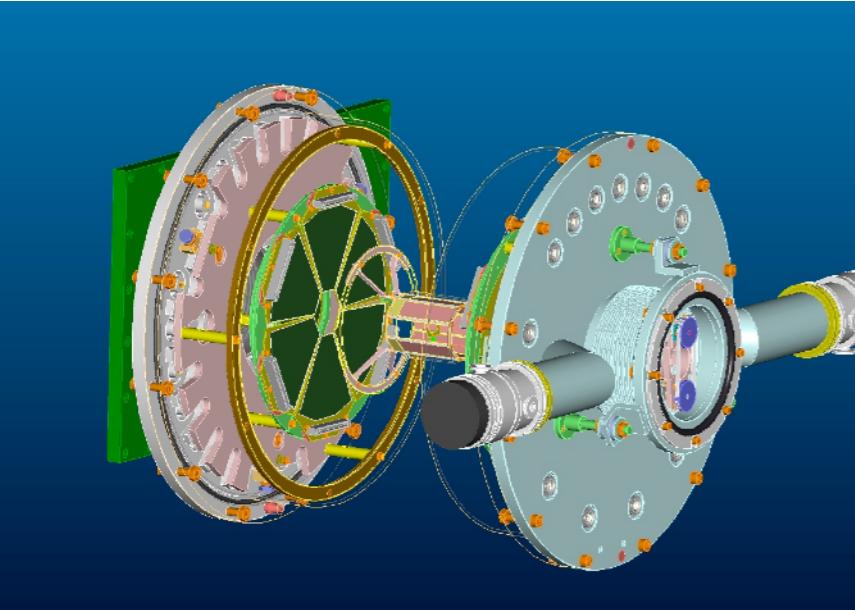
Courtesy of Alexandra Spiridon

$^{13}\text{C}(^{26}\text{Mg}, ^{27}\text{Mg})^{12}\text{C}$ @ 12 MeV/u



Courtesy of Alexandra Spiridon

TIARA for TEXAS (T4T): TIARA+Hyperion+MDM

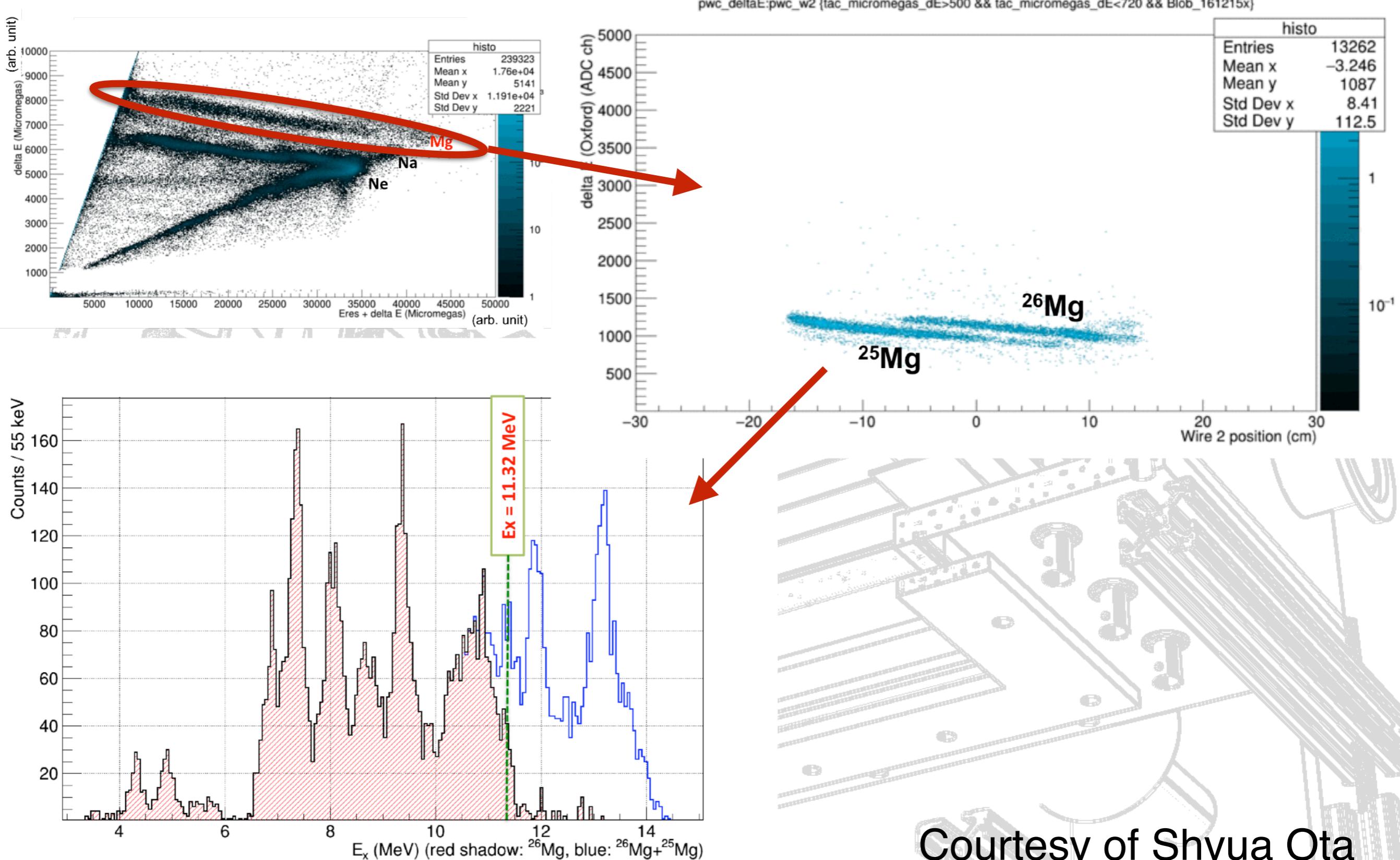


- Transfer reactions, e.g. (d,p), (${}^6\text{Li}$,d) in inverse kinematics
- Si barrel + backward (forward) Si array
- 4 x HPGe “clover” from LLNL Hyperion array
- MDM as 0 degree spectrometer
- Oxford FP detector with Micromegas

Stable beam commissioning with:

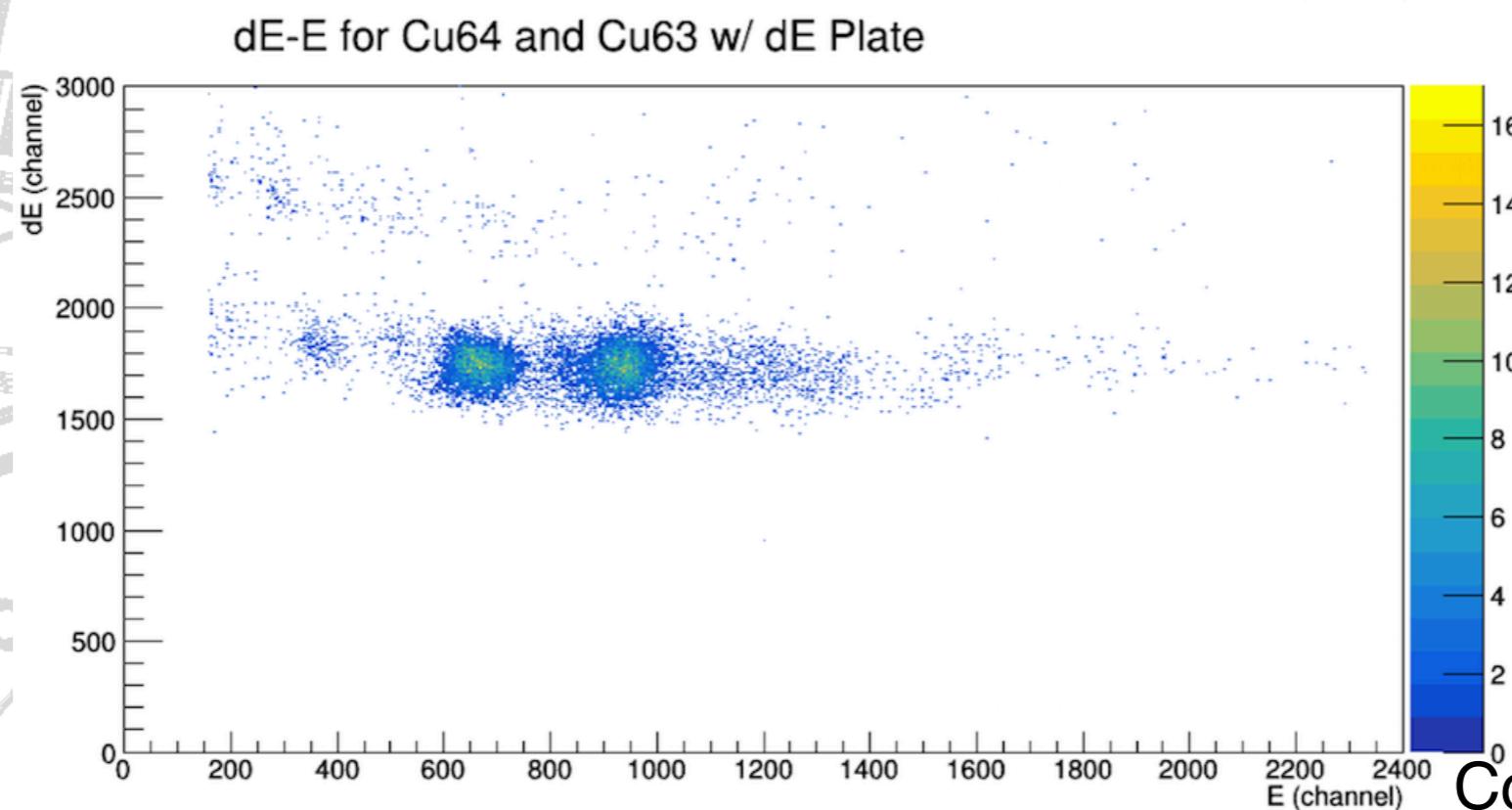
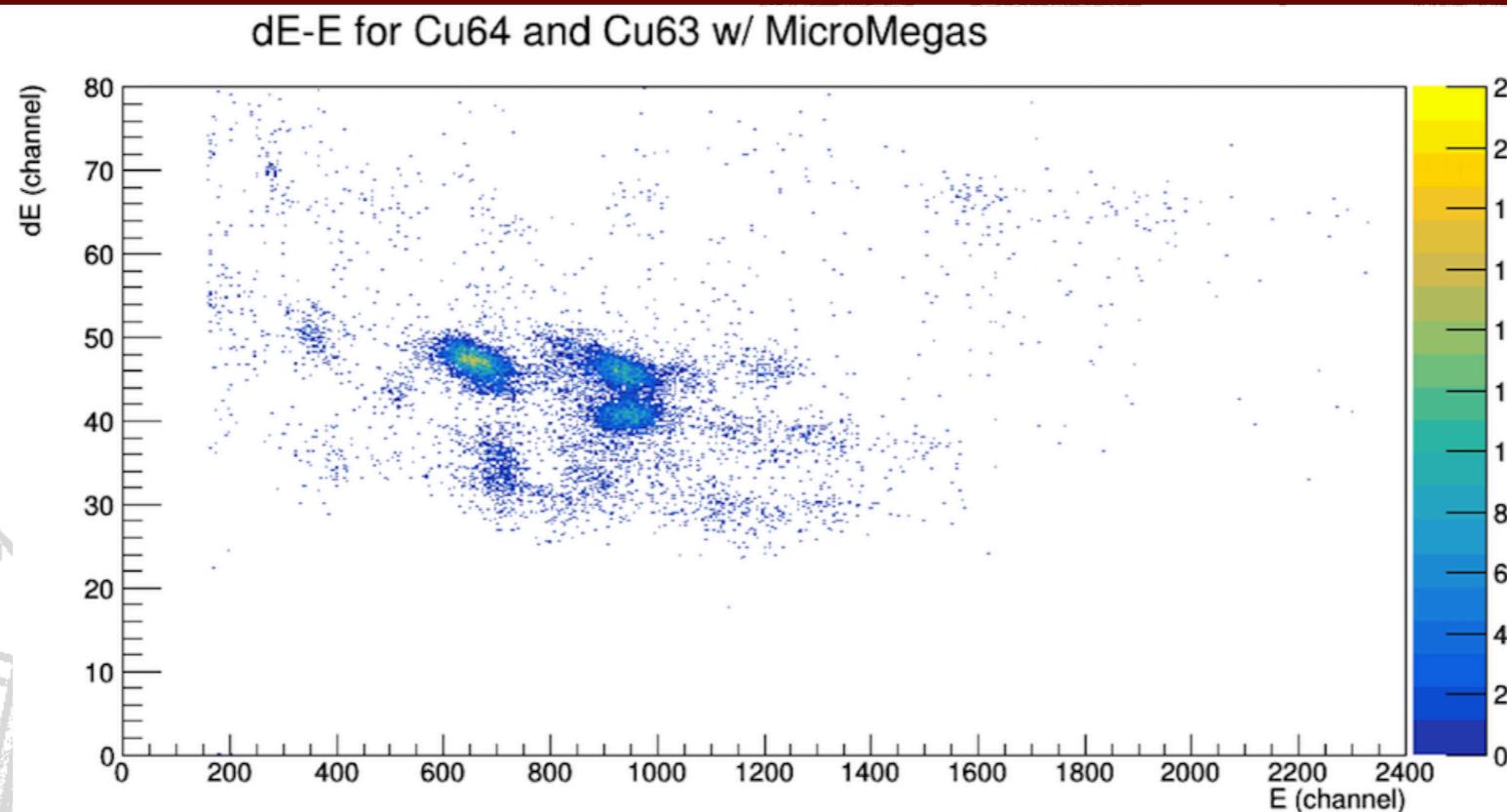
$d({}^{19}\text{F}, {}^{20}\text{F})p$, $d({}^{23}\text{Na}, {}^{24}\text{Na})p$, $d({}^{25}\text{Mg}, {}^{26}\text{Mg})p$, ${}^6\text{Li}({}^{22}\text{Ne}, {}^{25,26}\text{Mg})d$

${}^6\text{Li}({}^{22}\text{Ne}, {}^{25,26}\text{Mg})\text{d}$ @ 10 MeV/u



Courtesy of Shuya Ota

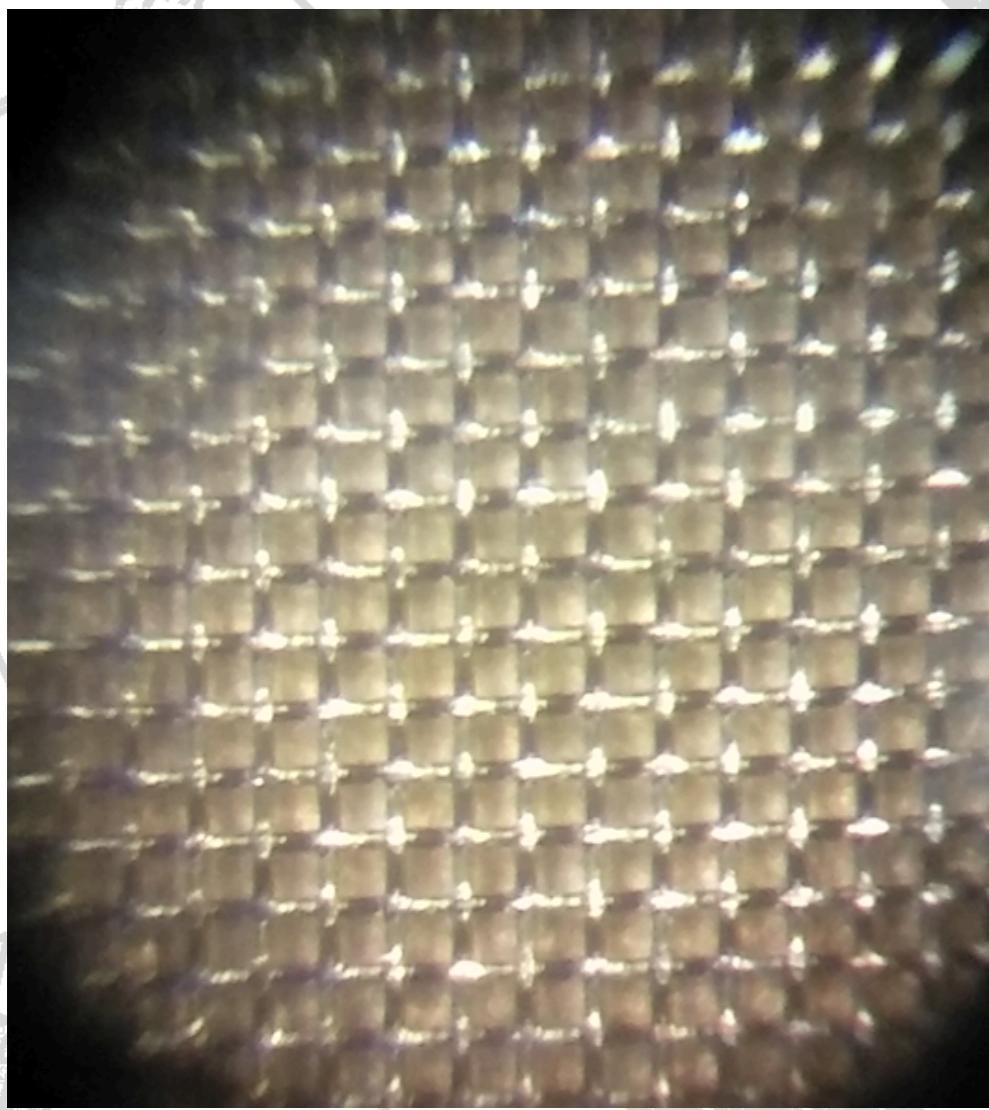
Push for heavier masses, test with d(^{63}Cu , ^{64}Cu)p



Courtesy of Dustin Scriven

No visible aging (polymer growth)?

Low pressure $i\text{C}_4\text{H}_{10}$ known to break down to smaller radicals, seeding polymer growth on wire counters in same conditions
→ Observed as dark spots with same optical microscope



Mag: 500x, optical

- Micromegas installed Oct 2014
- Inspected Jul 2018 during wire replacement
- Total beam time 300+ shifts (>2400 hrs)
- A = 2-64
- Up to 50 kHz rates, typical < 1kHz
- No visible deterioration
(replaced some wires twice during this time period!)
- Some sparks have killed individual PA ch, no effects on Micromegas observed

Few (personal) remarks on low ch count systems

In general: a few ch system can do a lot

More specifically, analogue systems so far:

- + Low overall cost (per ch still pretty high!)
- + Fast prototyping and development of detectors
- + Electronics easy to debug (old school)
- + Relatively highly integrated electronics available
(no need to fill racks for just few tens of ch)
- + Relatively simple analysis software
- Scaling up is expensive, takes a lot of space,...
- No pulse shapes recorded
- Relatively slow / limited data rates
- Hard to read small signals in noisy environment

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Already going digital in many projects at TAMU: MDM/TIARA (CAEN V1730), Hyperion/NeutronStars (SIS3316), NIMROD (SIS3316), LIG (CAEN DT5781)

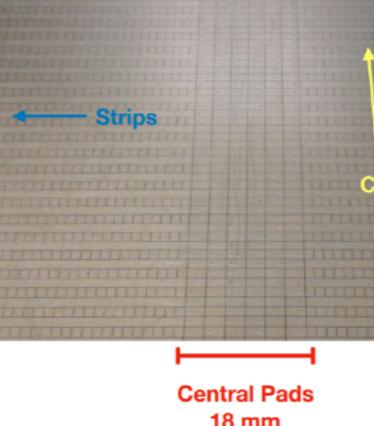
3. TexAT – Texas Active Target

GET Electronics for TexAT

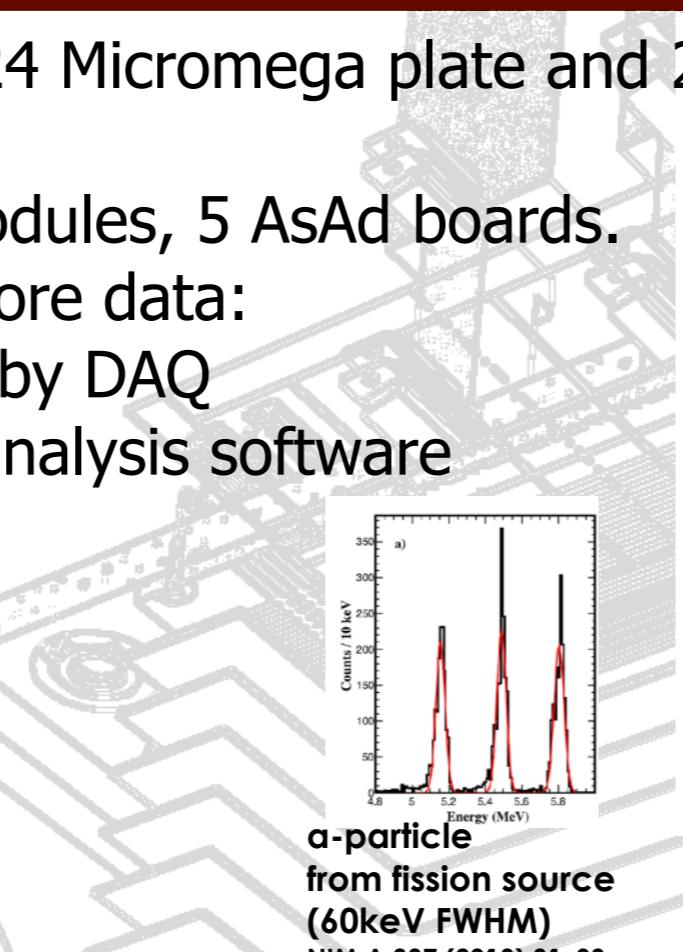
- 1274 channels total(1024 Micromega plate and 250 aux detectors)
- 2 CoBo and 1 Mutant modules, 5 AsAd boards.
- GANIL DAQ is used to store data:
 - ✓ Merged data format by DAQ
 - ✓ Online/Offline data analysis software



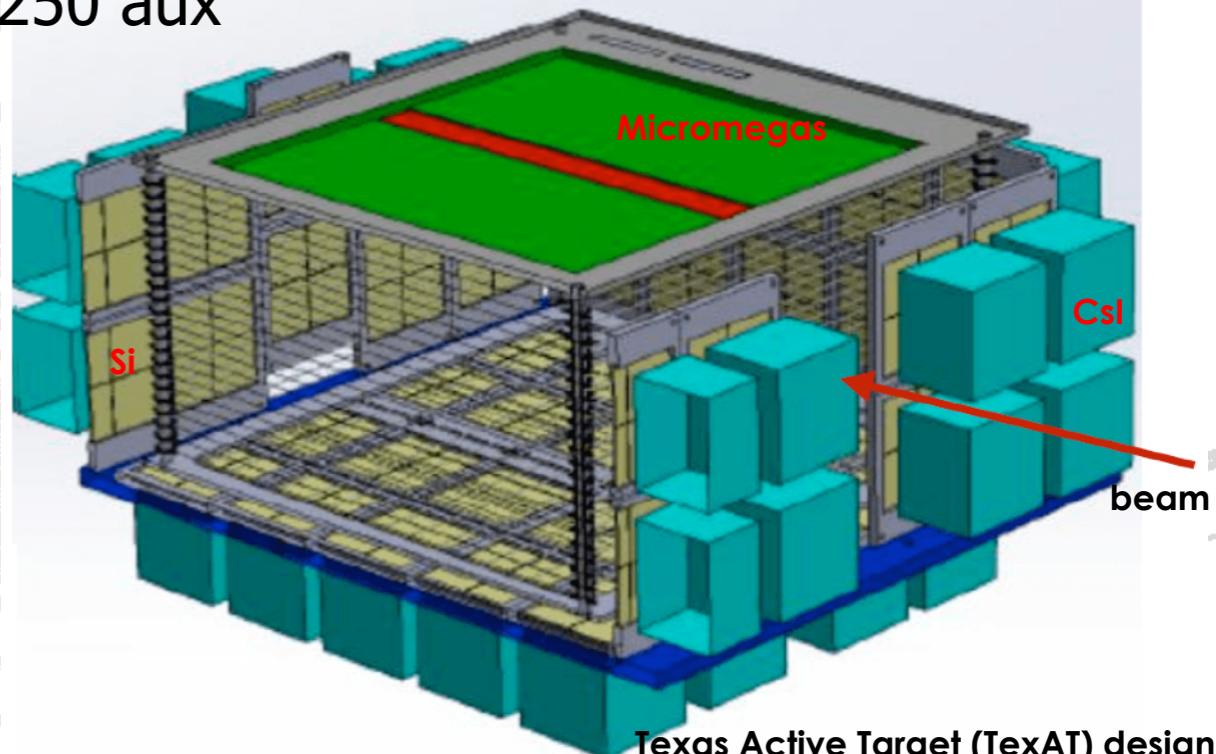
A picture for TexAT and GET setup
G. Rogechev, Gas Detection Systems Workshop (2018)



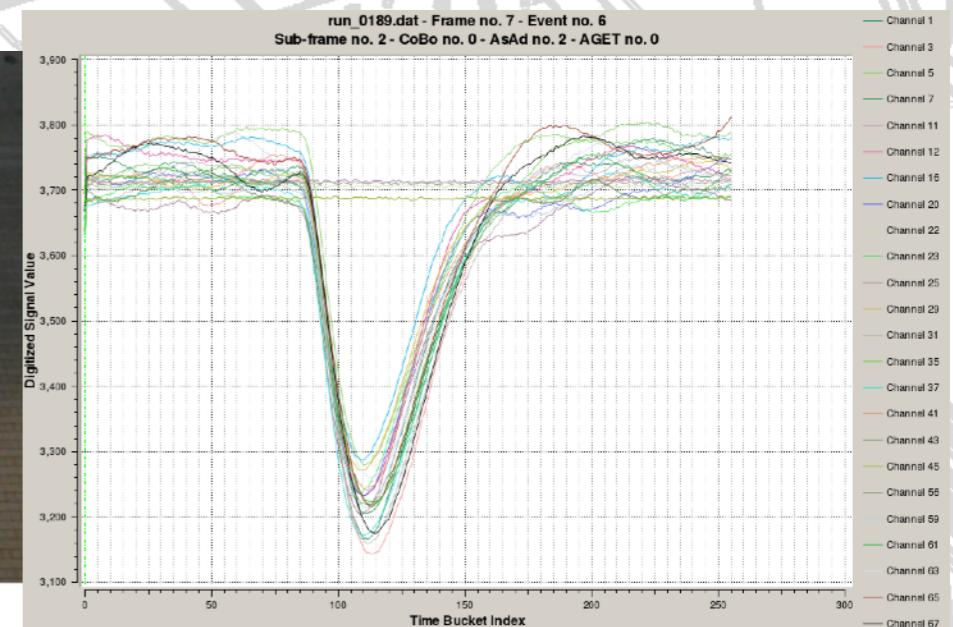
Oct 12, 2018



a-particle
from fission source
(60keV FWHM)
NIM A 887 (2018) 81-93



Texas Active Target (TexAT) design



A signal waveform from silicon detector

Courtesy of Sunghoon (Tony) Ahn

Data Analysis Cluster System

- Conversion time from raw waveform format to root tree (30 mins for 10GB data)
- 10GB data every hour for @10 evts/s
- 112 CPUs and 116GB Memory
- Apache Spark: cluster-computing framework
- Apache Hadoop: software utilities for cluster-computing
- Docker: operating-system-level virtualization



Slaves

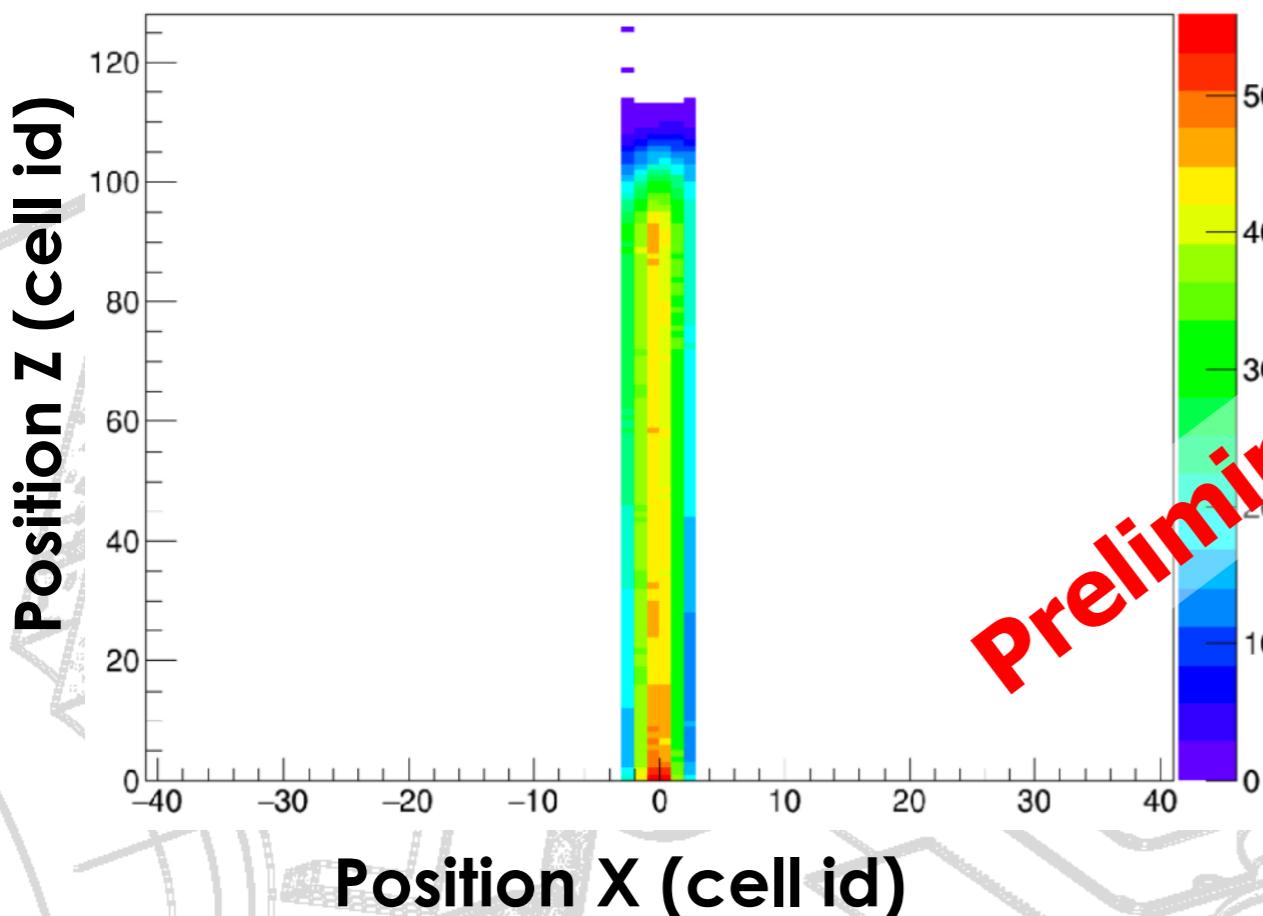
ID ▾	Host	CPUs	Mem	Disk	Registered	Re-Registered
...5050-2993-S51	gr-gnode-01.tamu.edu	12	14.5 GB	1816.1 GB	2 weeks ago	2 weeks ago
...5050-2993-S50	gr-gnode-02.tamu.edu	12	14.5 GB	1794.6 GB	2 weeks ago	2 weeks ago
...5050-2993-S48	gr-gnode-03.tamu.edu	12	14.5 GB	1794.6 GB	2 weeks ago	2 weeks ago
...5050-2993-S45	gr-gnode-04.tamu.edu	12	14.5 GB	1794.6 GB	2 weeks ago	2 weeks ago
...5050-2993-S33	gr-gnode-08.tamu.edu	16	14.6 GB	1792.6 GB	3 weeks ago	2 weeks ago
...5050-2993-S32	gr-gnode-07.tamu.edu	16	14.6 GB	1792.6 GB	3 weeks ago	2 weeks ago
...5050-2993-S31	gr-gnode-06.tamu.edu	16	14.6 GB	1792.6 GB	3 weeks ago	2 weeks ago
...5050-2993-S30	gr-gnode-05.tamu.edu	16	14.6 GB	1792.6 GB	3 weeks ago	2 weeks ago

Courtesy of Sungsoon (Tony) Ahn

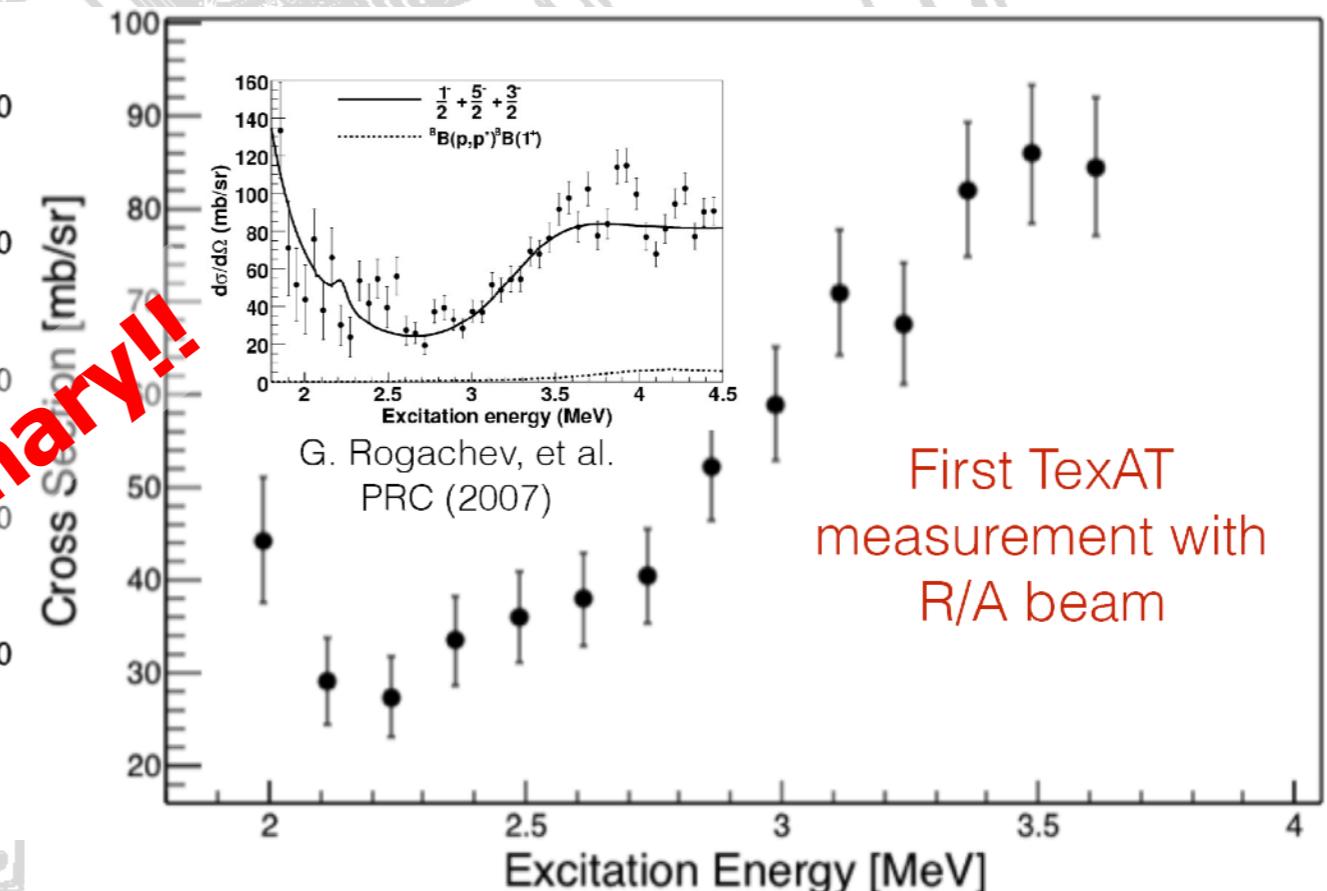
TexAT Example #1: Structure of ${}^9\text{C}$

- Reaction: ${}^8\text{B} + \text{p}$ with 7.5 MeV/u ${}^8\text{B}$ beam and 10^3 pps from MARS
- Target: Methane at 500 Torr

Hit pattern in the Micromegas Plate



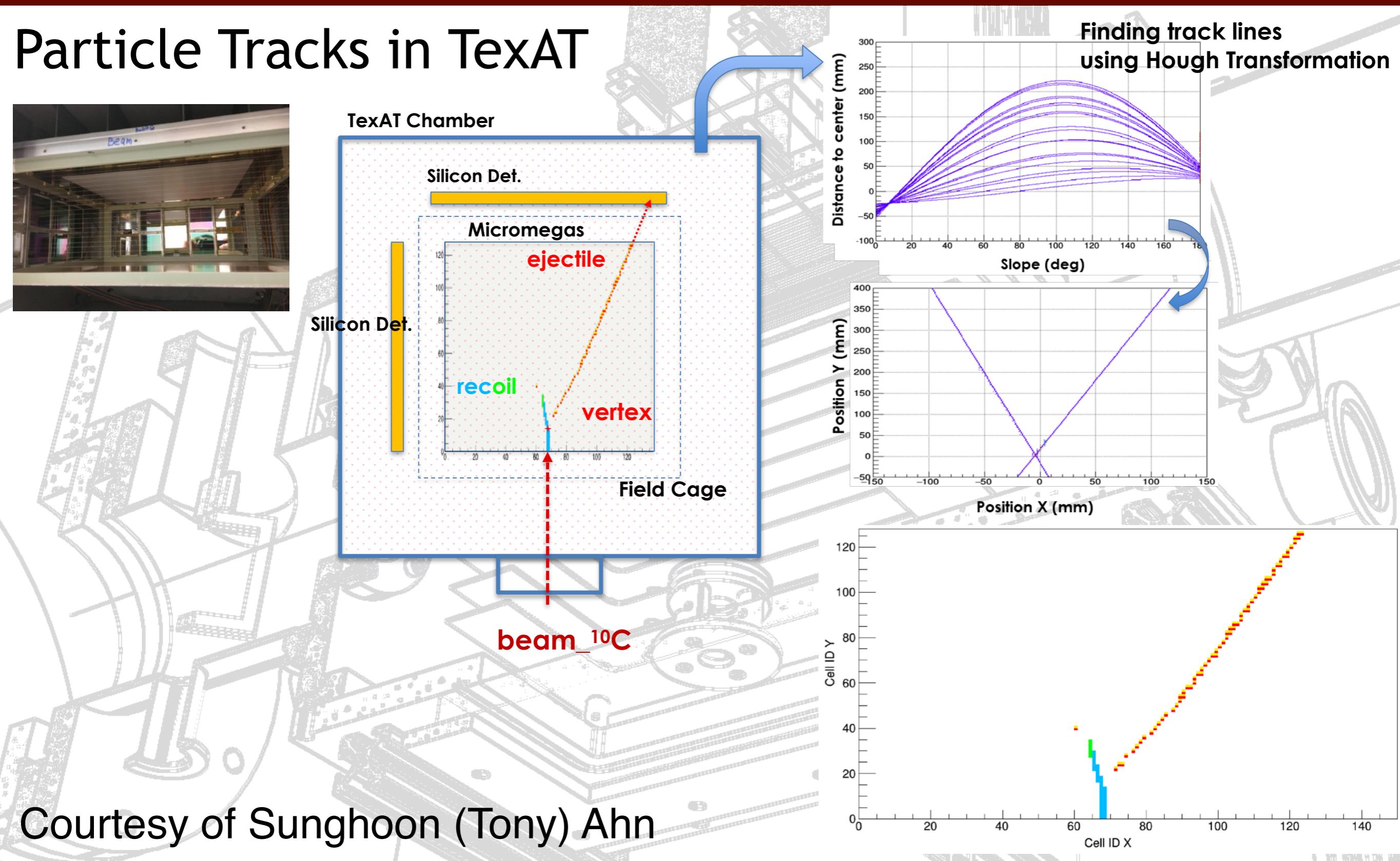
Excitation function for ${}^8\text{B} + \text{p}$



Courtesy of Sunghoon (Tony) Ahn, Josh Hooker

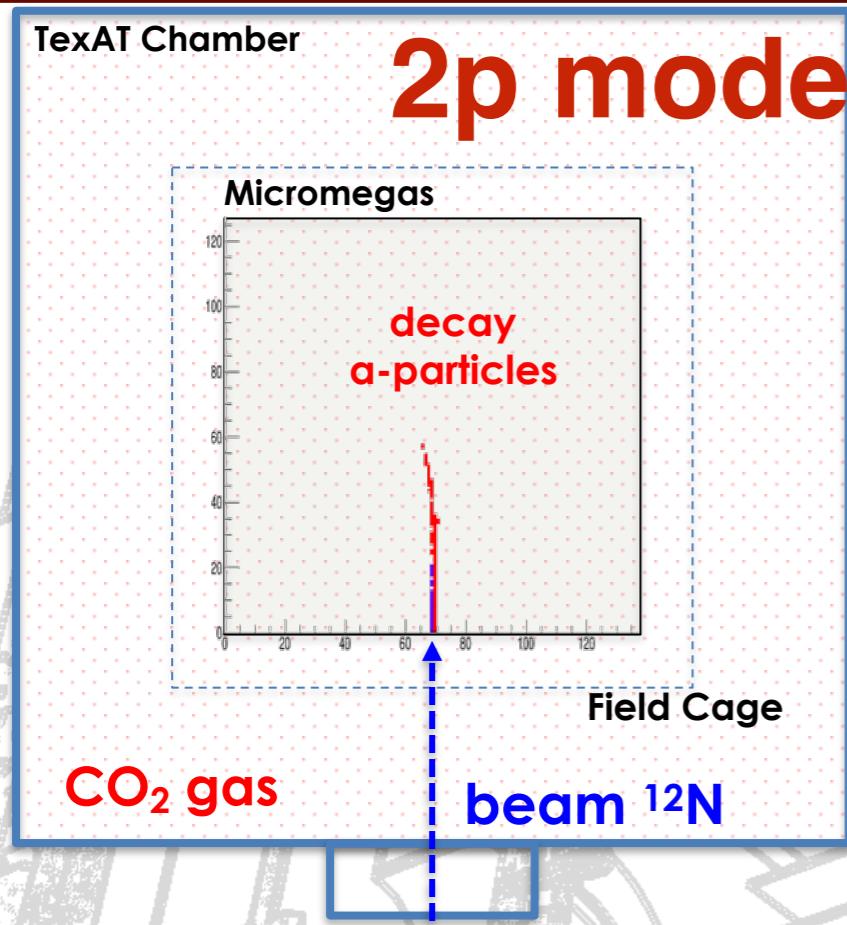
TexAT Example #2: $^{10}\text{C}(\text{a,a})$, $^{14}\text{O}(\text{a,a})$

Particle Tracks in TexAT



Courtesy of Sunghoon (Tony) Ahn

TexAT Example #3: $^{12}\text{N}(\beta^+)^{12}\text{C} \rightarrow {}^8\text{Be} + \alpha \rightarrow \alpha + \alpha + \alpha$

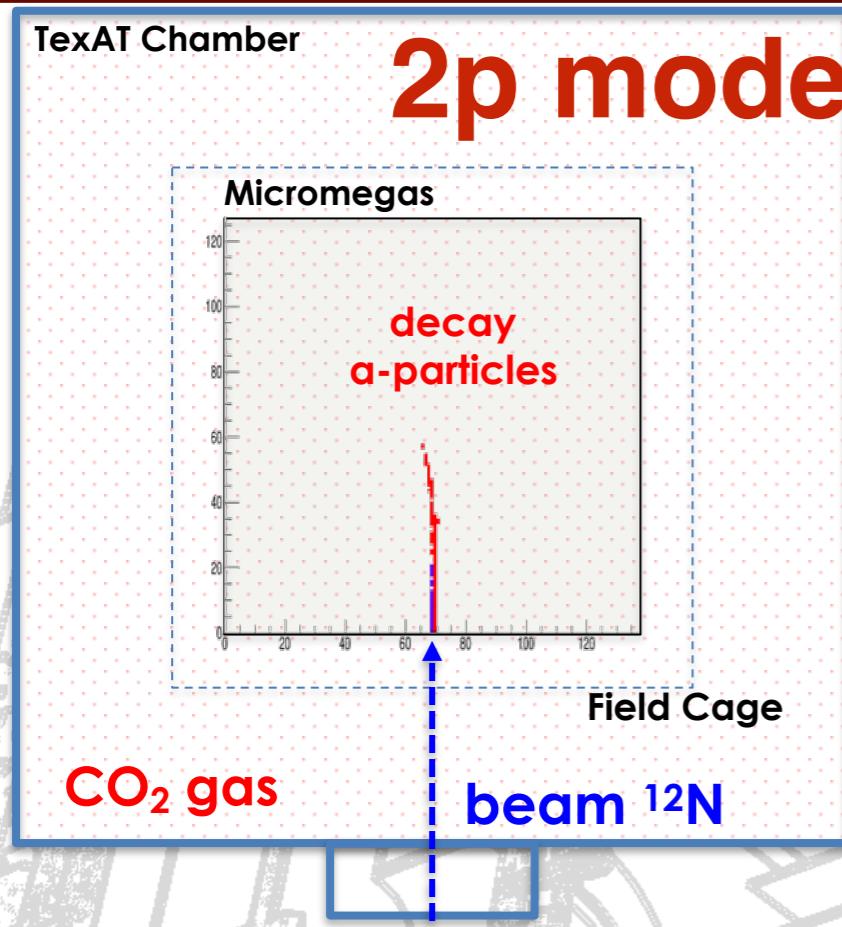


Trigger for 2p mode:

- 1st trigger: L1A from ^{12}N implant ($T_{1/2} = 11$ ms)
- Timeout 30 ms: if no 2nd trigger (L1B) \rightarrow discard event
- Time between triggers stored as D2P_time
- Channel multiplicity (MTL) for both L1A or L1B is 10 (> 5 time buckets)
- No beam while waiting L1B
- If no L1B generated new beam pulse 50 ms after previous beam pulse
- If L1B was generated, new beam pulse for next event

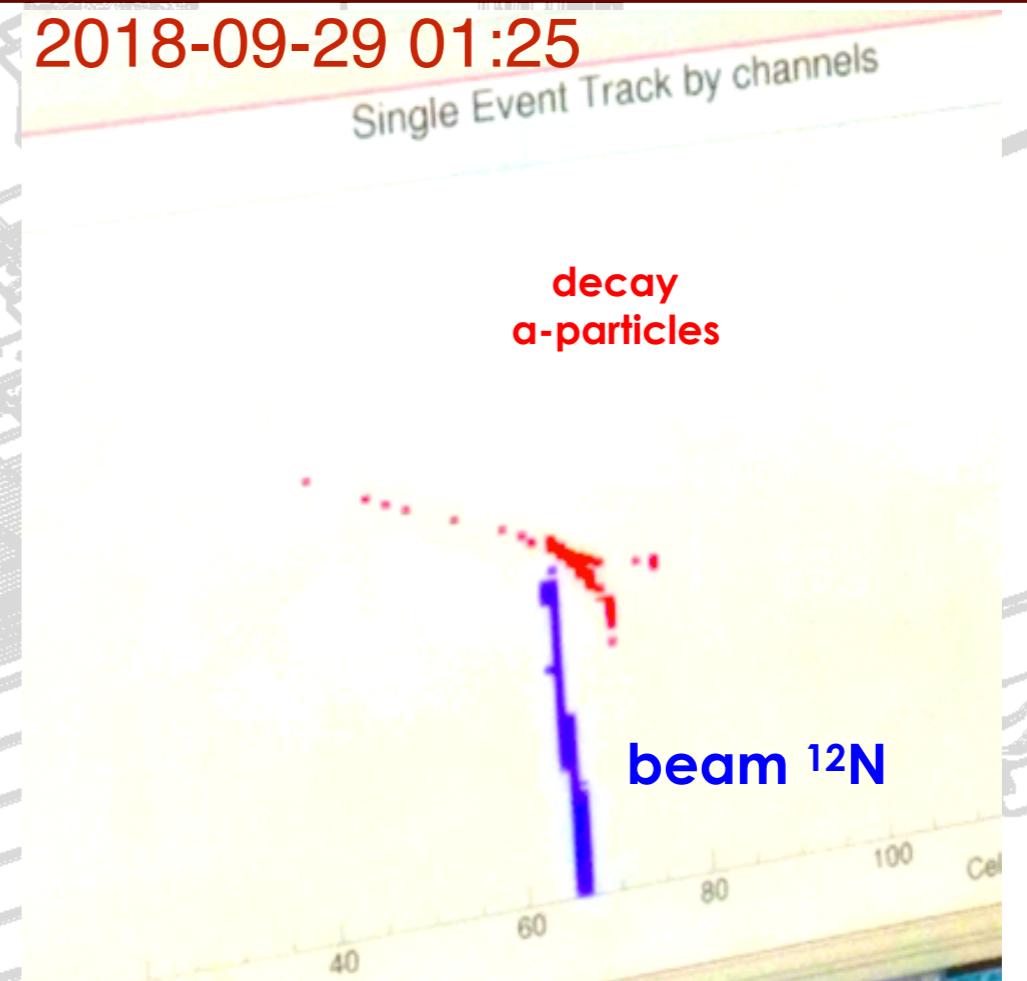
Courtesy of Sunghoon (Tony) Ahn

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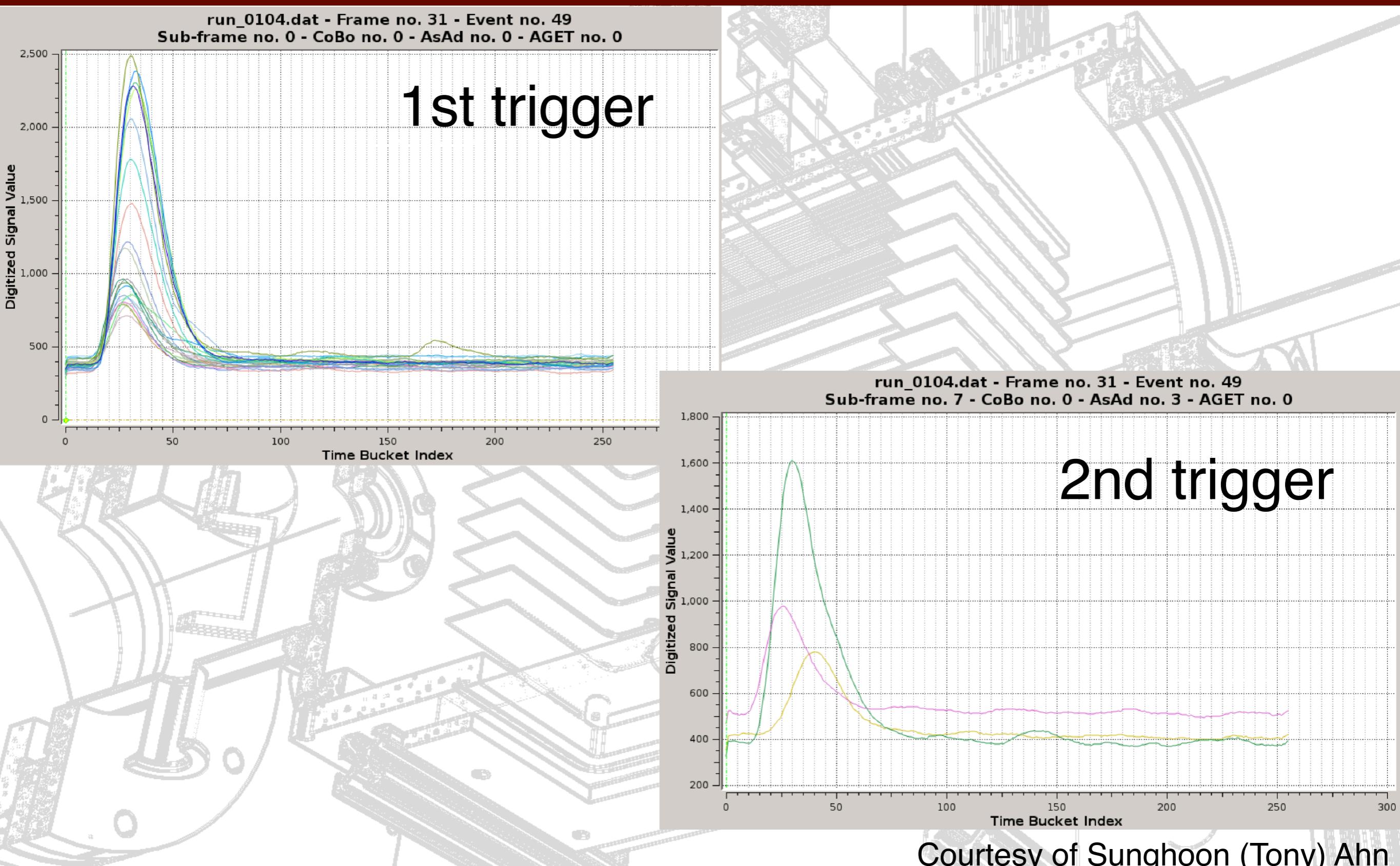
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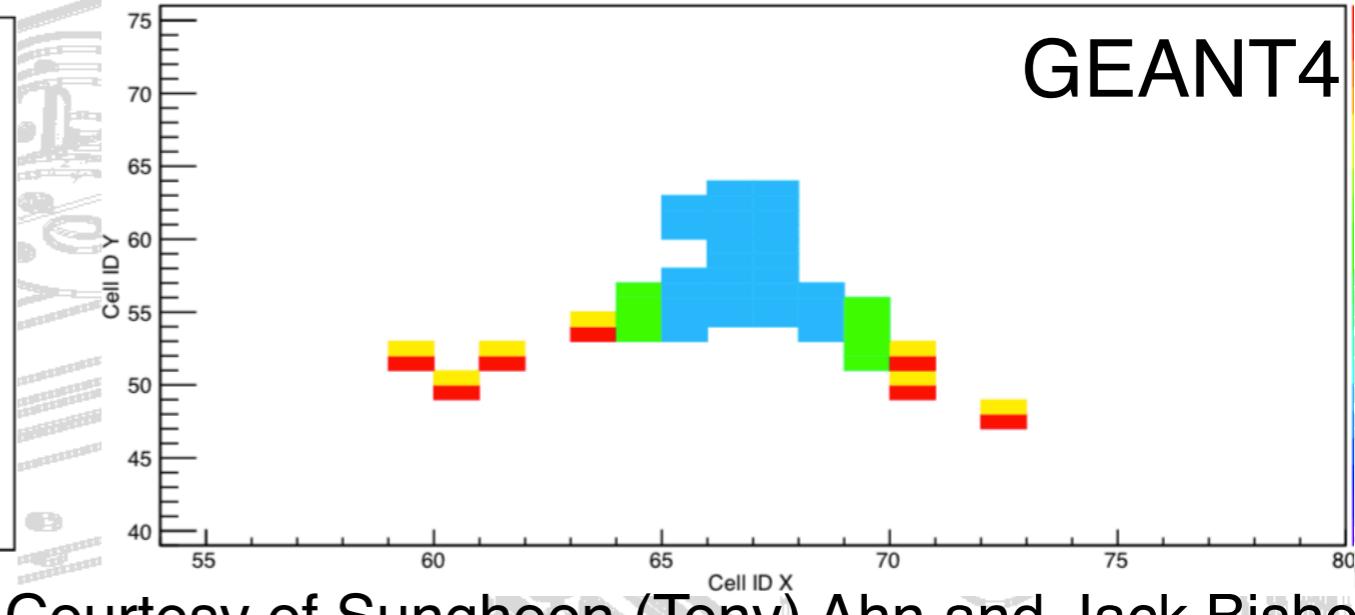
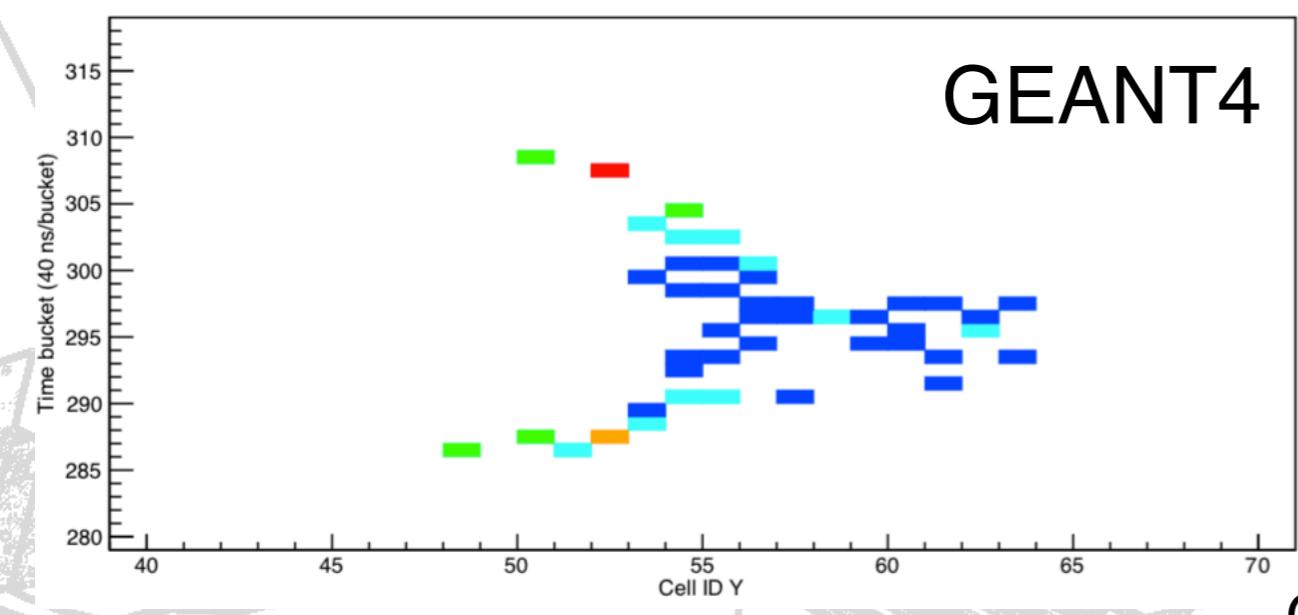
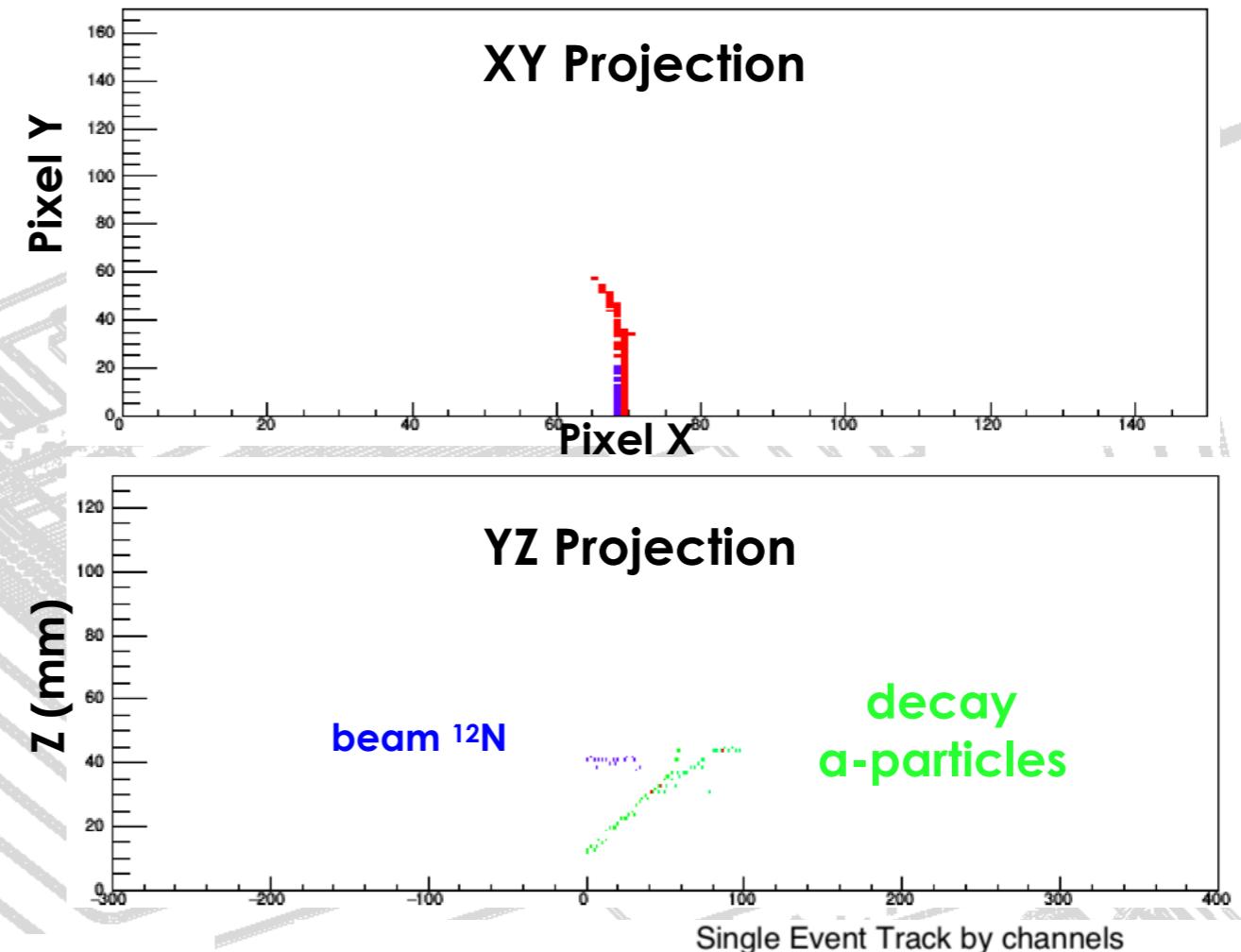
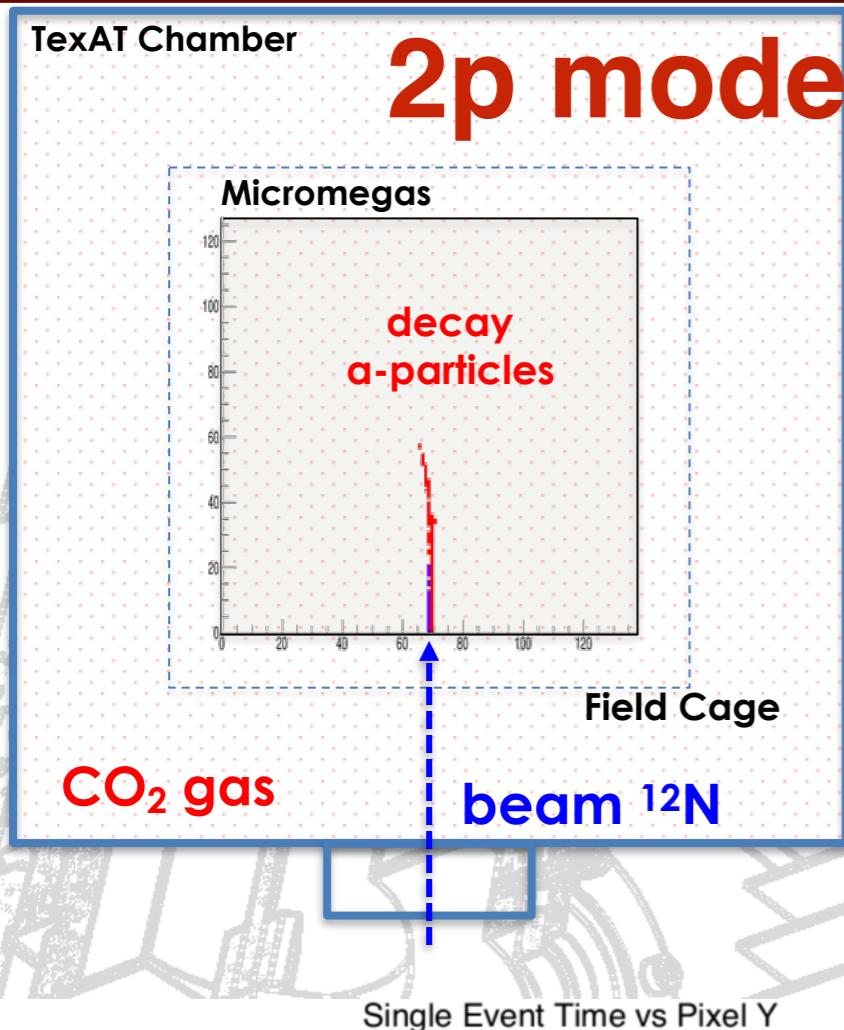


Courtesy of Sunghoon (Tony) Ahn

TexAT Example #3: $^{12}\text{N}(\beta^+)^{12}\text{C} \rightarrow {}^8\text{Be} + \alpha \rightarrow \alpha + \alpha + \alpha$



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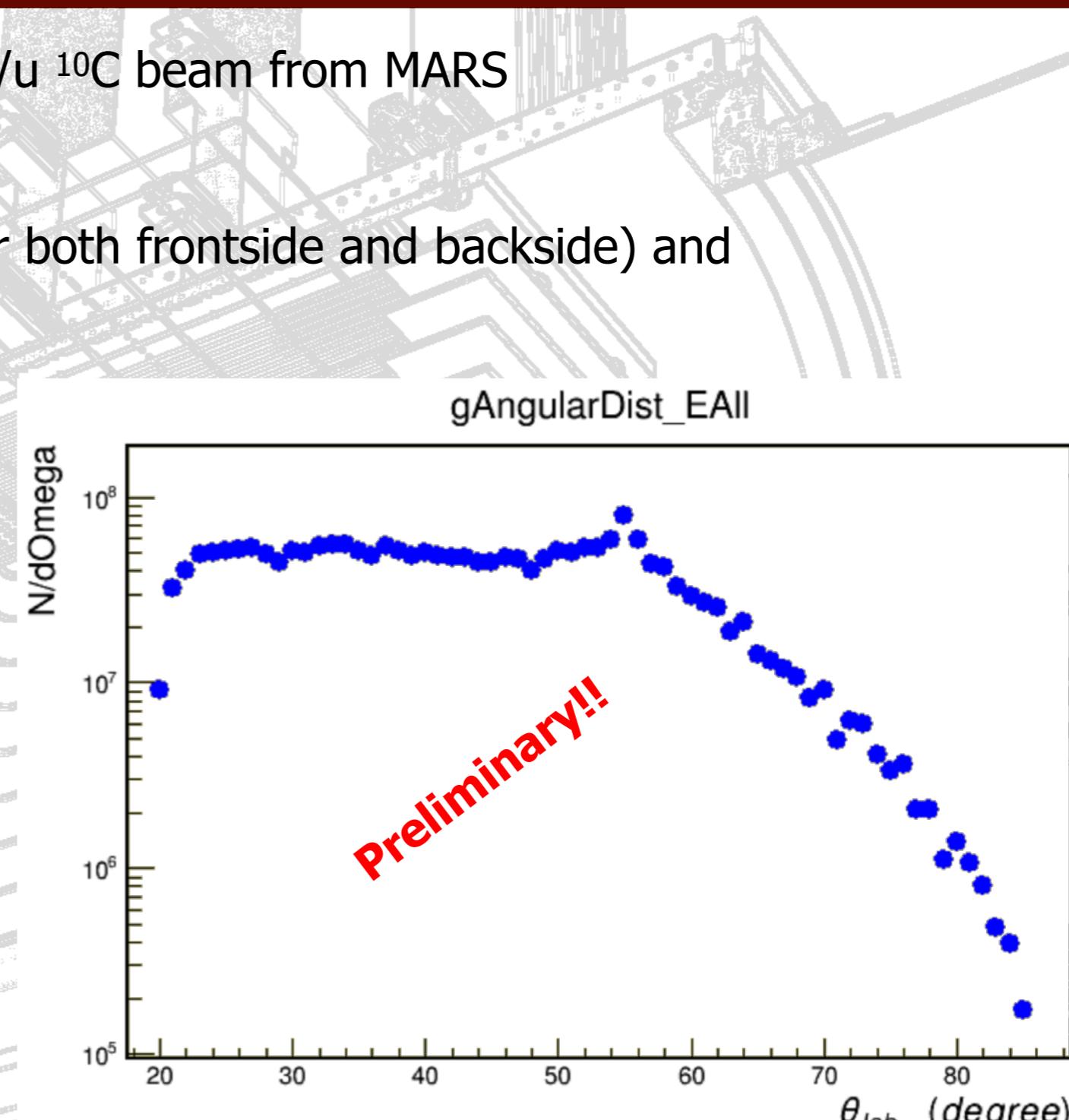
Courtesy of Sunghoon (Tony) Ahn and Jack Bishop

TexAT Example #4: Incomplete fusion of ^{10}C

- Reaction: $^{10}\text{C} + 208\text{Pb}$ with 7.5 MeV/u ^{10}C beam from MARS
- Target: ^{208}Pb
- Normal Kinematics
- Detectors: 2x E: TTT2 (126 strips for both frontside and backside) and 2x dE detectors (16+16 strips)
- GET: 2 AsAd boards



Detector Setup measuring ^{10}C from reactions

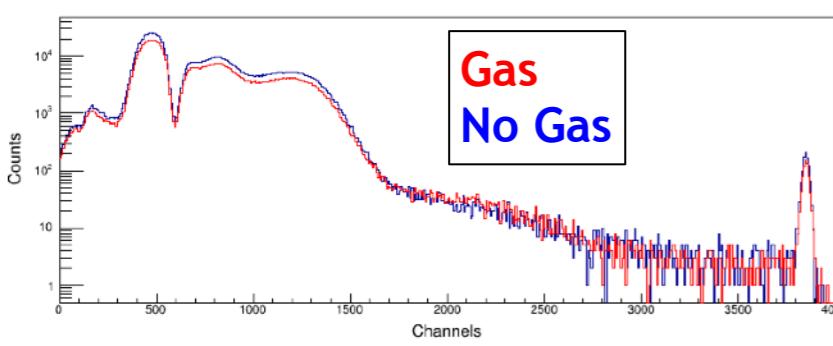
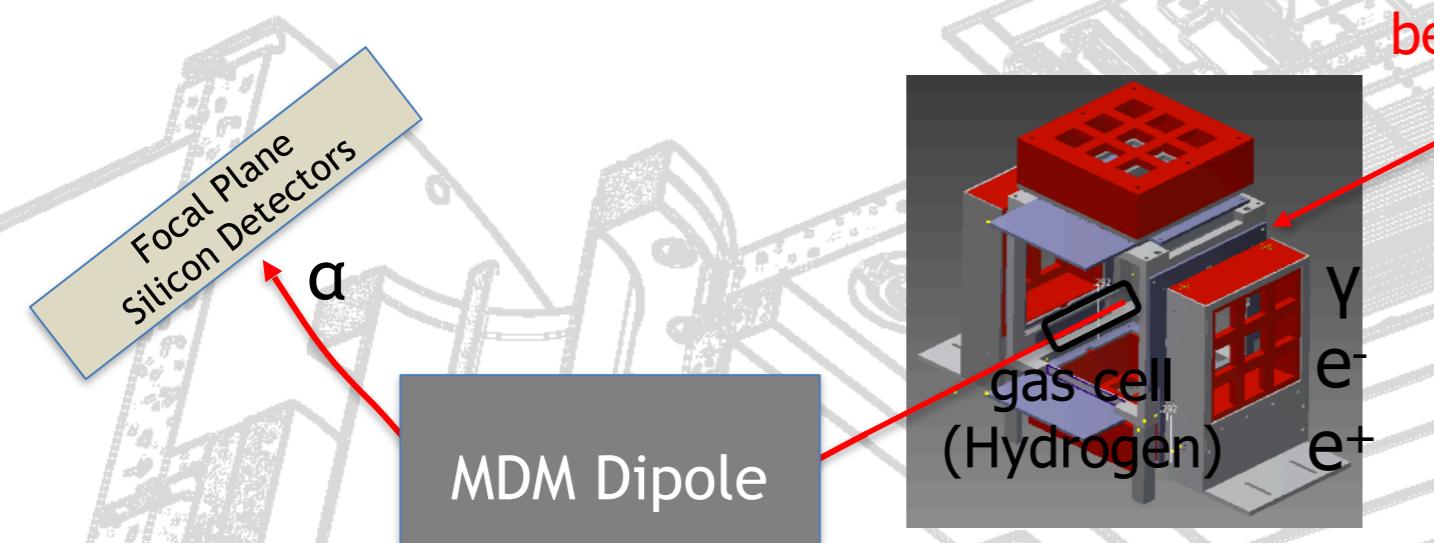


Angular Distribution of elastic scattering of ^{10}C

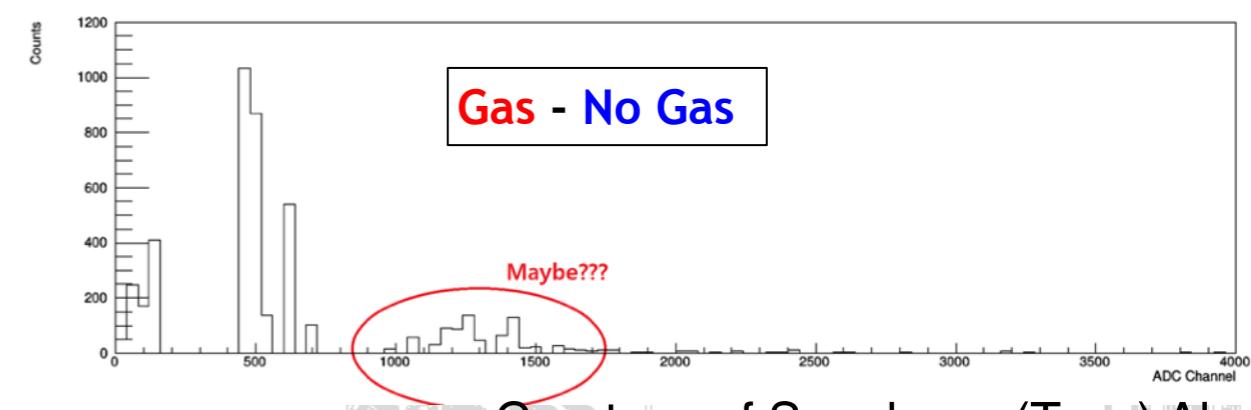
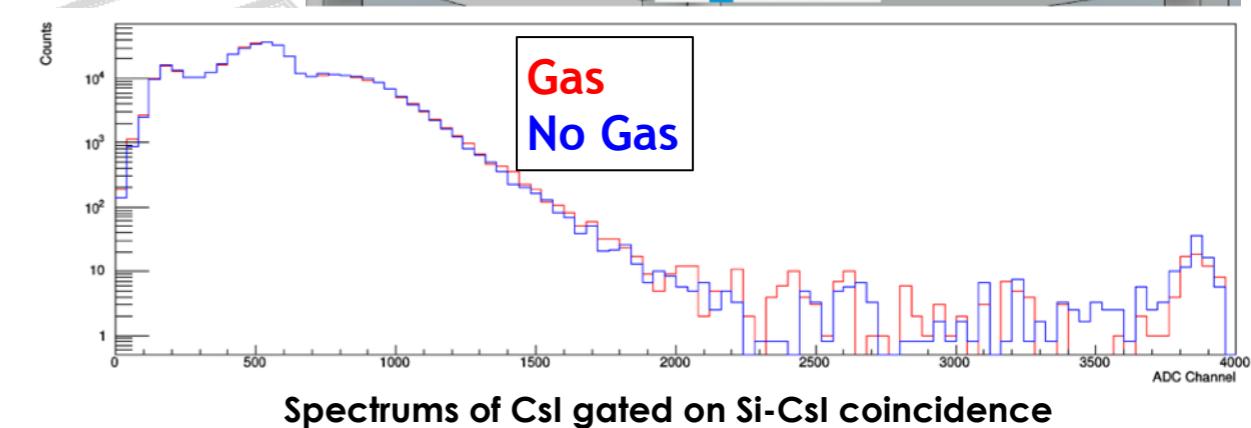
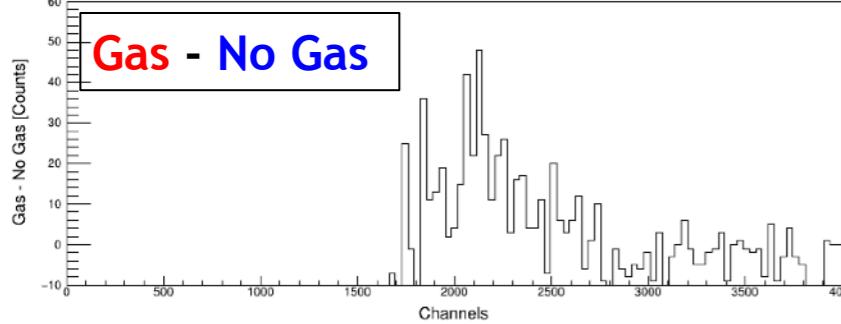
Courtesy of Sunghoon (Tony) Ahn

TexAT Example #5: Si+CsI array for ${}^8\text{Be}$ anomaly

- Reaction: ${}^7\text{Li} + \text{p} \rightarrow 2\alpha + \text{e}^- + \text{e}^+$ with 1.2 MeV/u ${}^7\text{Li}$ beam from K150
- Si detector setup for ${}^8\text{Be}$ Anomaly
- Target: Hydrogen gas cell at 2.5 atm pressure
- Detector: 4 TTT2, 36 CsI detectors and 7 FP silicon detectors
- GET: 6 AsAd boards



Gamma ray Spectrums of CsI from CsI only triggers



Thank you for your attention!

Collaborators

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E. Uberseder², J. Bishop²,

G. Christian², S. Ota², D. Scriven², E. Bennett², S. Dede², G. Lotay⁴,
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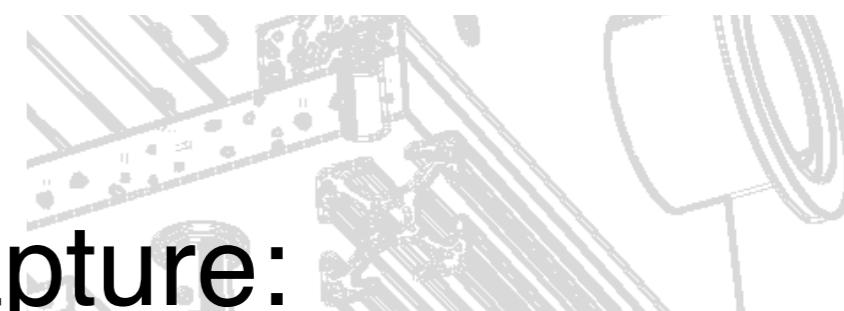
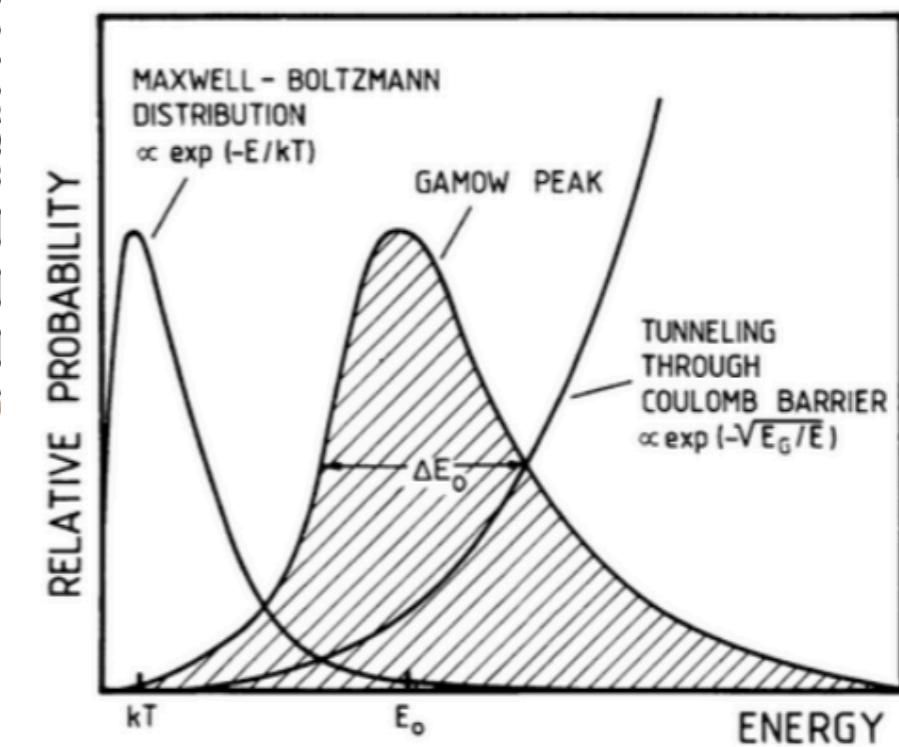
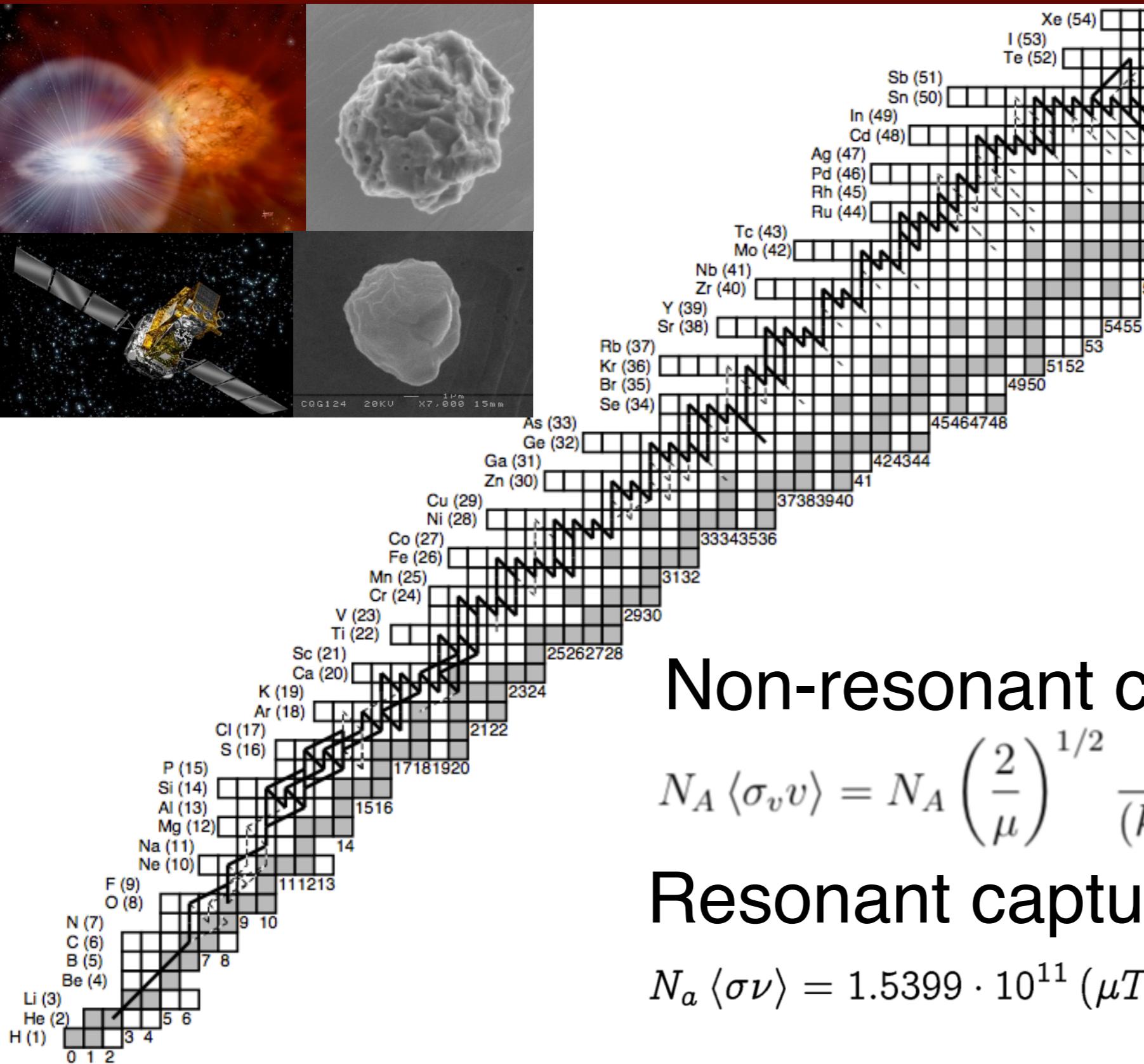
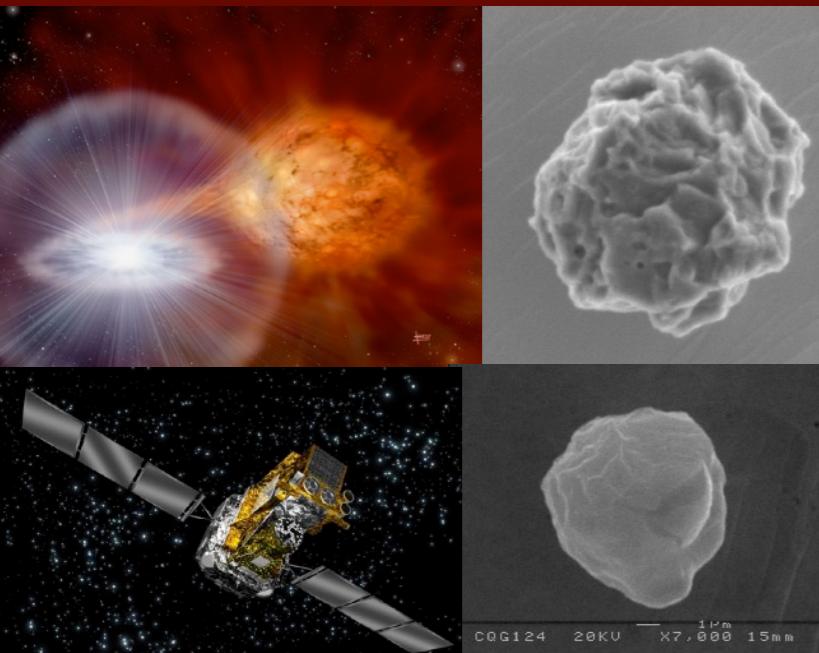
4 University of Surrey

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#: ahnt@tamu.edu, rogachev@tamu.edu

BACKUP SLIDES

Physics motivation: Explosive nucleosynthesis in novae/XRB



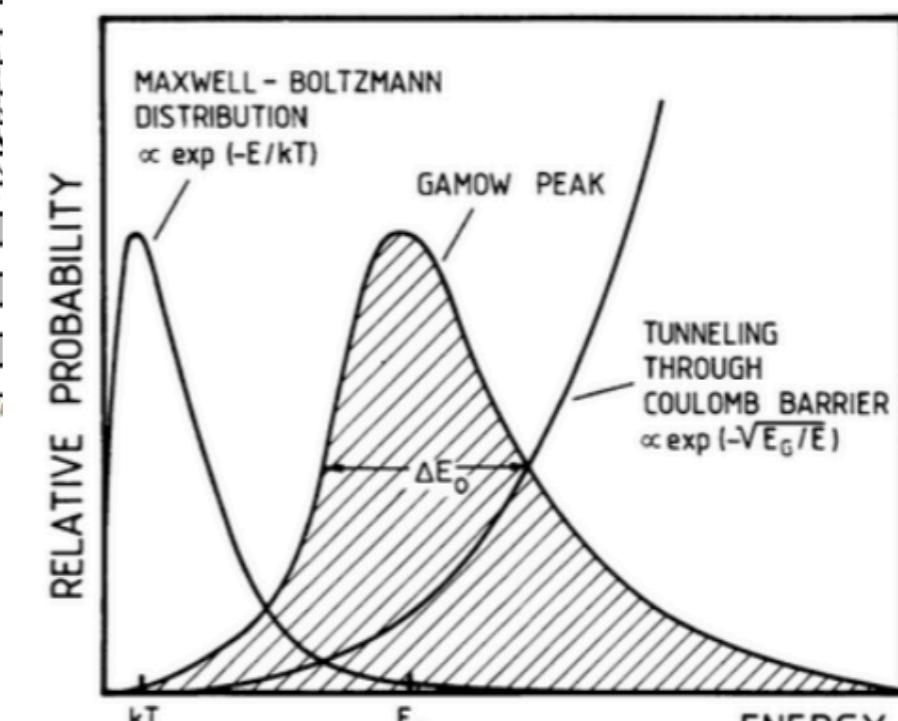
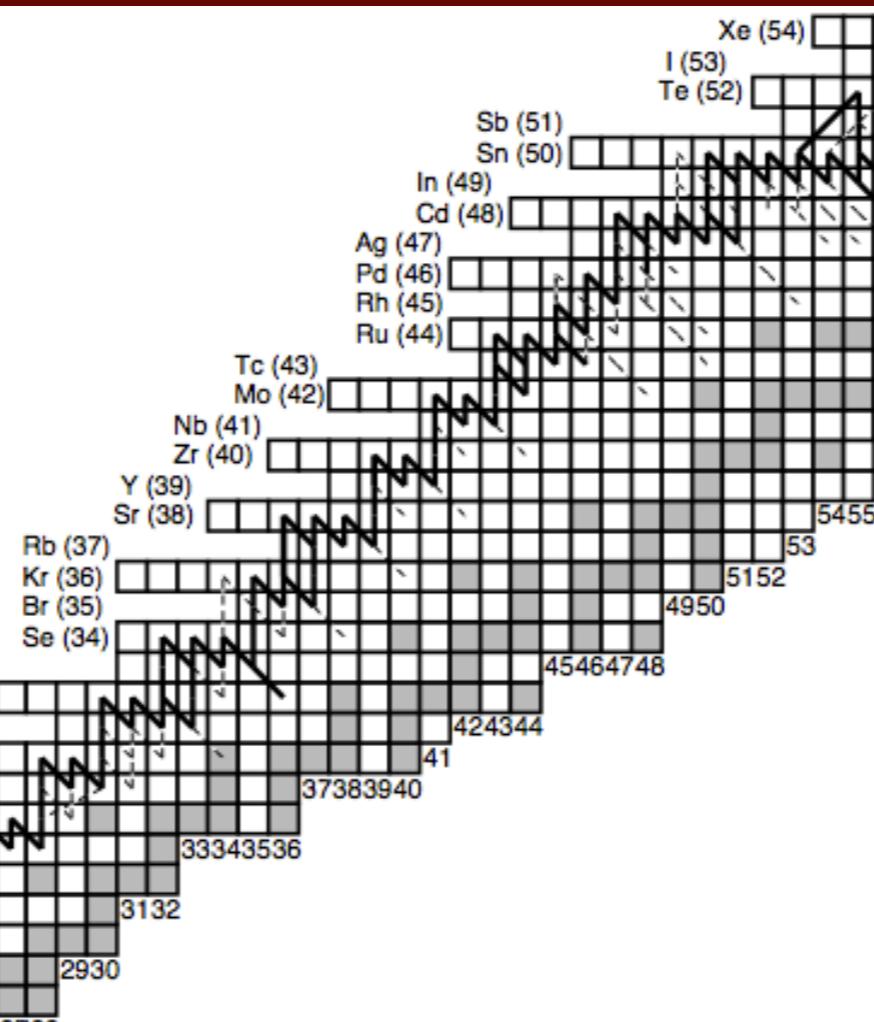
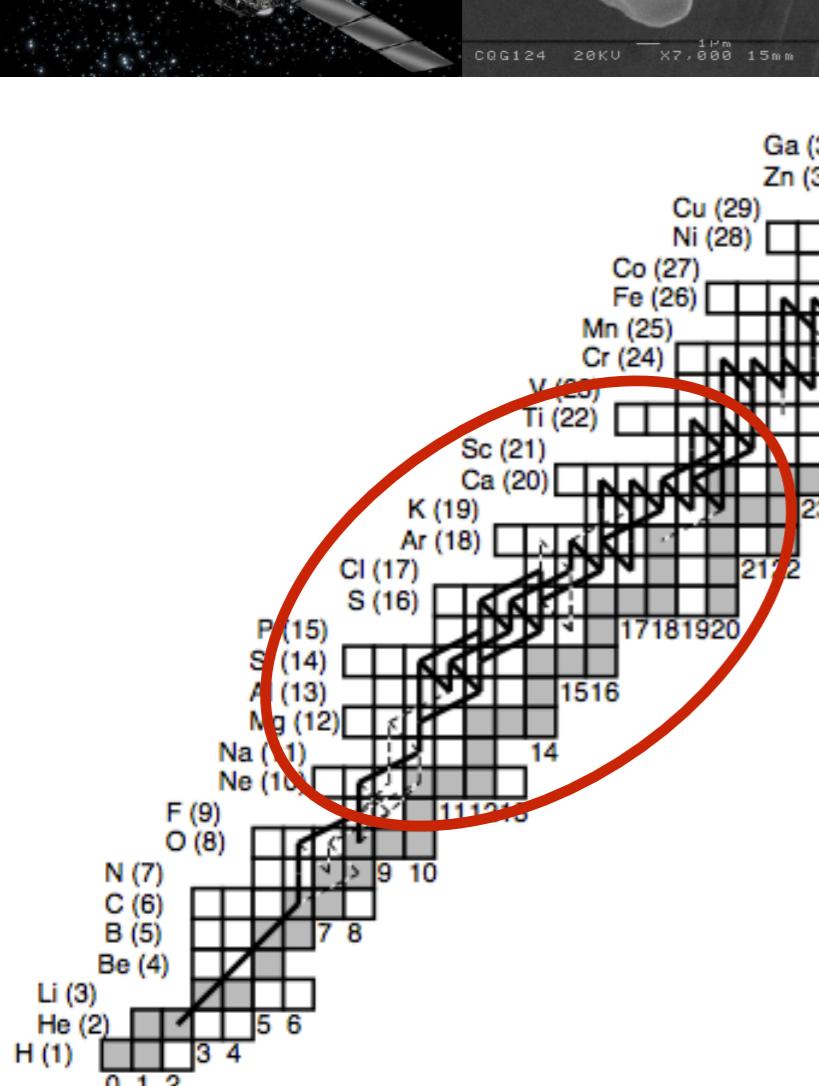
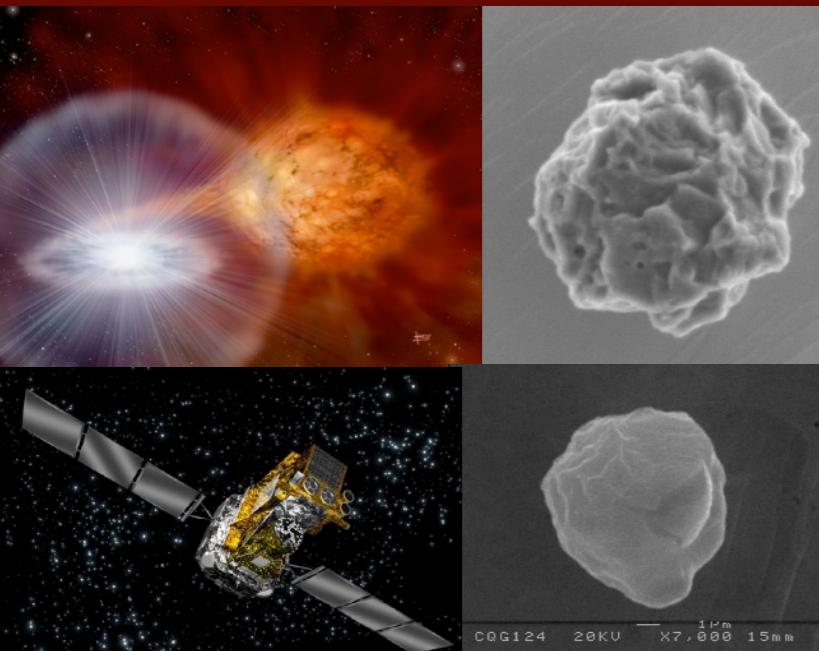
Non-resonant capture:

$$N_A \langle \sigma v \rangle = N_A \left(\frac{2}{\mu} \right)^{1/2} \frac{\Delta}{(k_B T)^{3/2}} S_{\text{eff}}(E_0) \exp \left(-\frac{3E_0}{k_B T} \right)$$

Resonant capture:

$$N_a \langle \sigma \nu \rangle = 1.5399 \cdot 10^{11} (\mu T_9)^{-3/2} \times \sum_i (\omega \gamma)_i e^{(-11.605 E_i / T_9)}$$

Physics motivation: Explosive nucleosynthesis in novae/XRB



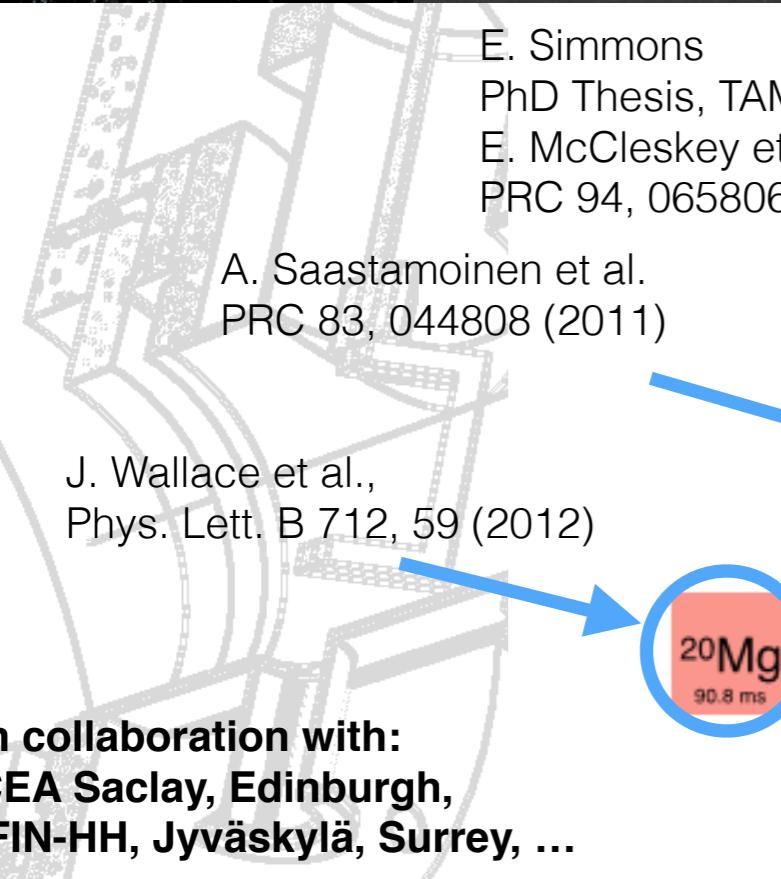
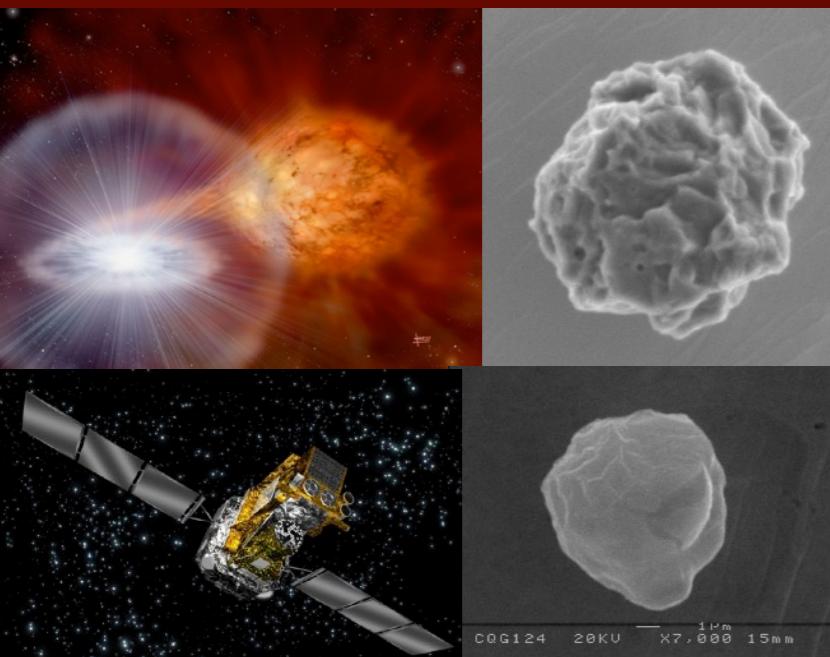
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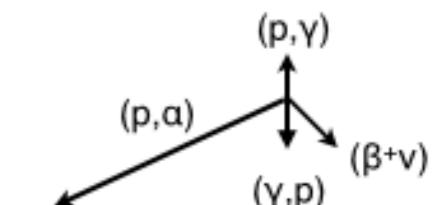
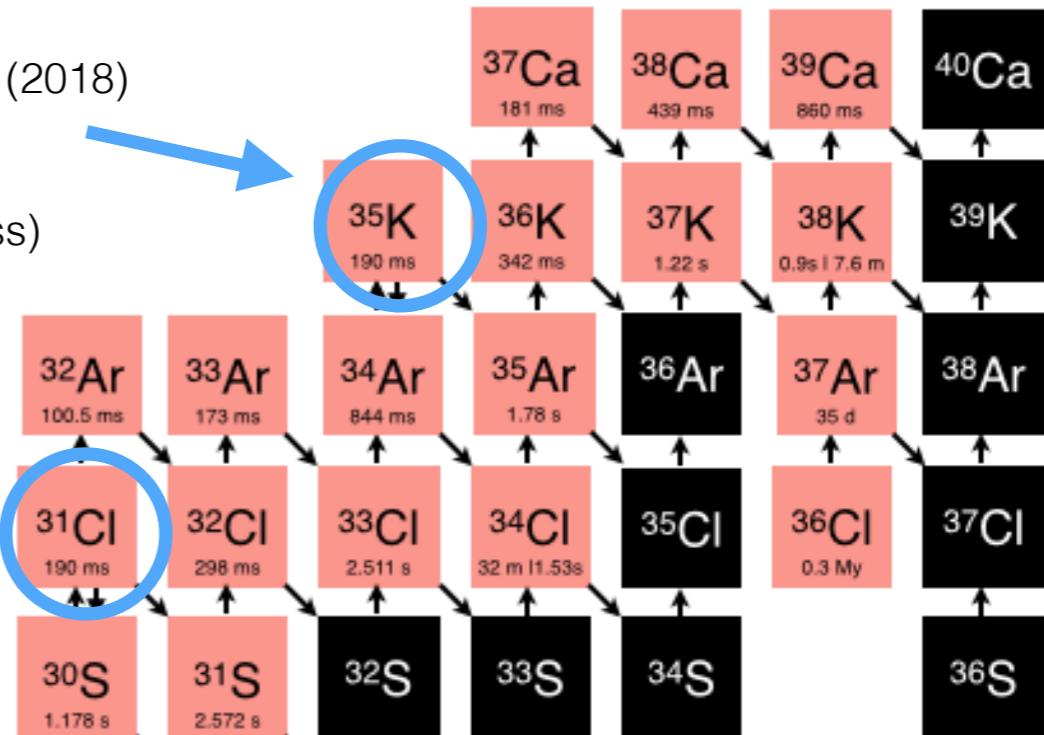
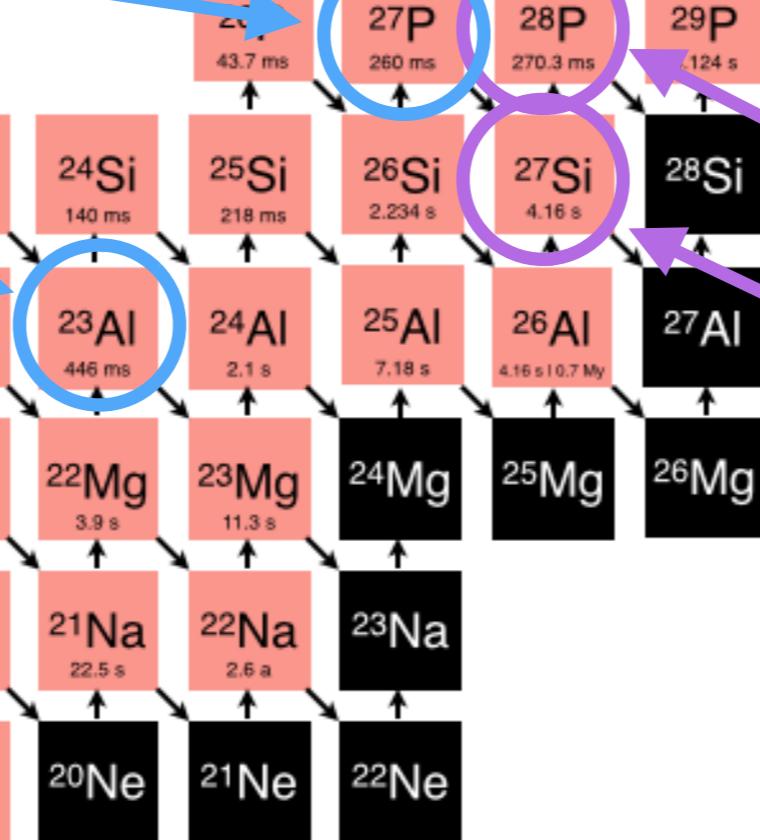
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Recent studies for nucleosynthesis at TAMU



A. Saastamoinen et al.
J. Phys.: Conf. Ser. 940 012004 (2018)
A. Saastamoinen et al.
In preparation
R. Chyzh PhD thesis (in progress)

L. Trache et al.
PoS (NICX), 163 (2008)
A. Saastamoinen
PhD thesis, JYFL (2011)
A. Saastamoinen et al.
In preparation

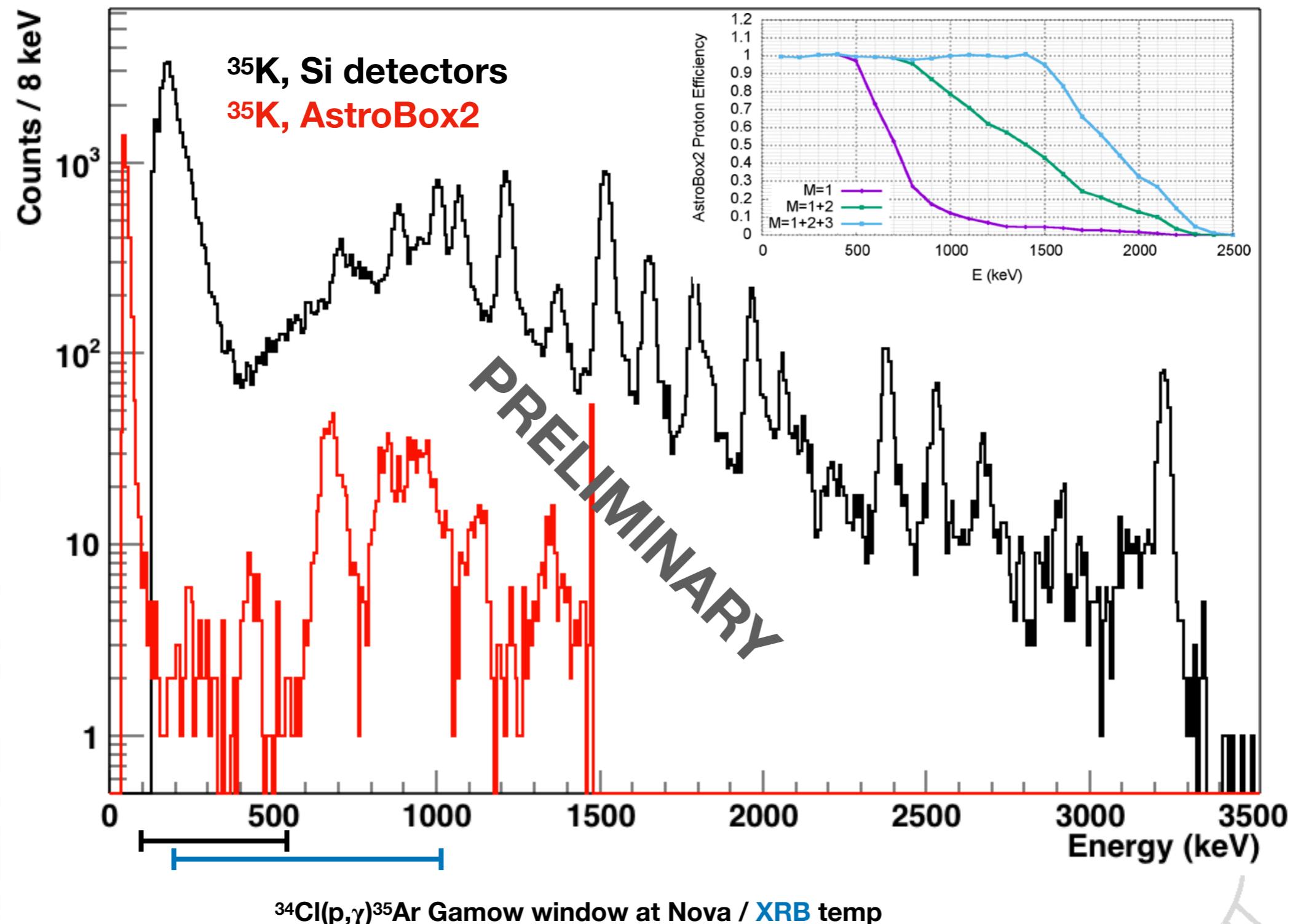


M. Dag
PhD Thesis, TAMU (2016)

A. Spiridon
PhD Thesis, TAMU (2017)



Most recent work: β -decay of ^{35}K



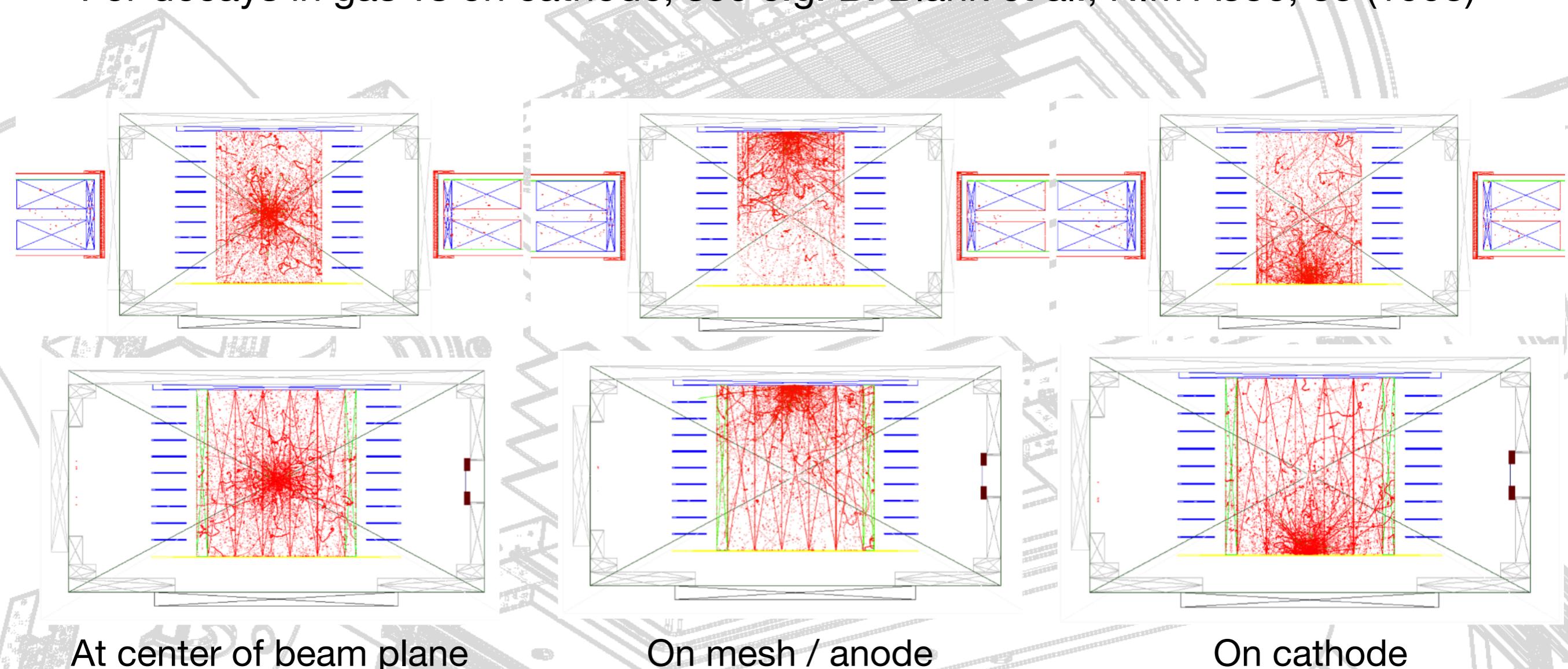
Si data: A. Saastamoinen et al. J. Phys. Conf. Ser. 940, 012004 (2018)

AB2 data: exp in Jul, Oct 2017, R. Chyzh PhD thesis (work in progress)

Effect of decay location?

In case the stopped beam has not fully neutralized and ions drift to cathode (or, depending of chemical element attach extra electron and drift to anode)

For decays in gas vs on cathode, see e.g. B. Blank et al., NIM A330, 83 (1993)

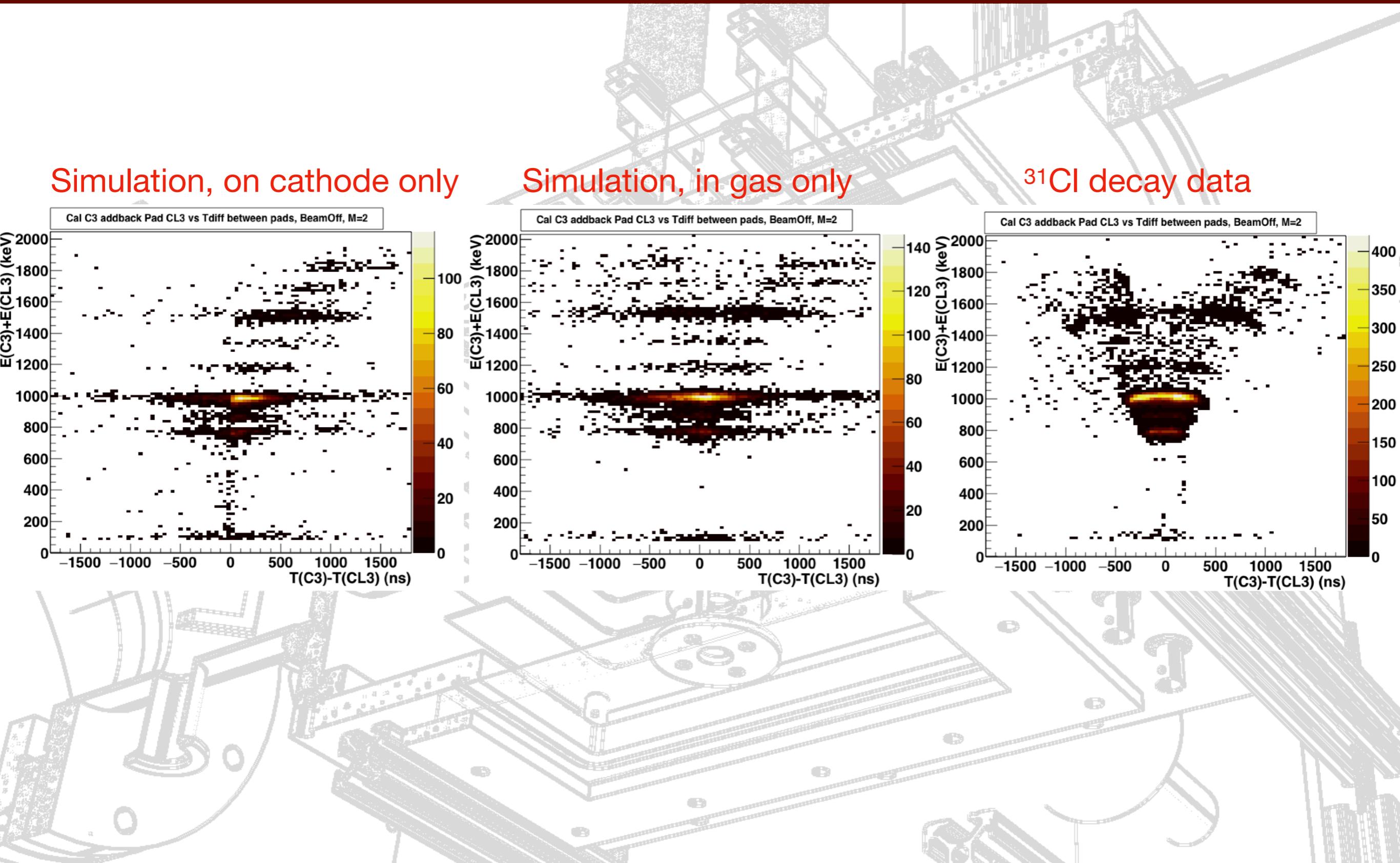


At center of beam plane

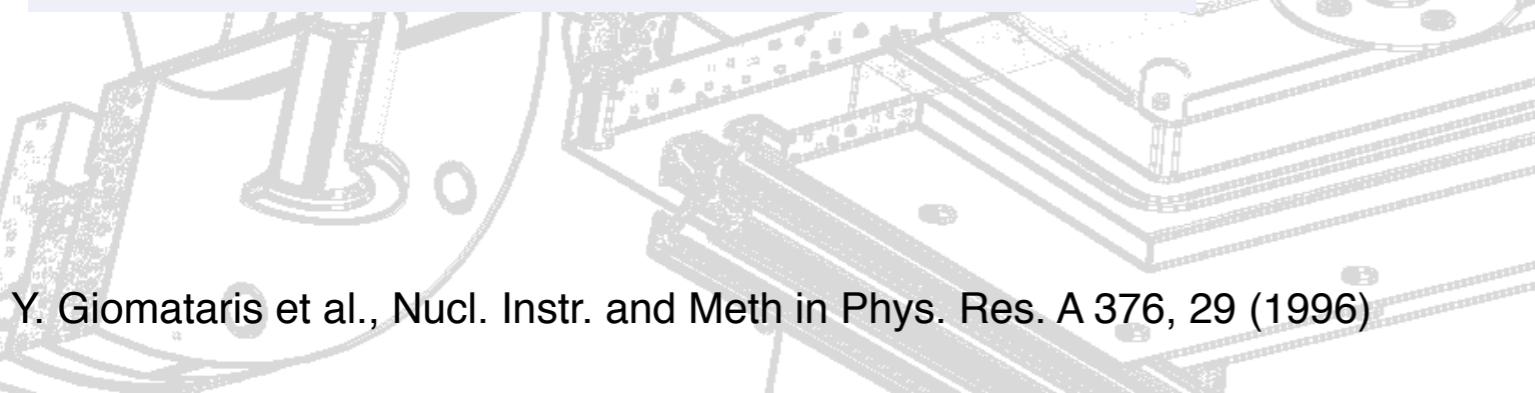
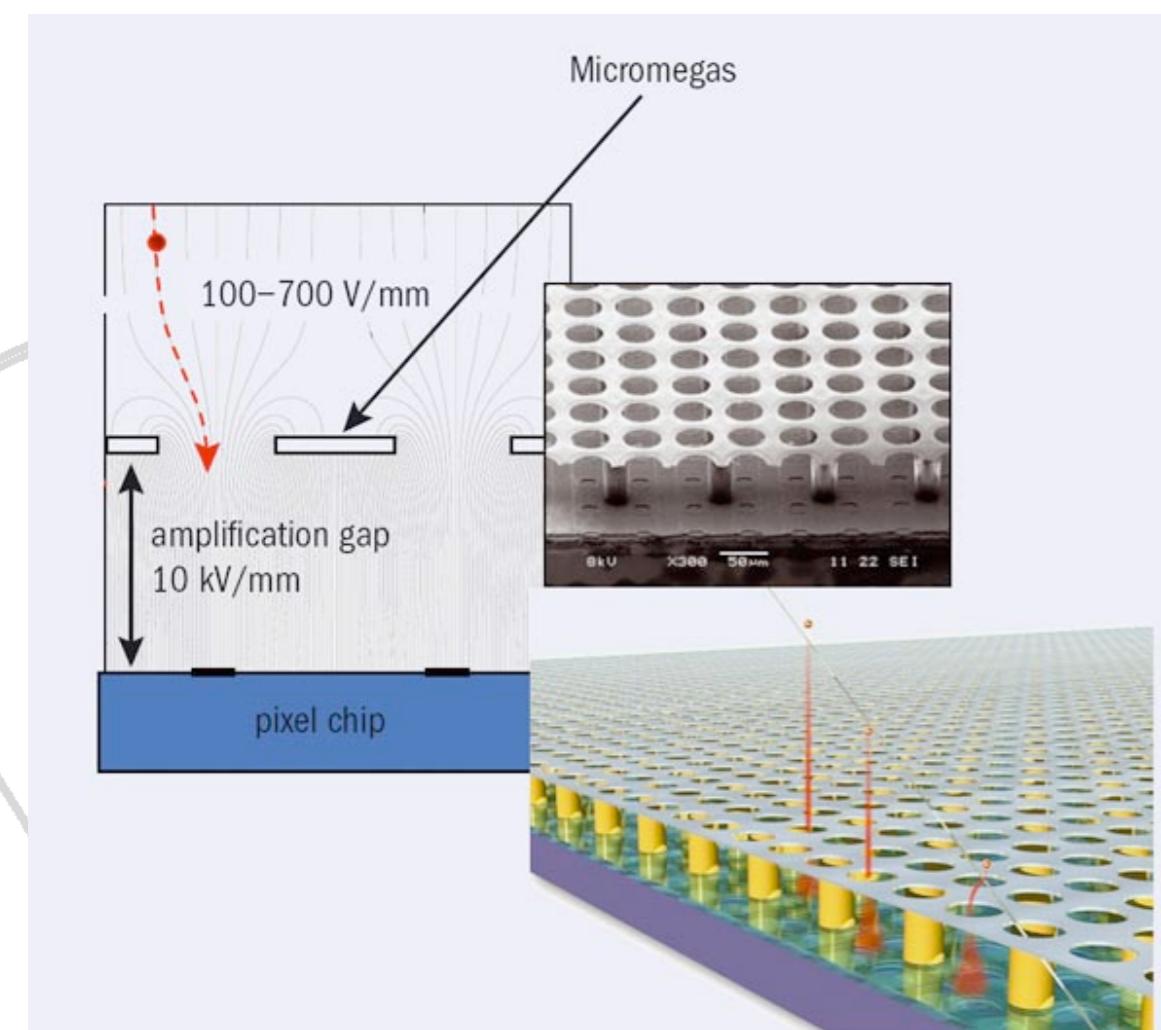
On mesh / anode

On cathode

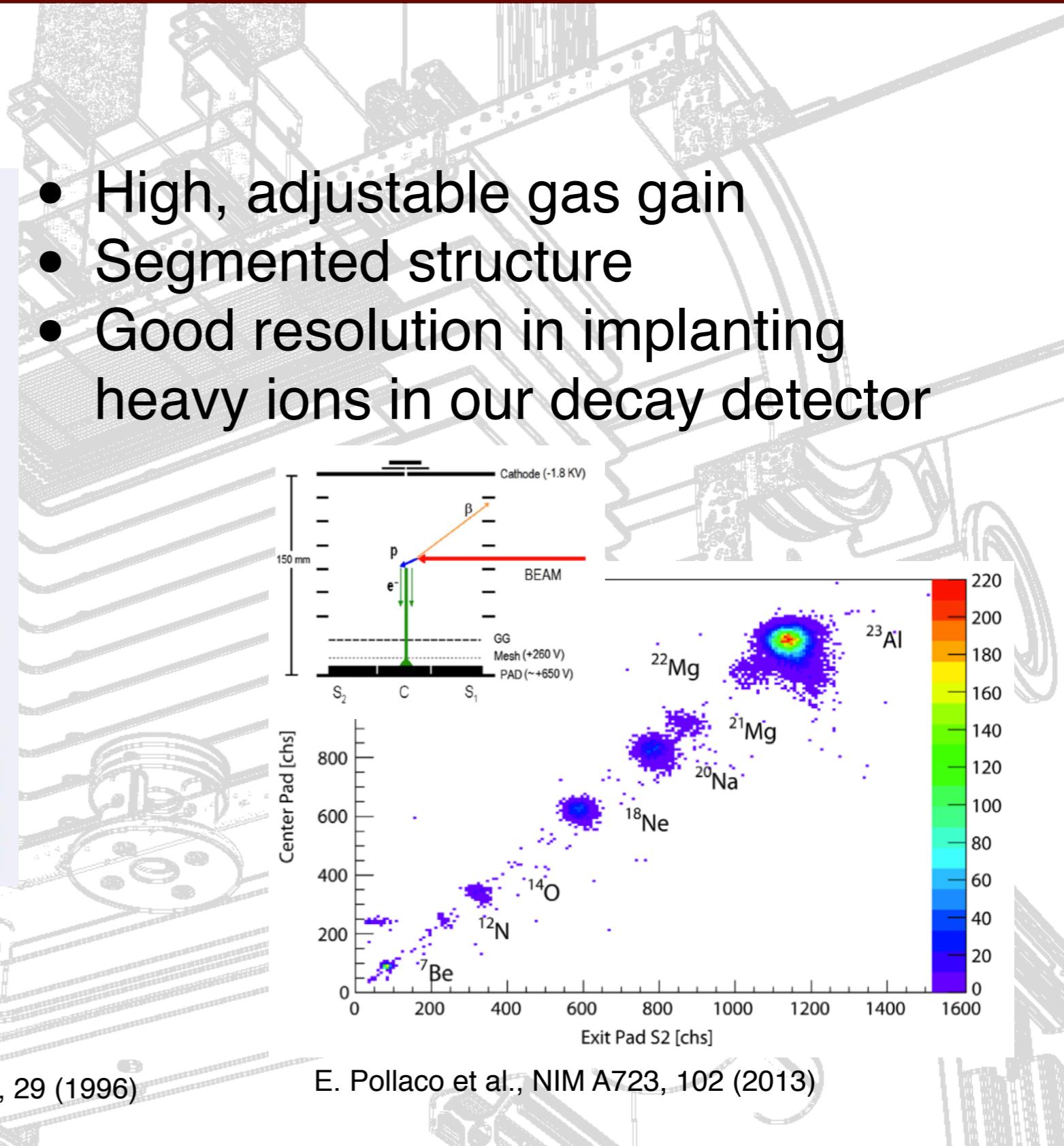
Effect of decay location?



MICROMEGAS Detectors for ΔE measurement



Y. Giomataris et al., Nucl. Instr. and Meth in Phys. Res. A 376, 29 (1996)



E. Pollaco et al., NIM A723, 102 (2013)

Example #5: Looking for “Y”s

- Reaction: $^{12}\text{N} \rightarrow ^{12}\text{C}^* \rightarrow ^8\text{Be} + \alpha \rightarrow \alpha + \alpha + \alpha$
- TexAT for measuring decay α particles
- CO_2 gas stops ^{12}N beams in the chamber.

