TexAT and TeBAT: a multitude of experiments

Jack Bishop
Cyclotron Institute
Texas A&M University

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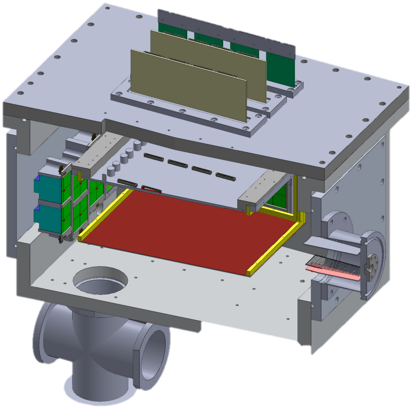
TexAT overview

TexAT TPC - TEXas Active Target Time Projection Chamber

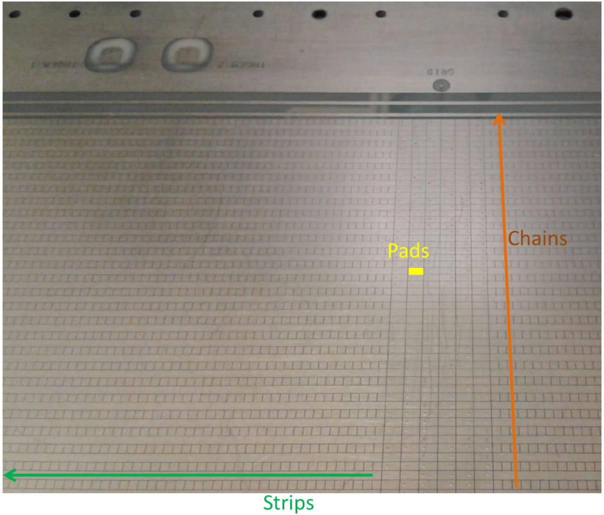
- 224 (beam) x 245 x 130 (height) mm sensitive volume
- Segmented readout using Micromegas, 1024 channels, pos. res. $\approx$ 1.5 mm in beam direction
- Gas Electron Multipliers (GEMs) provide additional gain. Low dE/dx particle tracks possible
- MUTANT module (practically essential)
- Ancillary Si+CsI telescope wall



NIM paper: E. Koshchiy et al. - NIMA 957, 163398 (2020)

Micromegas

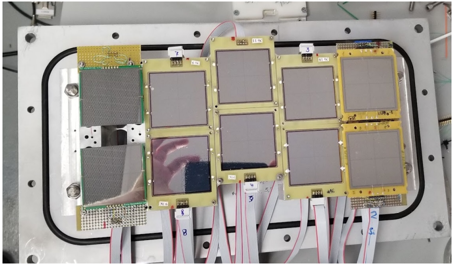
- 128-μm-gap
- Central region pads 1.75 x 3.5 mm
- Side regions require multiplexing into 'strips' and 'chains' parallel and perpendicular to beamline
- THGEMs (1.25-mm-thick) and thin GEMs (50-μm-thick)



Ancillary detectors

Si detectors

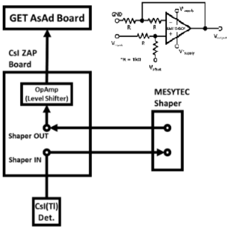
- 625-μm-thick "Dubna" detectors
- 1000-μm-thick Micron MSQ25, 4 junction pads, 1 ohmic
- 0° 500-μm-thick W1 DSSD



CsI detectors

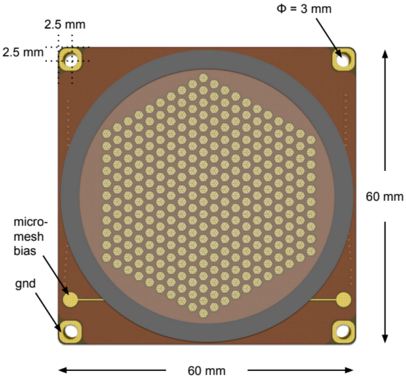
- 40-mm-thick readout by single Hamamatsu 20×20 cm^2 S3204 PIN diode
- Max AGET shaping time 1 μs ⚠
- Take CsI signal to external Mesytec MSCF-16 with 8 μs shaping-time

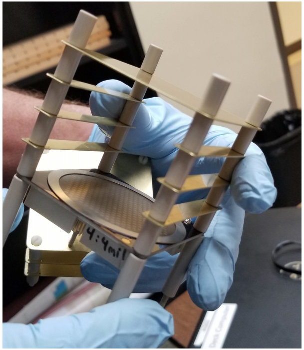
- → Fed back into AsAd board with "Gain2Input" option and level-shifter to bypass CSA



Ancillary detectors: Micromegas Junior

Built by Radiation Detection and Imaging (RDI) - Arizona

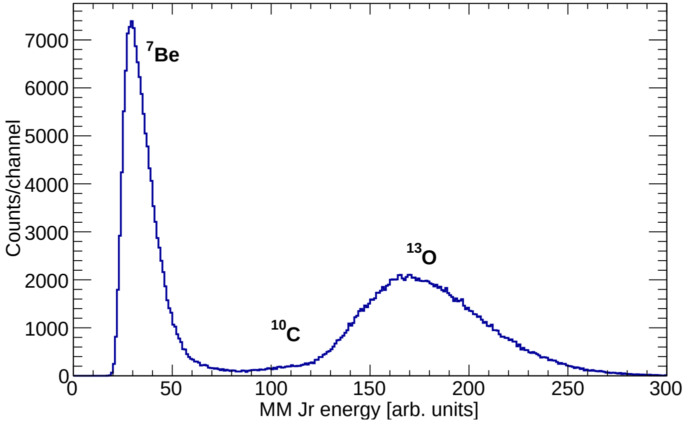




Used as a beam monitor (dE_{beam}) from mesh
Signal on pads too small for proper reconstruction - need a new design

Ancillary detectors: Micromegas Junior

Built by Radiation Detection and Imaging (RDI) - Arizona



Mesh signal

Past experiments

Nuclear structure/exotic nuclei

- ^{8}B(p,p) ✓
- ^{10}C(α,α)
- ^{14}O(α,α) ✓
- ^{12}Be(p,p) at TRIUMF ✓
- ^{9}Li(p,p) ✓
- ^{9}Li(p,n) TexNeut

Direct fusion measurement

- $^{8}\mathrm{B}+{}^{40}\mathrm{Ar}$ ✓

Trojan Horse Method studies

- $\alpha(^{20}\mathrm{Ne},\alpha)^{16}\mathrm{O}+\alpha$

Nuclear astro (α,p) studies

- ^{14}O(α,p) at RIKEN (CRIB)

Transfer reactions

- $^{12/13}$B$(d,{}^{3}\mathrm{He})$
- ^{1}H$(^{6}\mathrm{He},t^{\star})$ ✓

β-delayed particle decay

- $(^{12}\mathrm{N},\beta 3\alpha)$ ✓
- $(^{13}\mathrm{O},\beta 3\alpha p)$ ✓

Neutron-induced measurements

- ^{12}C$(n,n_2)3\alpha$ ✓
- ^{12}C(n,α_0), ^{16}O(n,α_0) ✓

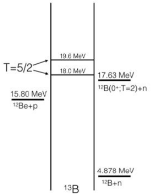
✓ Published ✓ Analysis completed - paper in prep.

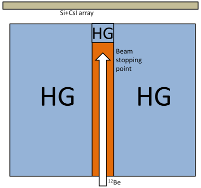
TexAT snapshots

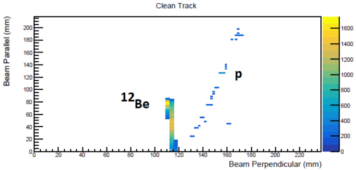
^{12}Be(p,p) - Curtis Hunt's thesis work

TRIUMF experiment: July 2019 - 2 weeks setup

- Populate T=5/2 IAS of ^{13}Be g.s. in ^{13}B
- 6 MeV/u ^{12}Be beam - 500 pps
- 260 Torr iC_4H_{10} to stop beam 7/8th into the MM: TTIK
- Trigger on Si (m=1)
- Proton track in side region and last 1/8th (HG) - gain not quite good enough for reliable p/d/t separation
- Lesson learnt - 260 Torr → 210 Torr enough for high-enough gain. Not enough experience with GEMs yet





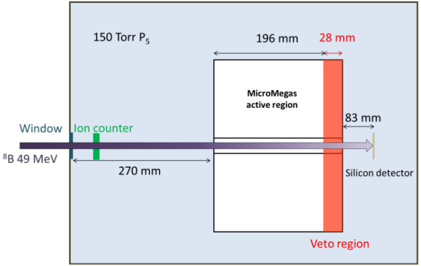


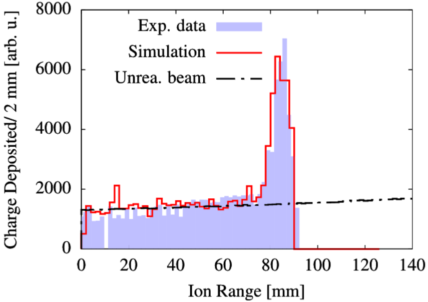
Direct fusion studies

Measure ^{8}B+^{40}Ar fusion directly - weakly-bound proton-halo nucleus

No model dependency based on evaporation yields

5.1 MeV/u ^{8}B 1000 pps into P5 (^{40}Ar (95%) + CH_4 (5%)) at 150 Torr





Trigger here on the ion counter (external), veto trigger with Si and MM last $1/8^{th}$

→ L0 trigger with MUTANT for interacting beams only

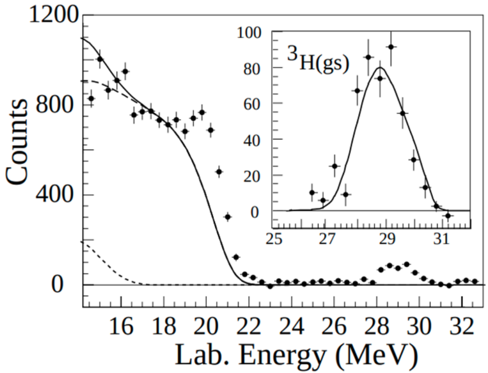
J. Zamora++ Phys. Lett. B 816, 136256

Select example highlighting possibilities of TPCs

t 85% (7000 pps), ^{9}Li 10% (800 pps), ^{6}He 5% (400 pps)

260 Torr iC_4H_{10} measuring ^{6}He(p,t*)α

Excited state of tritium? Measure missing mass spectrum from α-particles



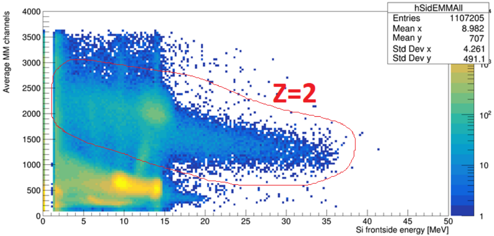
Peak from α-spectrum at $E_x = 6.8$ MeV

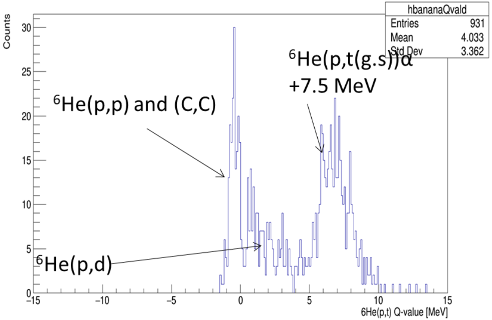
Or possibly a final state interaction?

Re-do with range of beam energies and with greater sensitivity of TPC

Can also observe the breakup of any excited state

^{6}He(p,t*)α



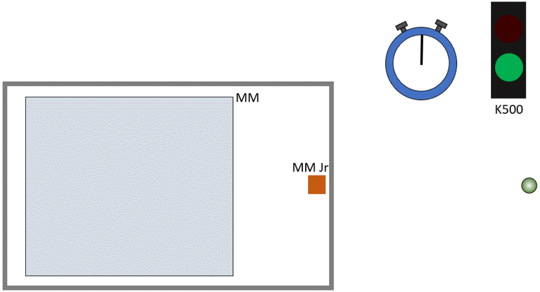


Peaks seen for ^{6}He(p,t(g.s)), ^{6}He(p,p) and ^{6}He(p,d)

No peak seen for t* and missing momentum distribution not consistent with t*

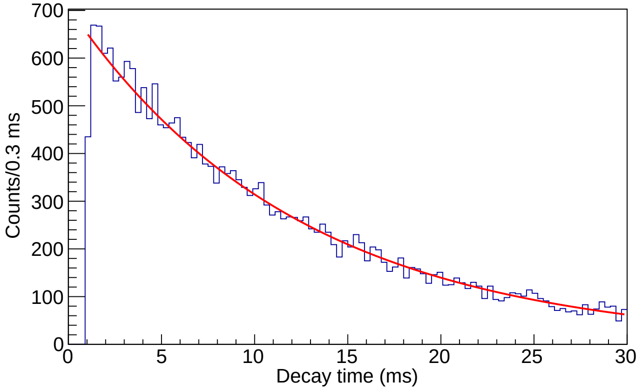
2p-mode: (^{13}O, $\beta 3\alpha p$)

2p-mode: L1A and L1B trigger
30 ms timeout between L1A and L1B



d2p: decay-time measurement

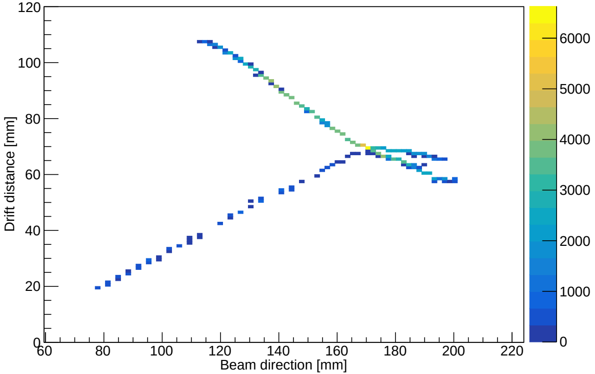
Correlate implant and decay location



Backgroundless $t_{1/2}$=8.55±0.09 (stat.) ms c.f. adopted value of 8.58±0.05 ms

New decay modes

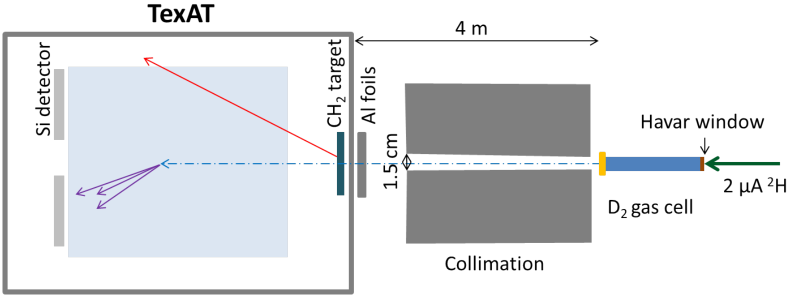
Highly-sensitive - new decay modes: $\beta 3\alpha p$.
Recently accepted in PRL - arxiv:2302.14111



0.078(6)% branching ratio from few pps beam. Thank you 2p-mode!

Neutron-induced measurements: $^{12}C(n, n_2)3\alpha$

Thin Al entrance flange (3-mm-thick) for 7.2-10 MeV neutrons
Edwards Accelerator Lab, Ohio University



Measure $^{12}C(n, n_2)3\alpha$ with 50 Torr CO_2 from 5000 pps of neutrons
Answered important question of role of neutron-upscattering in the triple-alpha process: JB++ Nat. Comm. 13, 2151 (2022)
Plenty of further opportunities for TPCs+neutrons

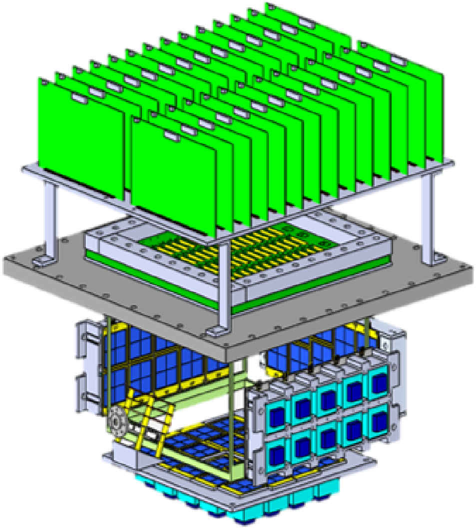
TeBAT

Next generation - TeBAT

Major changes:

- "External" Micromegas PCB
- Resistive Micromegas
- 1K → 7K channels
- Addition of STAGE chips for Si/CsI
- Additional ^{3}He gas system

Flange Micromegas



8K connections - better debug needed
Micromegas PCB now a flange - huge pressure differential at vacuum
Stainless steel stiffener attached to PCB stops bending

1.2 tons of lead = 1 atm
300μm deflection total

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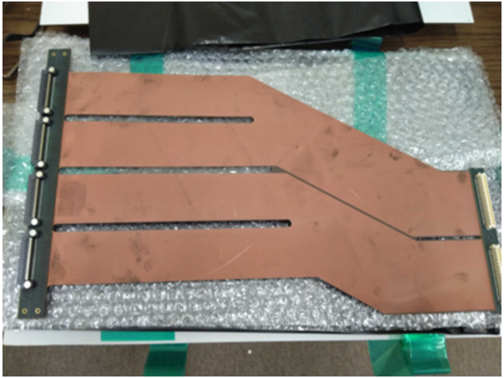
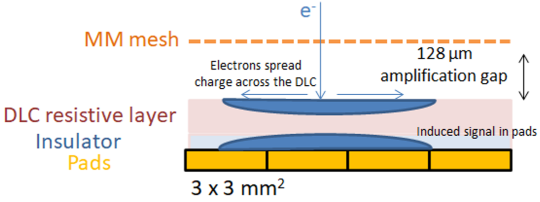
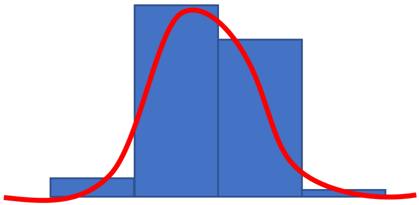
Flex cables



- “Flex” cables then connect PCB connectors to ASAD boards
- High-density cables → capacitance and crosstalk carefully calculated
- Plugged into "dummy" MM board - no noticeable waveform degradation

Resistive Micromegas

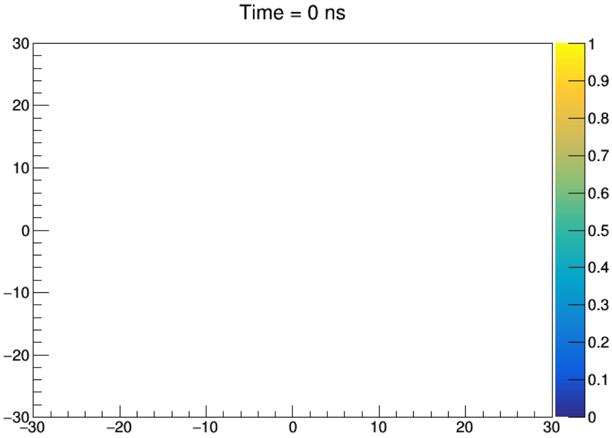




DLC layer deliberately spreads the charge across multiple pads - continuous RC network
→ need to choose the ‘best’ RC time: want to spread across enough pads to get good position resolution but not too many pads to dilute the signal and increase multiplicity

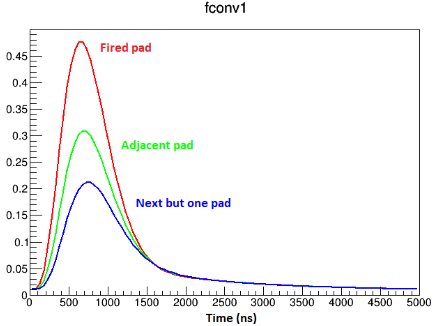
RC simulation work

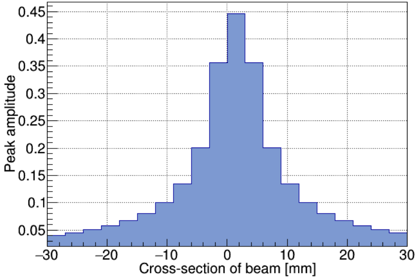
Unshaped charge propagation - then shaped by GET



RC simulation work

Found that 0.1-2 MΩ/□ shows good signal spread
>2 MΩ/□ RC time too large - charge hangs around but gives best spark-resistance
1.4 MΩ/□ selected (c.f. DESY TPC 0.5 MΩ/□)
Estimated position resolution of 300 μm - limited by threshold (gain) and noise





RC = 10 ns/mm^2: 500 ns peaking time

Increased channel count

New MM, 128 μm gap
84 x 84 pads: 3 x 3 mm^2

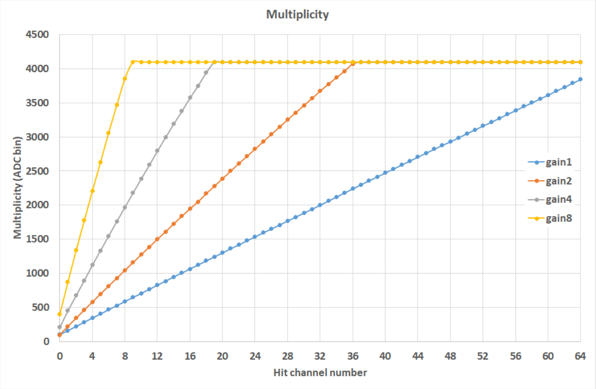
- 7056 MM channels (7 CoBos)
- 40 Si front + 10 Si back + 10 CsI (1 CoBo - all STAGE)
- 1 spare CoBo

New electronics challenges:

- Data throughput - bypass Narval Merger?
- Writing to disk - parallel computers/drives?
- Micromegas region triggering - tedious xcfg files

STAGE

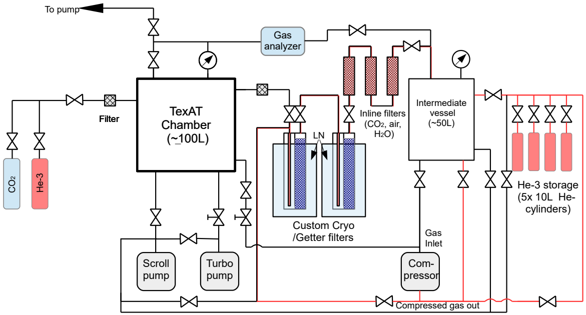
Overcome m=1 triggering problems with AGET



Preliminary tests show this works well: 100% triggers regained with 1 chnl firing

8 μs shaping time also works well!

^{3}He gas handling system



$\approx$ 100 L of ^{3}He - separated from CO_2 and recycled
Allows a multitude of new experiments: (^{3}He,n), (^{3}He,d)...

The team