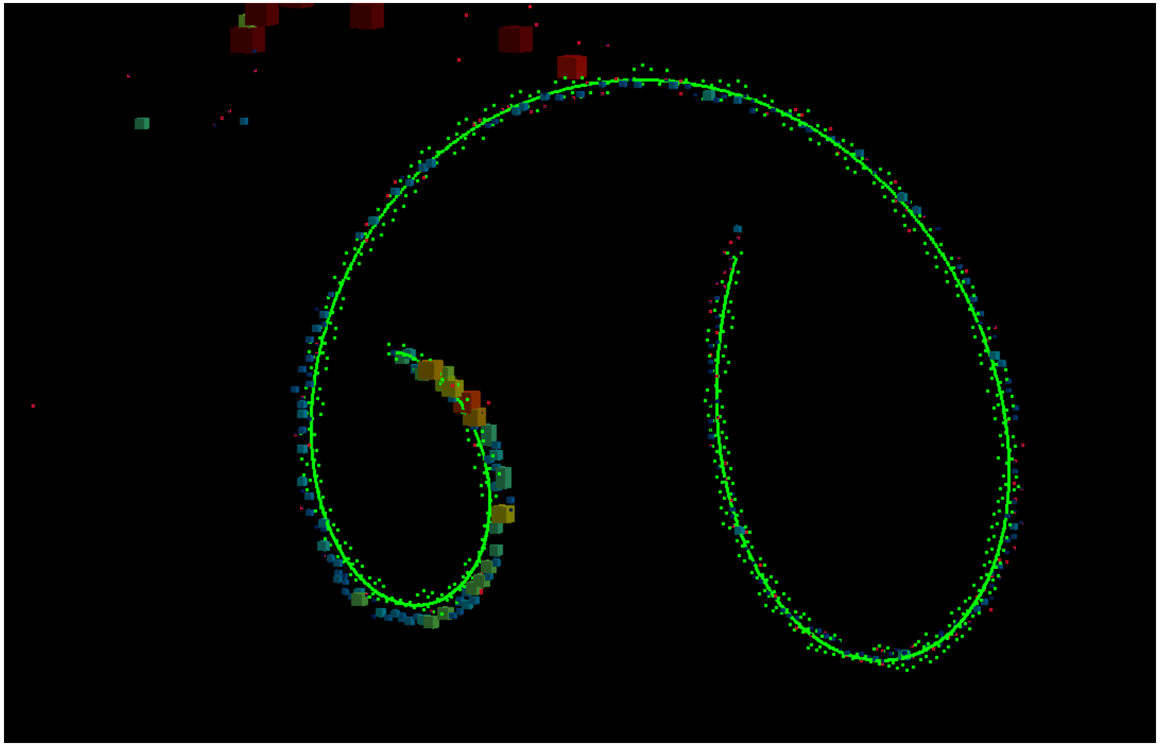


Active Targets: next steps

Wolfgang Mittig
Michigan State University-NSCL

MICHIGAN STATE UNIVERSITY

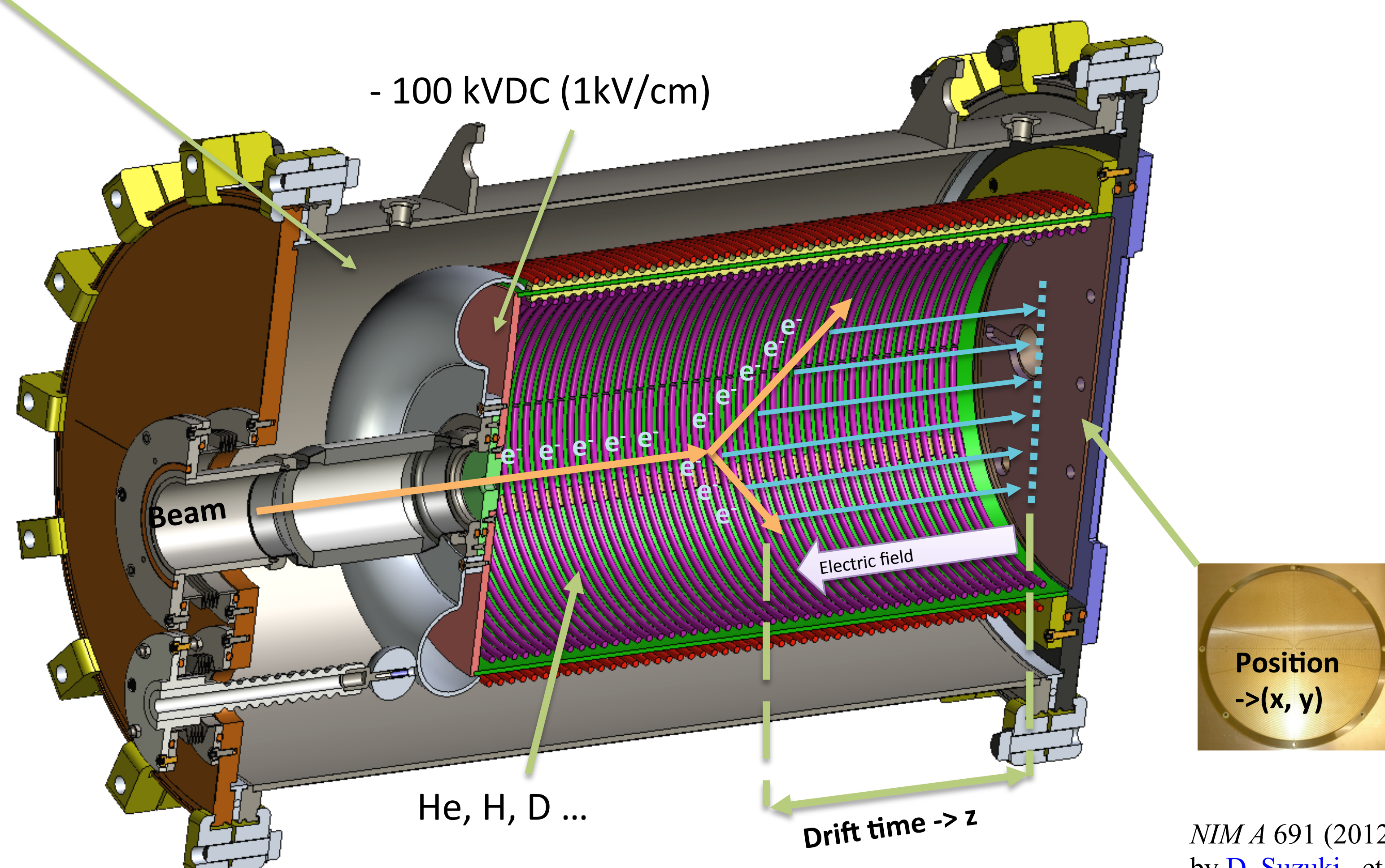
U.S. DEPARTMENT OF ENERGY | Office of Science

FRIB

Principle of detection- AT-TPC

Insulator gas volume

- ❑ N_2 gas 30 kV/cm x 6 cm = 180 kV



NIM A 691 (2012)39
by D. Suzuki, et al.

New Targets: Active Targets, Pure Targets

Used until now (perhaps not complete):
(H_2, D_2, ^4He, C_4H_{10}, Ar,…)

Missing in this list: specific targets for 2 particle transfer

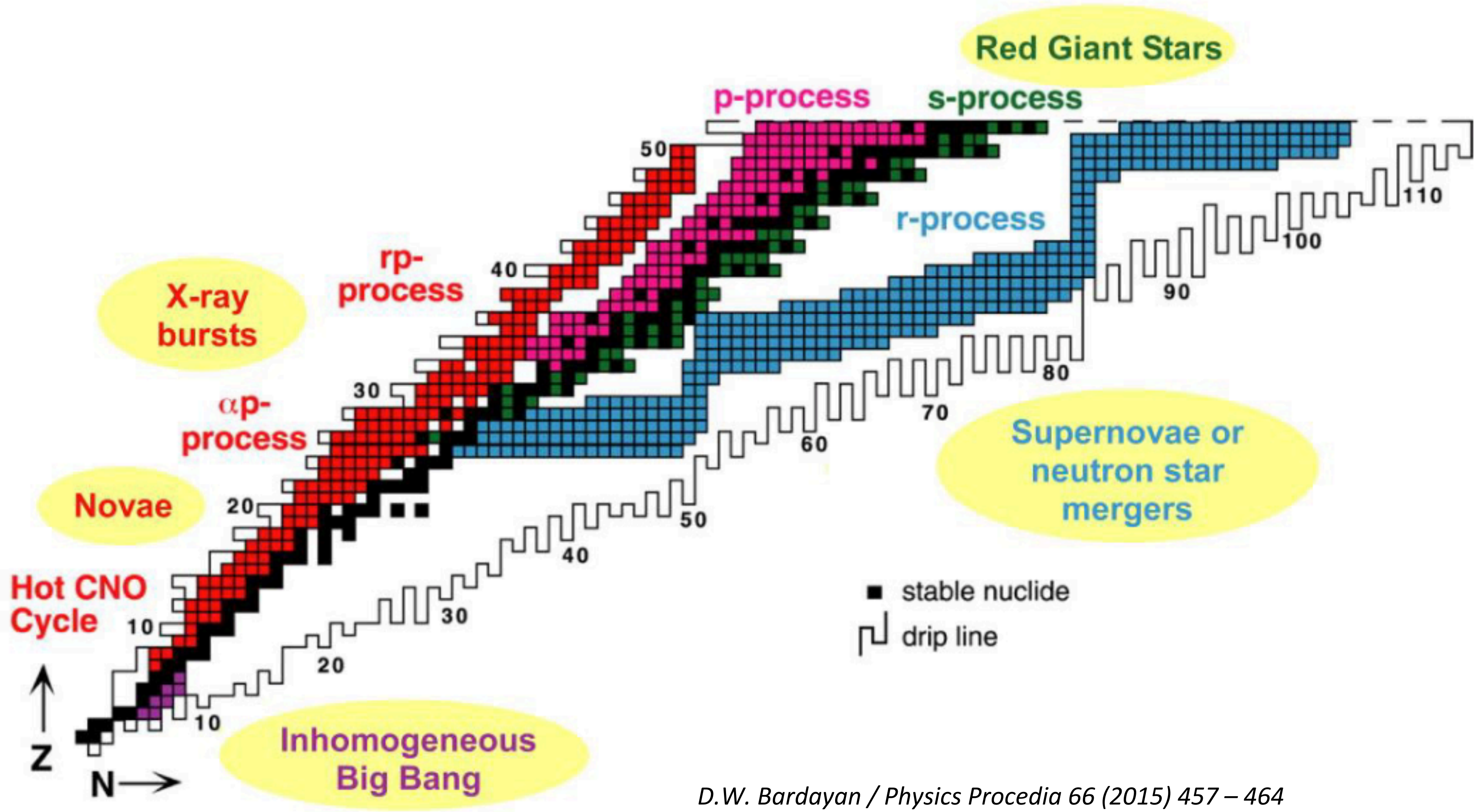
Pairing

"In nuclei near stability with sufficient valence nucleons to form *a condensate, the effects of pairing between like nucleons, neutrons or protons are observable*, but it is only recently that the opportunity has arisen to study the exotic, proton-rich species with masses in the range of 60–100 where *deuteronlike, neutron-proton pairing may be manifest*. This is predicted to occur on the specific locus defined by equal numbers of neutrons and protons ($N = Z$), where the valence nucleons move in orbits with identical quantum numbers. " P. Van Isacker et al., PRL **94,** 162502 (2005)

→ (^{3}He,p) reactions

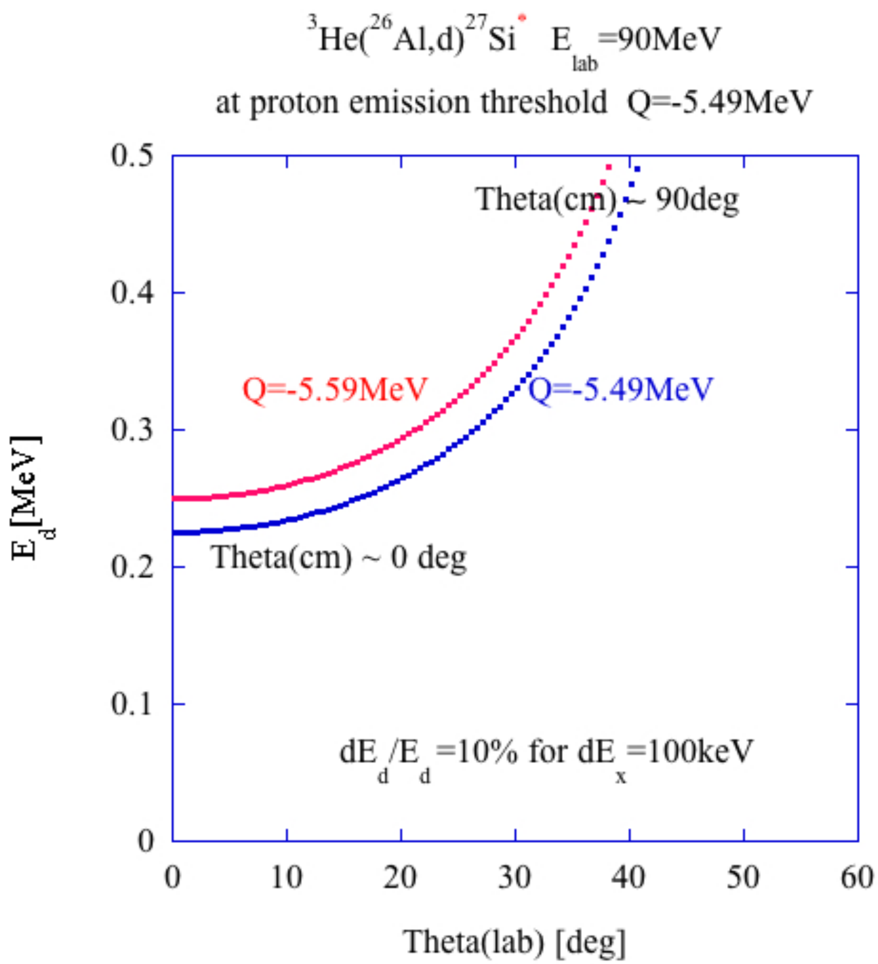
For the AT-TPC accepted proposal "Studying np pairing in N=Z nuclei: The ^{52}Fe(^{3}He,p) reaction at ReA3 with the AT-TPC" (Yassid Ayyad, Augusto O. Macchiavelli)

Astrophysics: Proton capture

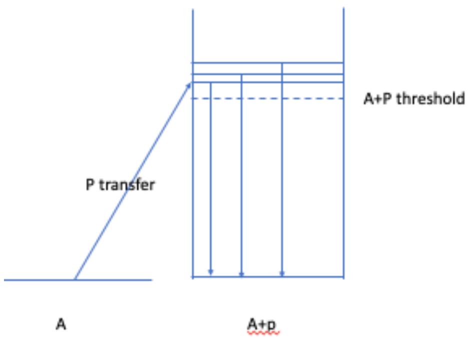


D.W. Bardayan / Physics Procedia 66 (2015) 457 – 464
[Smith+Rehm 2001]

Astrophysics: Proton capture
A kinematical magnifying glass in (^{3}He,d)

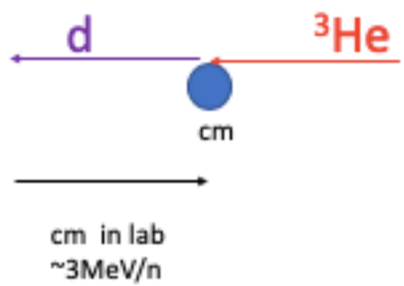


Fernando Montes et al.



Q-value independent of A

Q=-S_p(^{3}He)+ Gamow Window=-5.5MeV+…

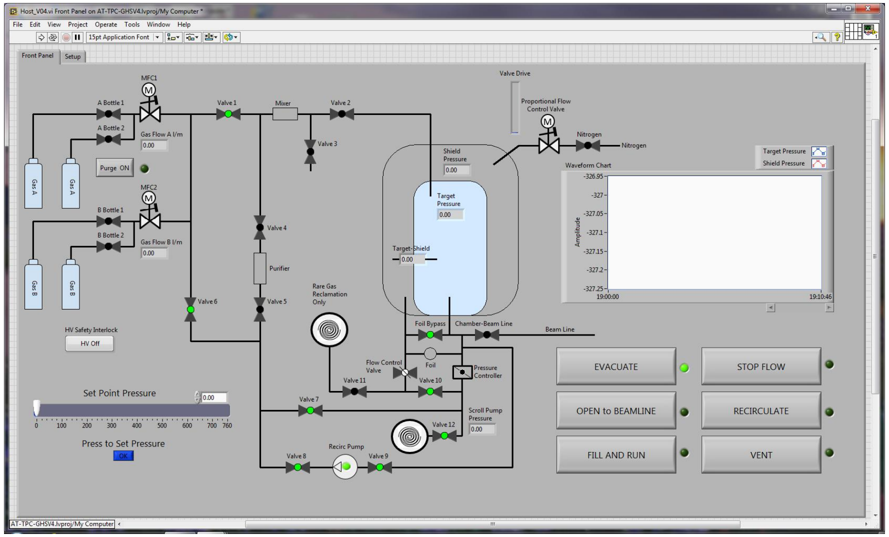


See too A. Kankainen et al Eur. Phys. J. A (2016) **52**: 6 with gammas

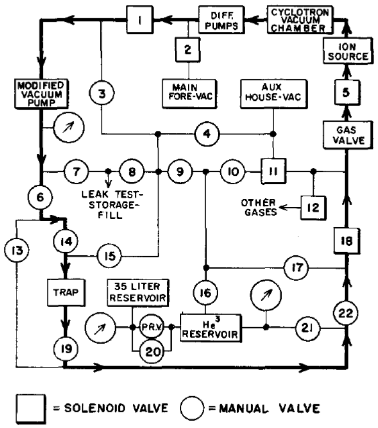
^3He: practical problems

- Cost ~1k$/(atm liter)
- Export control: we bought in a co-owner ship with LBL, Notre Dame, MSU 50liters→ ~ 80 mails

If used as detector gas, recycling and recovery



John Jurkon NSCL



Wegner and Hall, 1958
https://doi.org/10.1063/1.1716086

^{3}He: tube

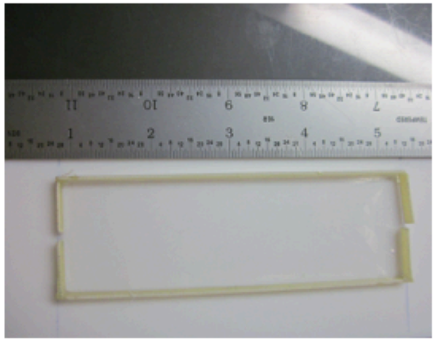


Figure 1: Initial gluing placement

Figure 2: Placement of the tube after cut of the rest of the Mylar.

Figure 5: Test-tube with 8 Torr overpressure

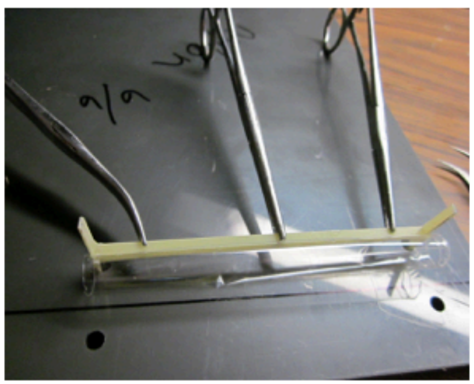
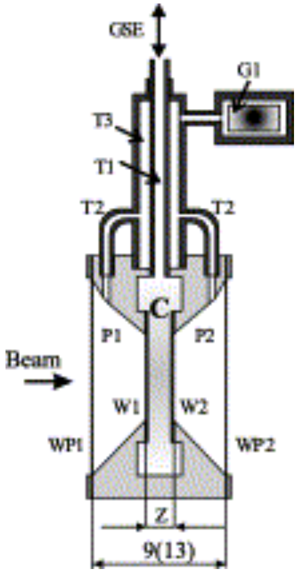


Figure 3: Tube clamped to glue the two backbones together.

Figure 4: Clamp used to support the gluing of the endcaps.

Tritium

If not discouraged by the difficulties with ^{3}He: Tritium is the ideal target for neutron pairing Transfer reactions



1 kCi activity is stored and transported in chemically combined state on 238U

Three safety barriers!

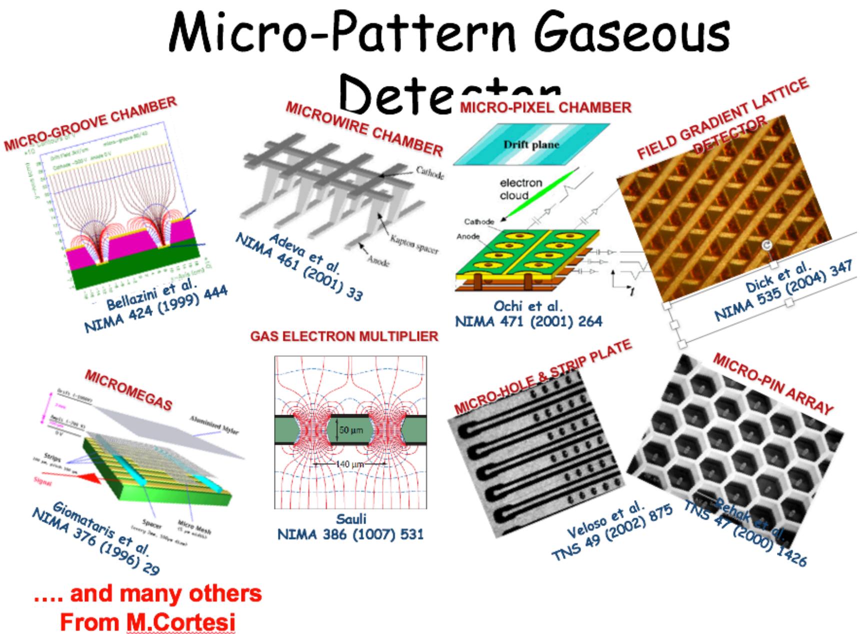
A.A.Yukhimchuk et al, 2003
https://doi.org/10.1016/j.nima.2003.06.002

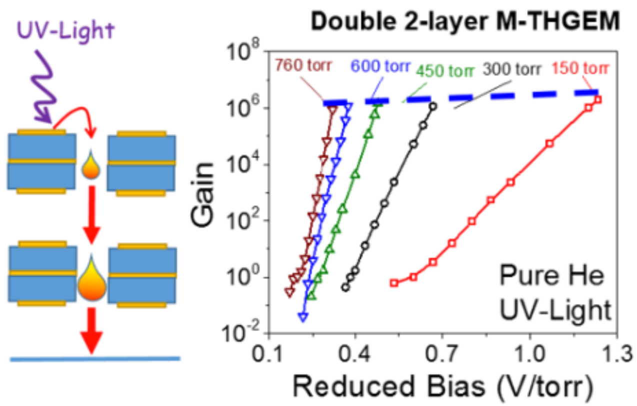
See too: Y.Ayyad et al 2018 https://doi.org/10.1016/j.nima.2018.10.019 and INTDS 2018

P. Gueye: FRIB Tritium Target Nano Workshop in spring 2019 (date to be fixed)

Pure gas!

In the active target you need a MPGA! High gain! Mostly this implies a quencher:
Example: He+CO_2 (5-10%)
Solution to avoid quencher: Combine Micromegas with Thick GEM





Y.Ayyad et al.,
Eur. Phys. J. A (2018) 54: 181

Low and High Pressure!

A large domain of pressures of the target-detector gas is needed:

- some Torr for hundreds of keV p,alpha

- A high energy loss gas (C_4H_{10},…) at high pressure ~1atm to stop for example protons from (d,p) reactions

Resolution

- Energy
- Angle
- Reaction Vertex
- (particle identification)

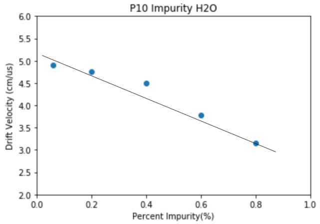


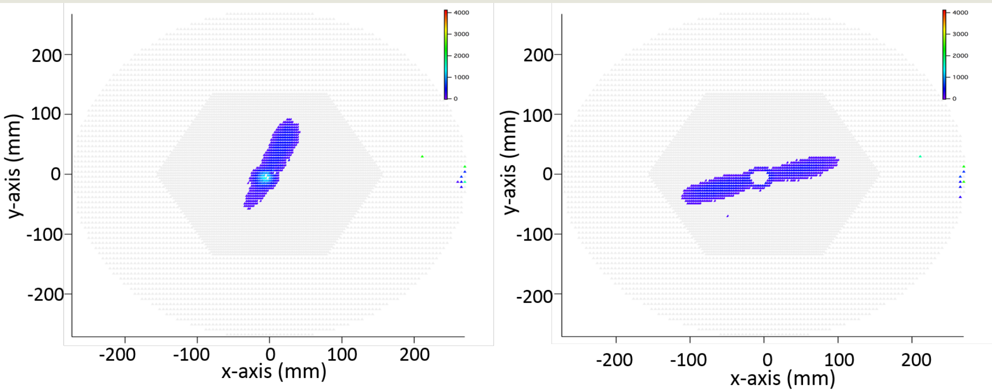
Figure 13: Drift Velocity VS Percent impurity (Water Vapor). This was extrapolated to a factor of two change of about 0.9 percent. The error was again estimated upon adding impurities to about 0.1 torr.

I.Mackendrick, Internship 2018

Comments: I do not understand the present limitation of energy resolution = charge resolution dE/E ~ 1/SQRT(N); for ^{56}Fe 5keV N~200 dE/E~15% for alpha 5.5 MeV N~ 200,000→ 0.5%?
Spacial resolution: ~100µ?

Limiting factors: gas quality, recombination, correlated effects like local gain variations?,
Impurities in the gas: drift velocity, recombination, gain,.. RGA, Laser to control drift velocity,…

Space Charge effects



Experiment

Already at very low intensity: 1000-2000/s of ^{46}K

But pulsed beam structure due to Ebit (~5% duty cycle)

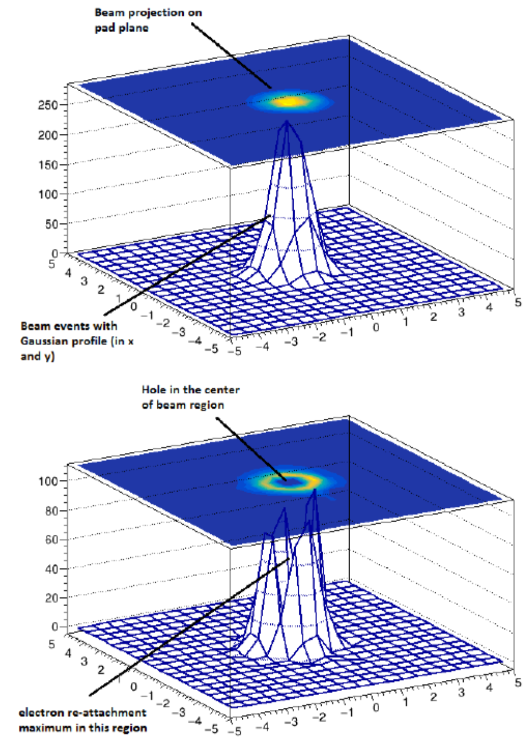
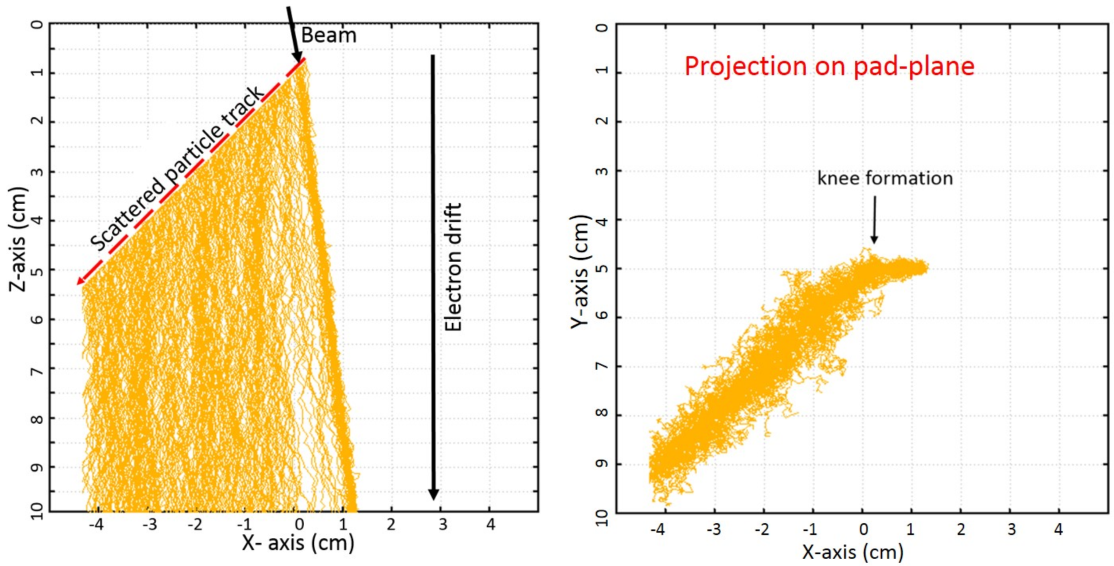


Figure 7: Simulated projection of beam on pad-plane (Gaussian distribution in x and y axis) with (above) and without (below) electron recombination.

J.Randhawa et al.

Simulation

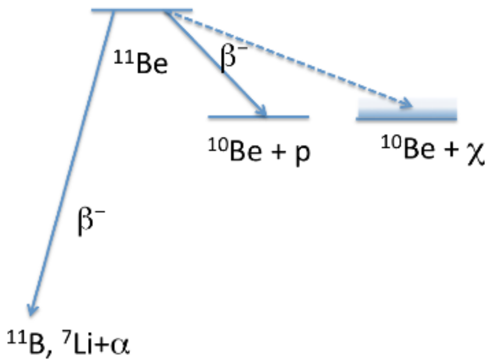
Space Charge effects



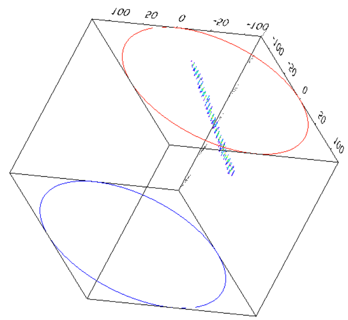
J.Randhawa et al.

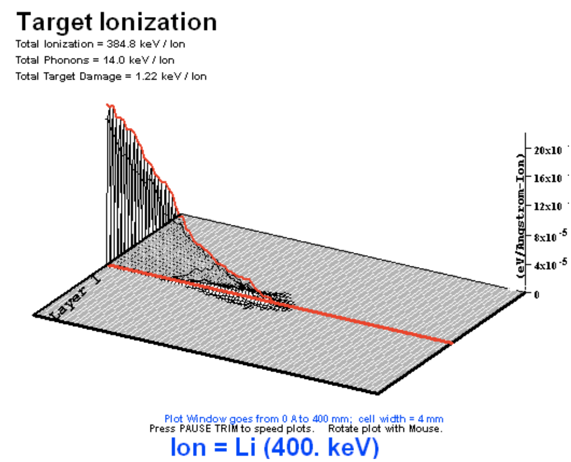
Simulation

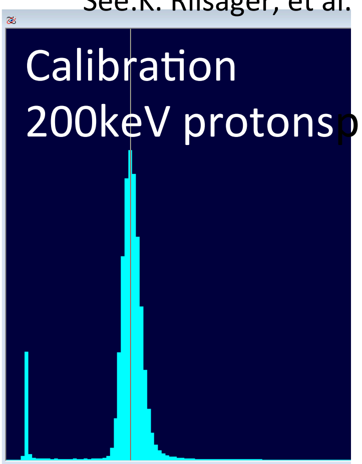
Space Charge effects in ^{11}Be decay

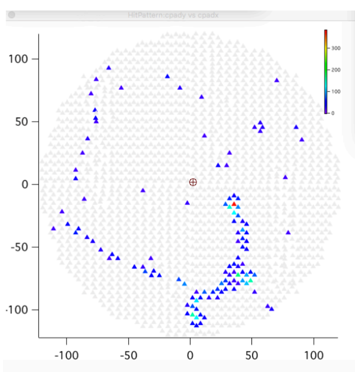


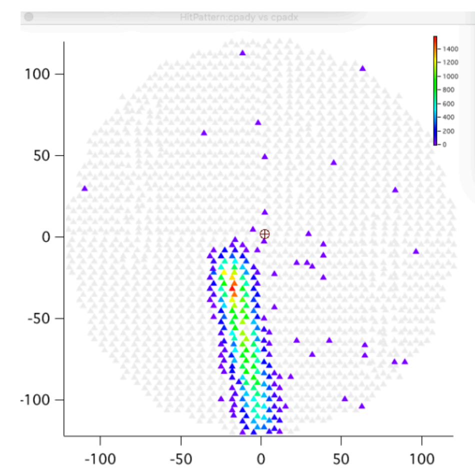
Possible decay modes of ^{11}Be, including the exotic proton-emission decay mode (^{10}Be+p) and the postulated ^{10}Be+χ dark-matter decay mode.
See:K. Riisager, et al. Physics Letters B, 732:305, 308, 2014)





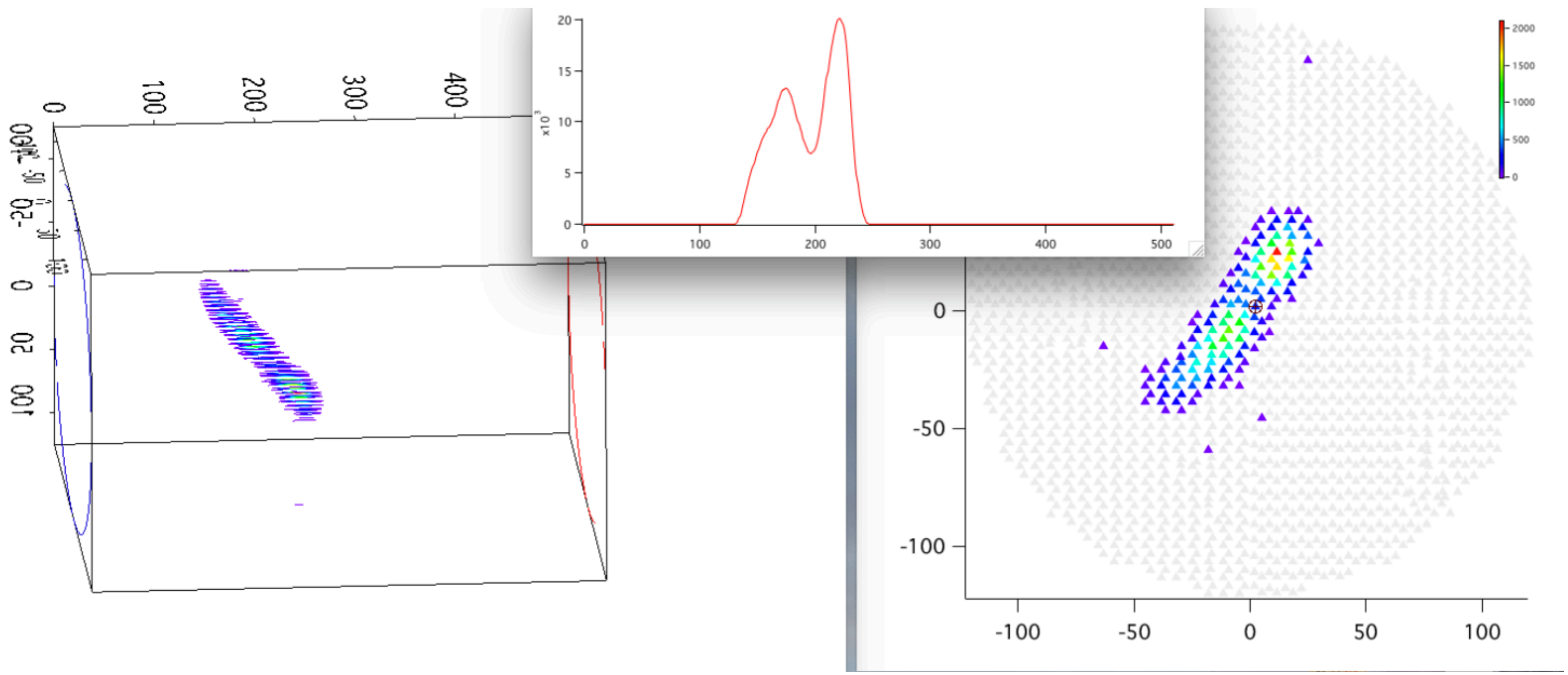






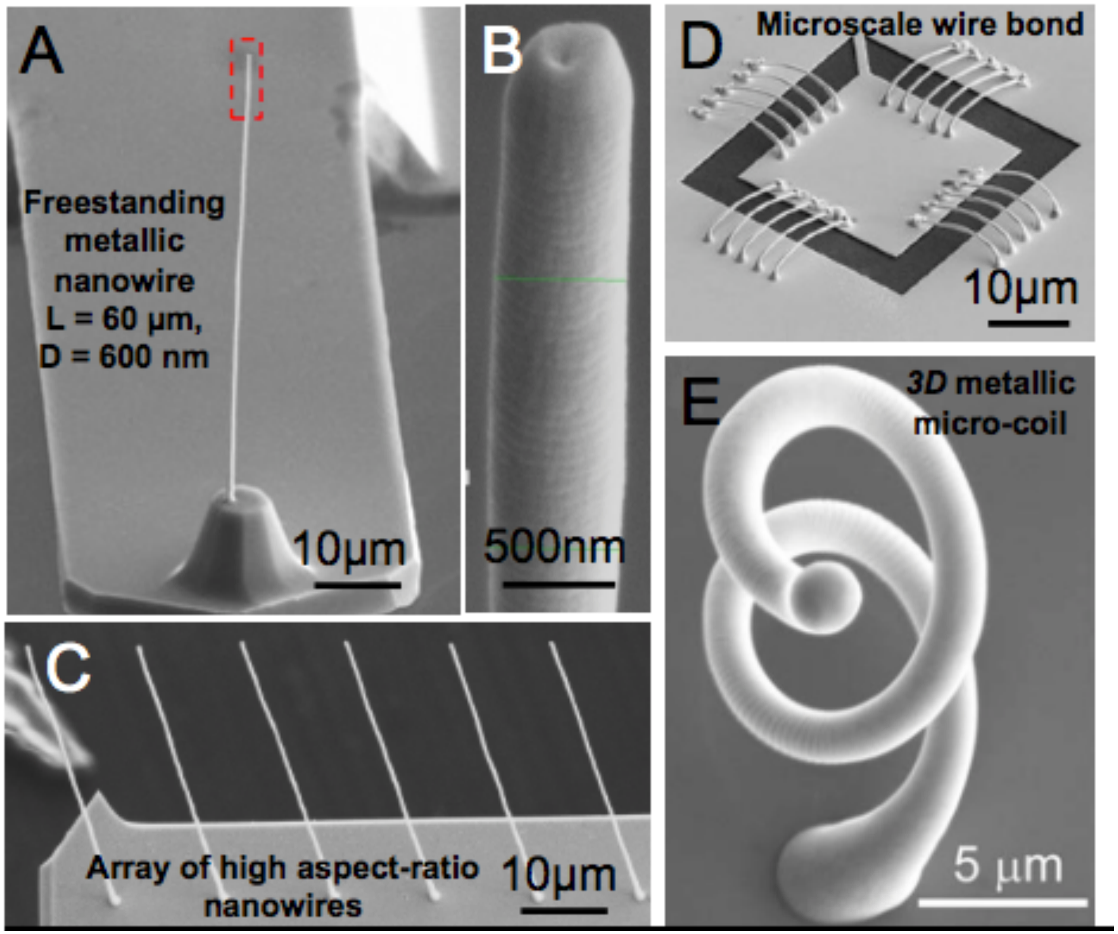
Y.Ayyad, B.Olaizola et al.

Space Charge effects in ^{11}Be decay



Implantation rate ~ 1-2*10^5 ^{11}Be/s DAQ 1s after end of implantation

3D nano-metal printing: New MPGA structures?



UHV Technologies, Inc

SBIR contract with NSCL

Conclusion

- We have new powerful detectors for the imaging of nuclear reactions, with a large solid angle and high resolution
- These provide 4π- 3D images of reactions with charged particles and are a tool specially for the reactions induced by secondary exotic beams
- Still the resolutions are below theoretical limits: why?
- To achieve best resolution, combination of analysis and detector properties

- New possibilities may arise from micro-nano 3D printing