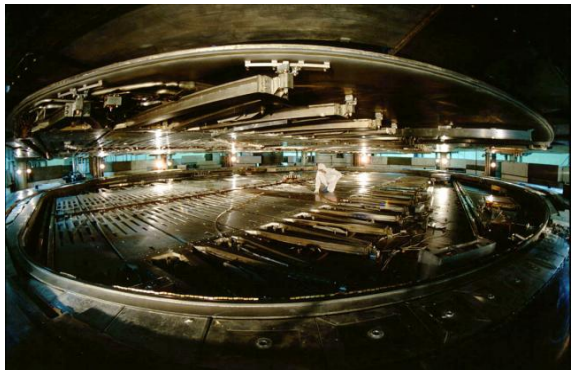
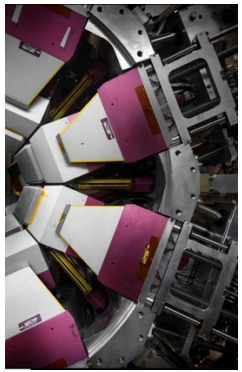
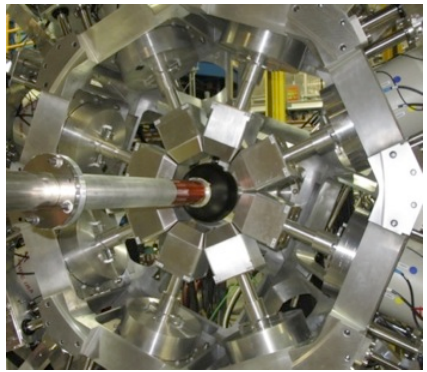
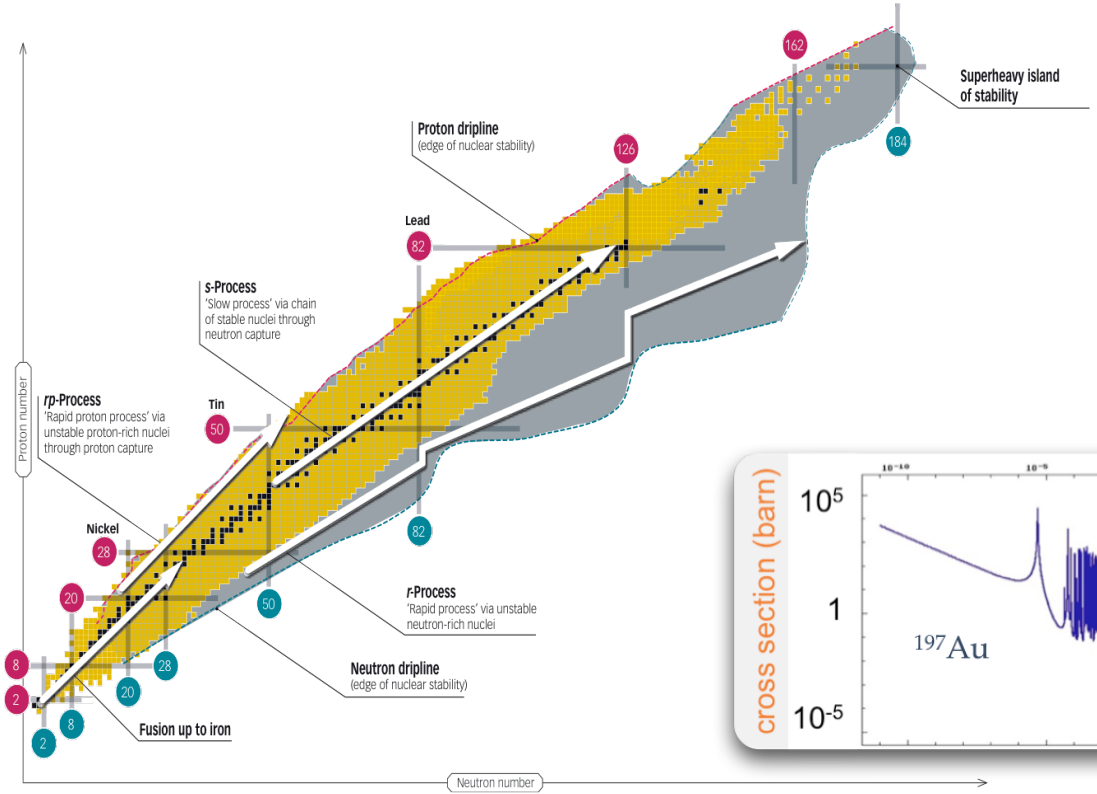
A Silicon Tracker for ISAC-II at TRIUMF

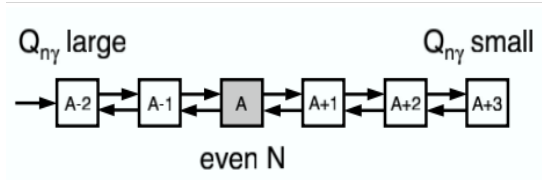
Dennis Mücher
University of Guelph
TRIUMF



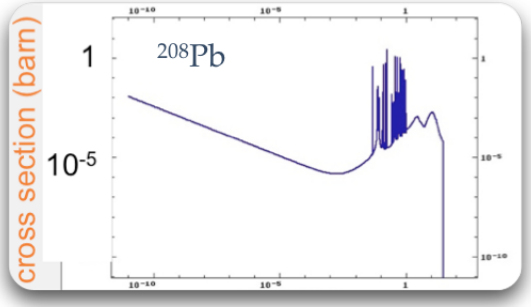



Nucleosynthesis and shell evolution



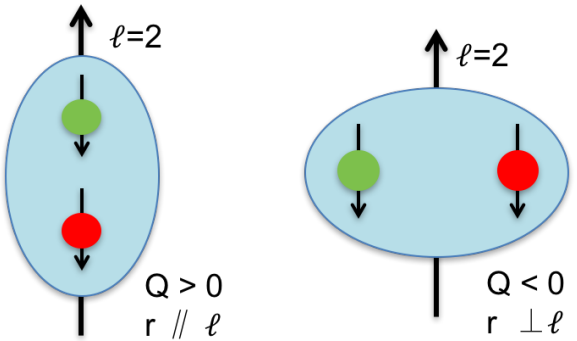


$$\frac{N(Z,A+1)}{N(Z,A)} \propto N_n \left(\frac{1}{kT}\right)^{3/2} e^{Q_{n\gamma}/kT}$$



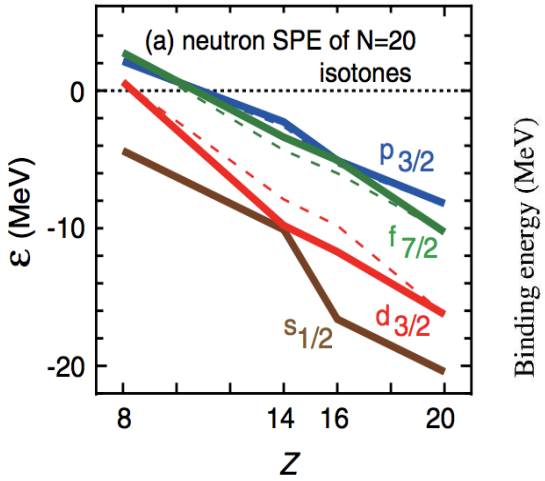
The origin of shell evolution

what dominates shell evolution in nuclei?



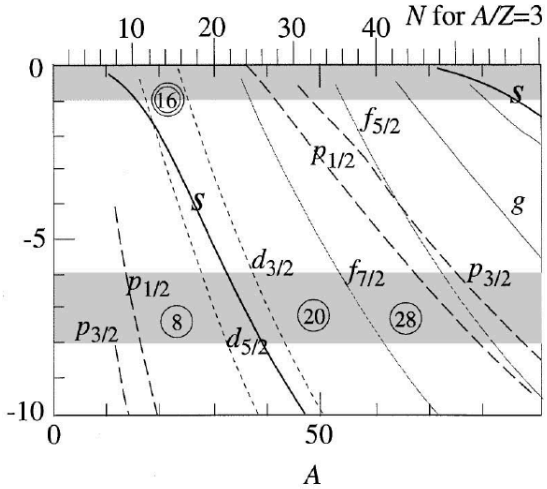
type-I/II shell evolution:
central + tensor force
or ...

T. Otsuka et al., PRL 104, 012501 (2010)



... properties of weakly bound neutron orbits in spherical potential?
or ...

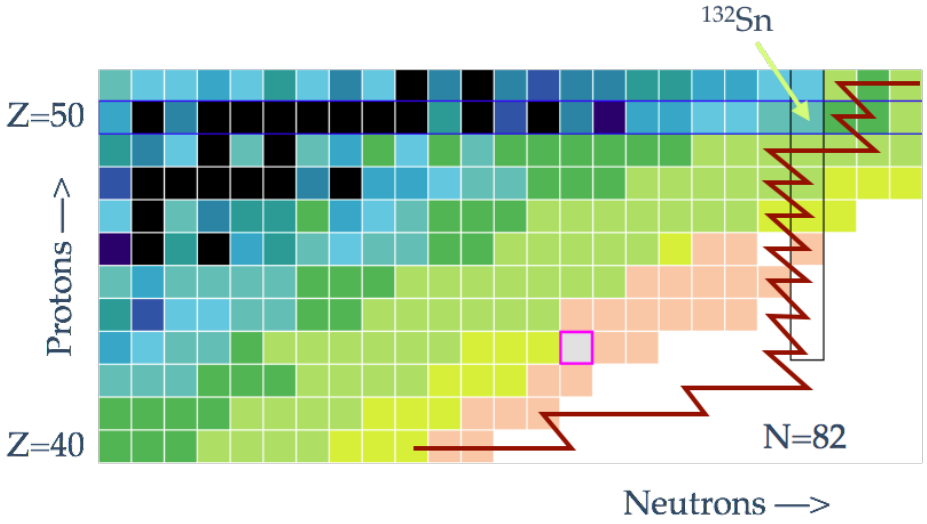
A. Ozawa et al., PRL 84, 5493 (2000)



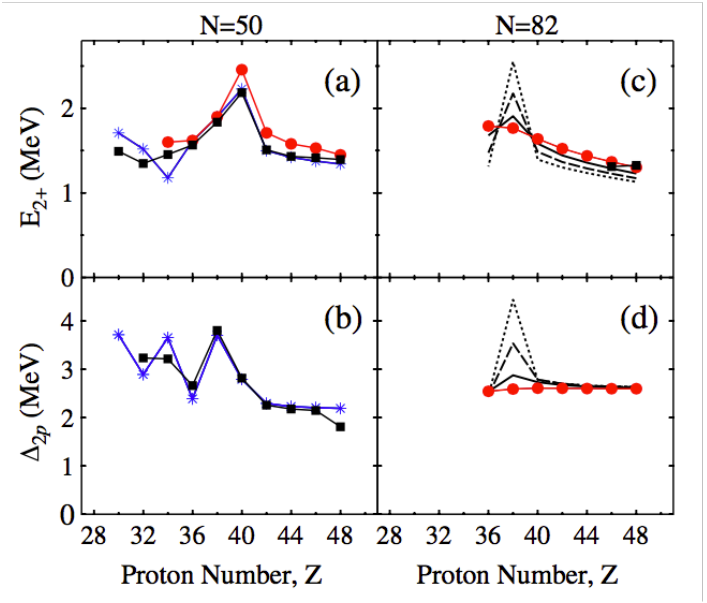
Z=40: following the r-process using GRIFFIN and DESCANT

proposed Z=40 quenching at N=82 from data: impact on r-process!

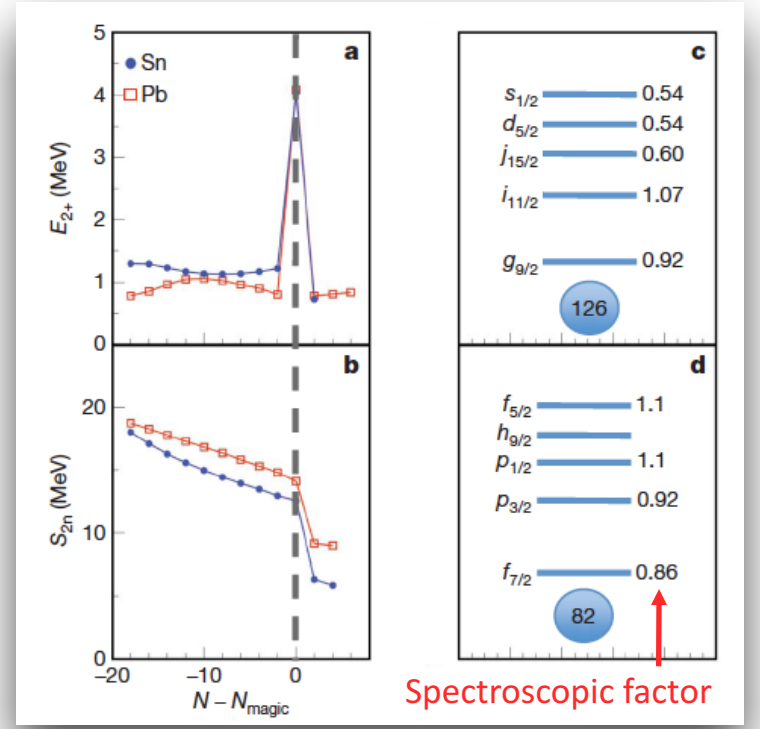
J. Taprogge et al., PRL **112**, 132501 (2014)



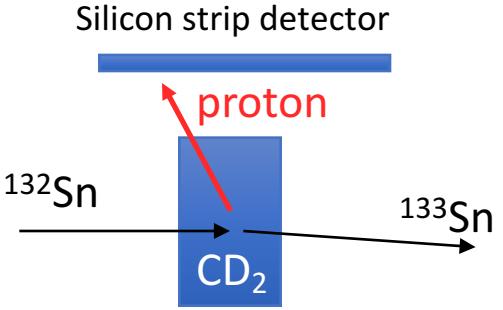
CANREB / ARIEL beams will offer unique opportunities to study nuclear structure along the r-process

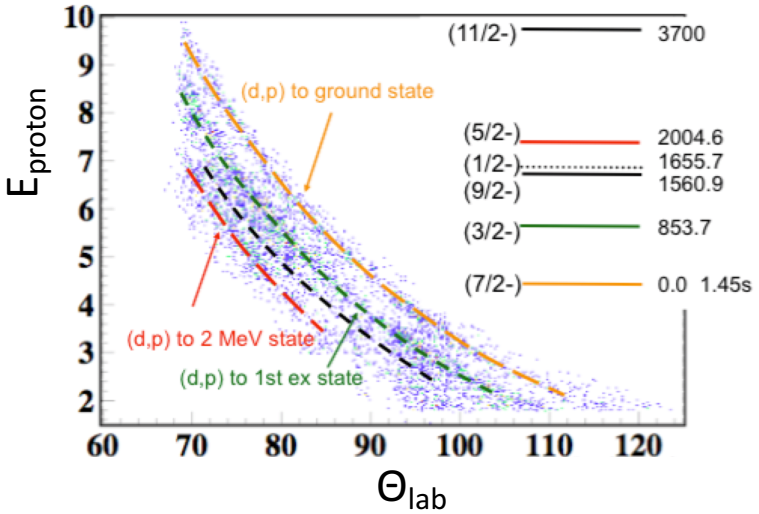


One-neutron transfer in inverse kinematics



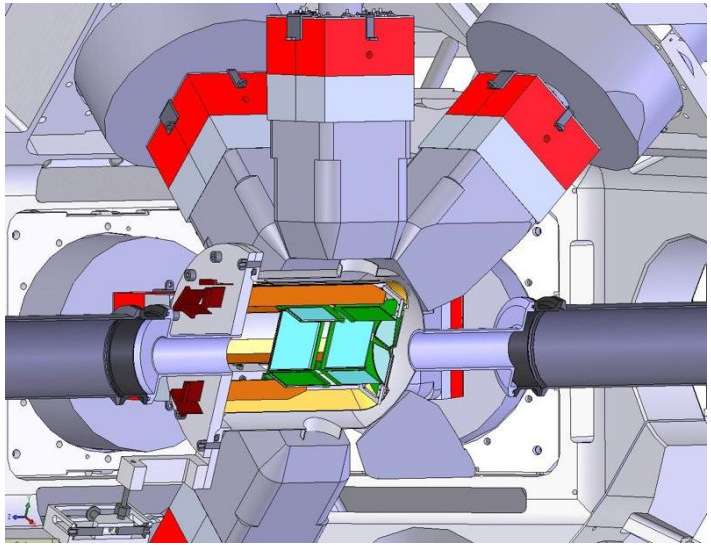
160 ug/cm^2 CD_2
400 keV FWHM





Jones et al., Nature Vol 465 (2010)

One-neutron transfer in inverse kinematics



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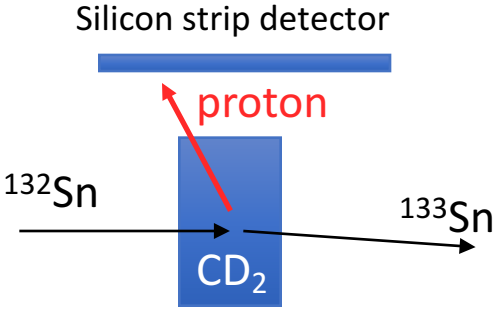
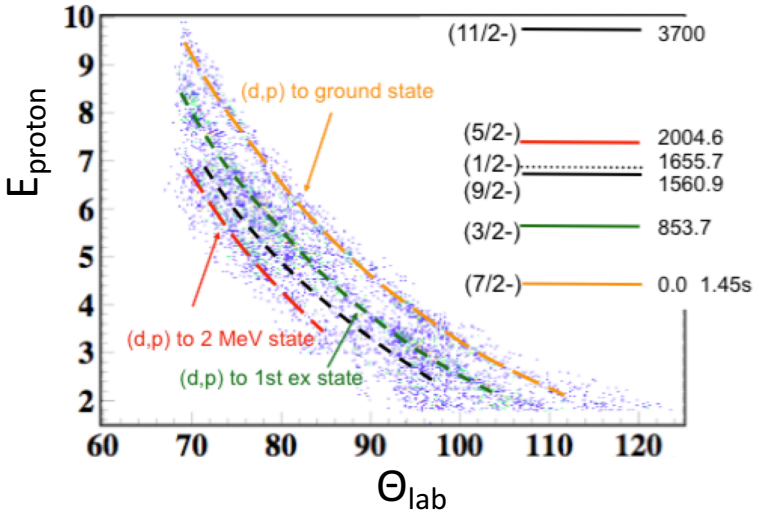
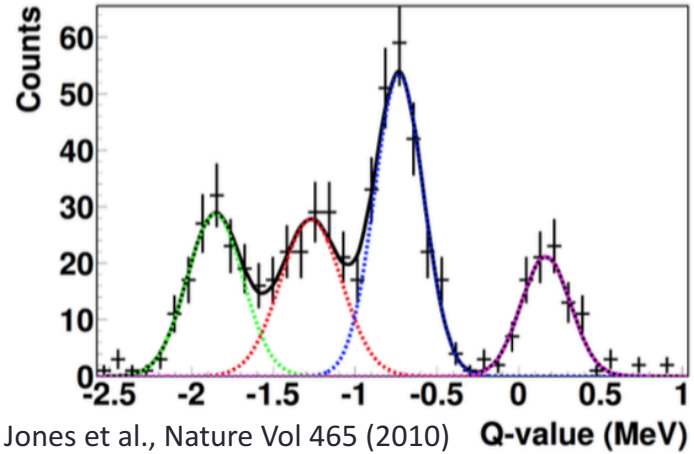




- SHARC: 4π silicon strip detector; fully digital readout
- TIGRESS: high granularity, high efficiency HPGe detector array

One-neutron transfer in inverse kinematics

^{132}Sn(d,p), 0.04 mg/cm^2 D_2



Jones et al., Nature Vol 465 (2010)

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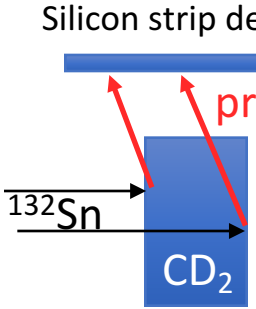
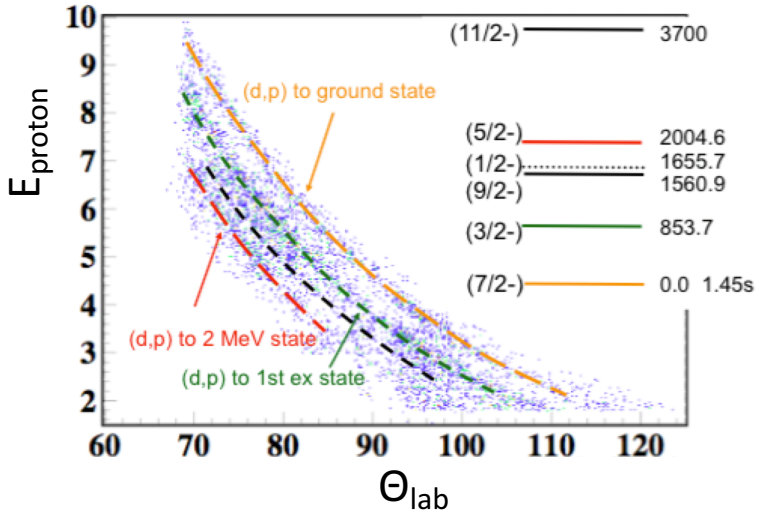
400 keV FWHM



20% E_{beam} loss
-> $\Delta\varepsilon_p \approx 2$ MeV



goal:
remove the compromise between luminosity and Q-value resolution

One-neutron transfer in inverse kinematics

Physics Letters B 740 (2015) 298–302

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Physics Letters B

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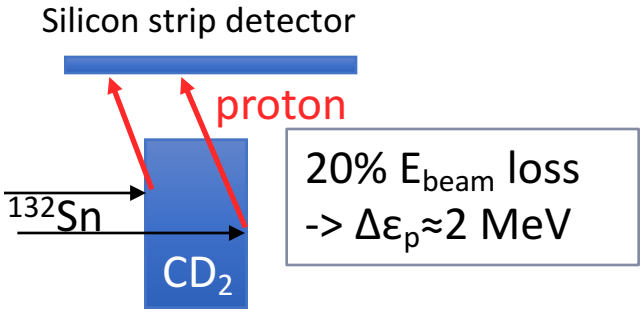
Single-neutron orbits near ^{78}Ni: Spectroscopy of the $N = 49$ isotope ^{79}Zn

R. Orlandi [a,b,c,d,e,*], D. Mücher [f], R. Raabe [b], A. Jungclaus [a], S.D. Pain [g], V. Bildstein [f], R. Chapman [c,d], G. de Angelis [h], J.G. Johansen [i], P. Van Duppen [b], A.N. Andreyev [c,d,j,e],

160 ug/cm^2 CD_2
400 keV FWHM



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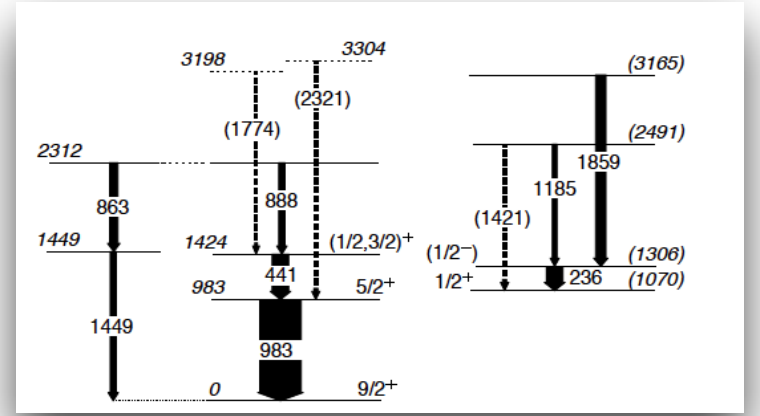
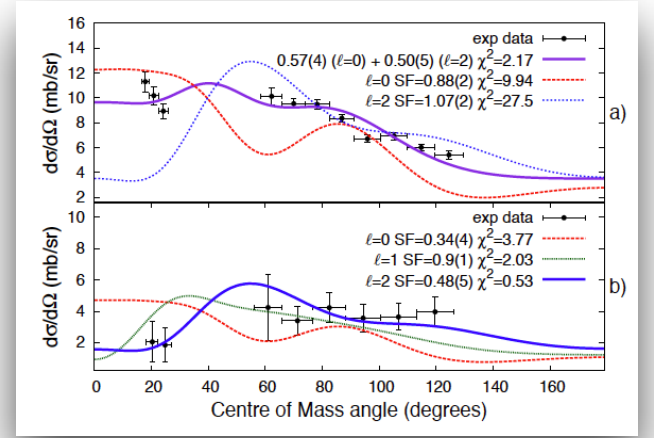
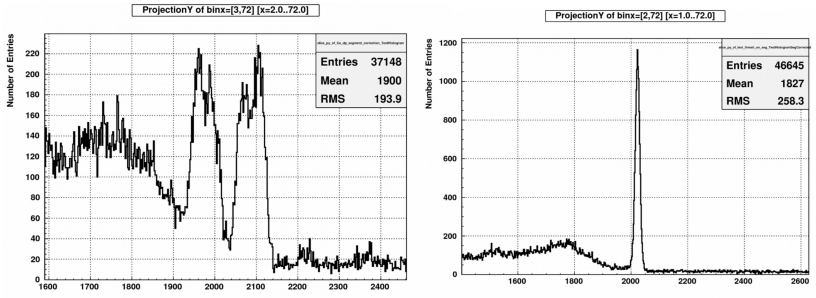




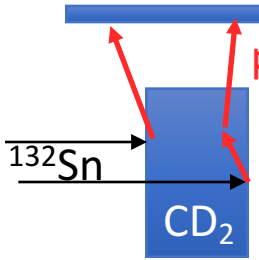
One-neutron transfer in inverse kinematics

$^{48}Ca(d,p)^{49}Ca$
Projections after Doppler Correction

160 ug/cm^2 CD_2
400 keV FWHM



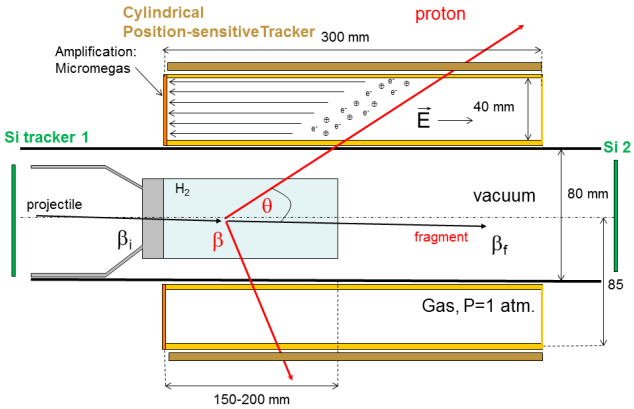
Silicon strip detector



20% E_{beam} loss
-> $\Delta\varepsilon_p \approx 2$ MeV

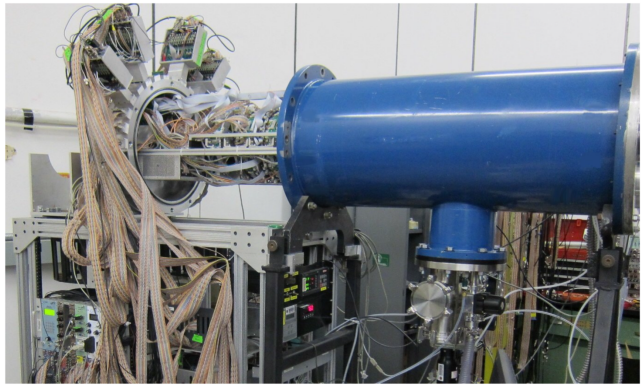
Q-value resolution:

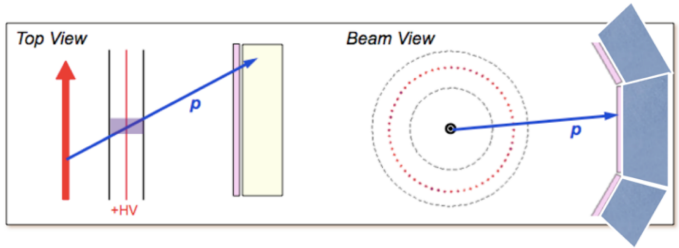
- Construct level scheme
- Measure l transfer
- Doppler correction
- Control feeding
- …



Active targets at ISOL facilities

ANASEN detector, NSCL

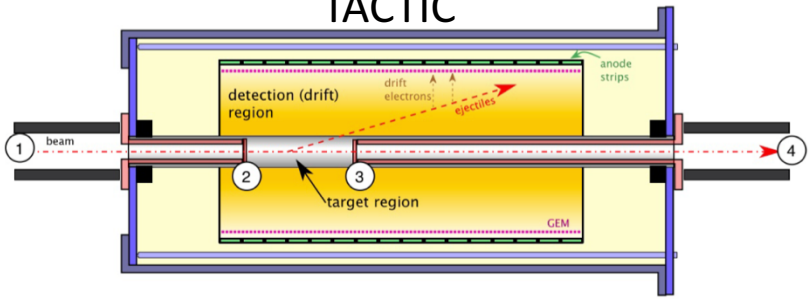




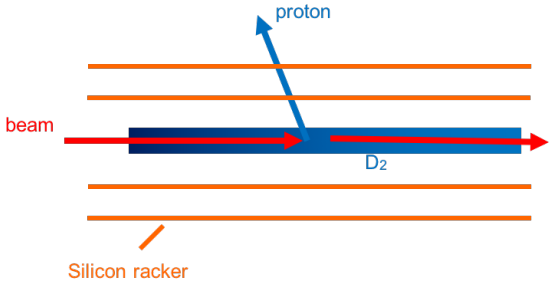
TACTIC @ TRIUMF (unfinished):

- not coupled to TIGRESS
- angular resolution not sufficient for good Q-value resolution
- about 10% CO_2 detector gas → background from fusion evaporation
- timing and energy resolution not optimal

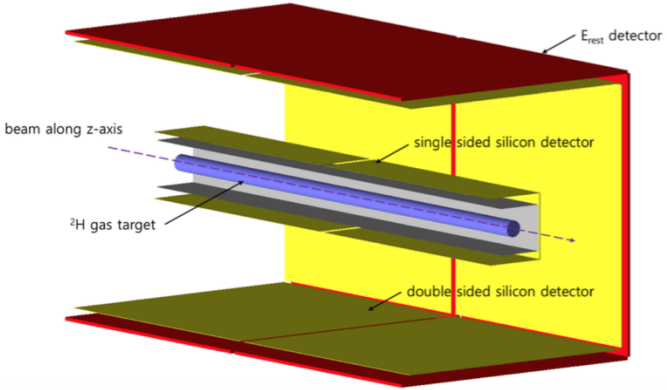
TACTIC



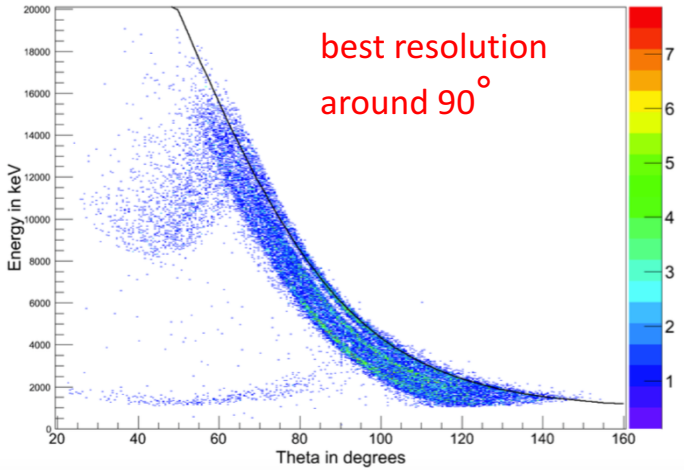
Silicon Tracker: Geant4 simulations

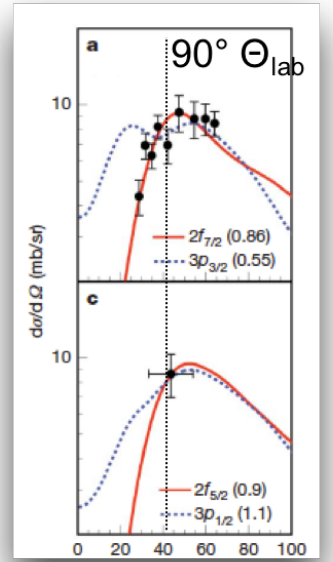


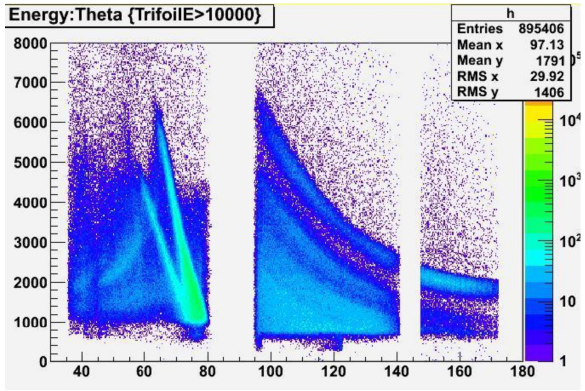
1. layer: 20 µm single-sided
2. layer: 140 µm double-sided
3. layer: 2mm pad, CsI
- gas(H, He): up to 1 bar



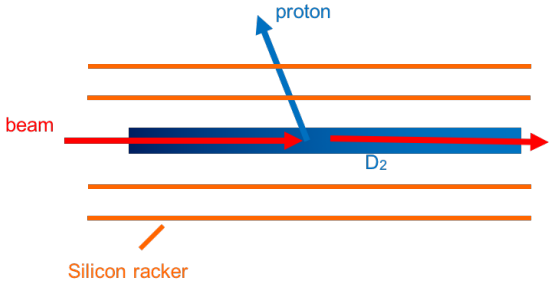
^{132}Sn(d,p), 1 mg/cm^2 D_2



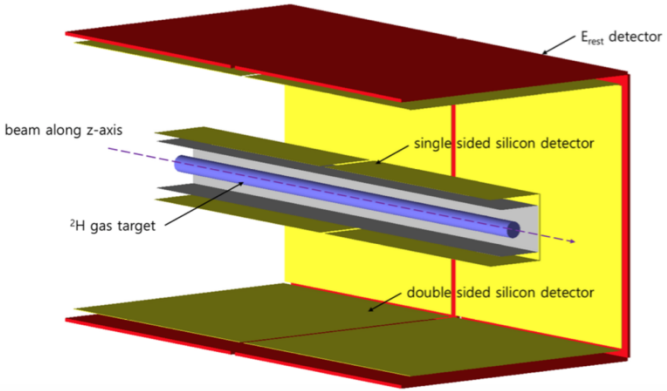


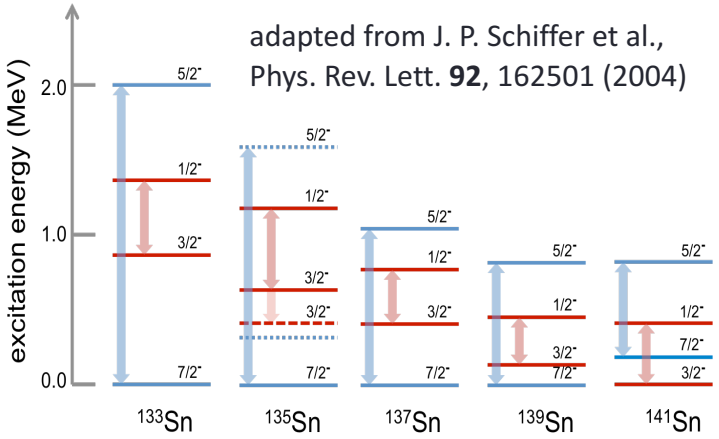


Silicon Tracker: Geant4 simulations

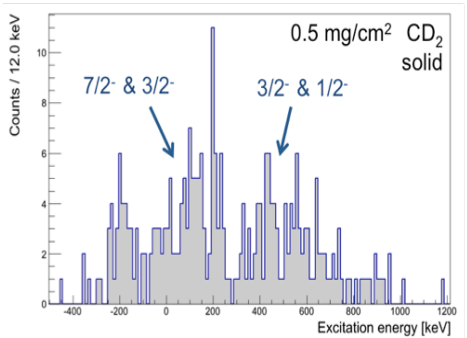


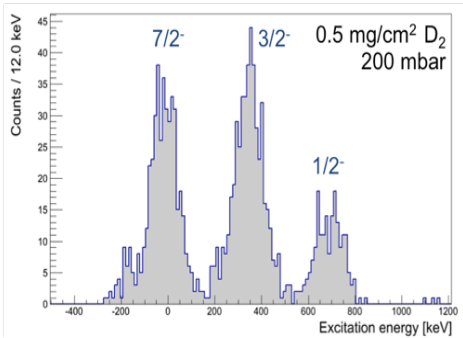
1. layer: 20 µm single-sided
2. layer: 140 µm double-sided
3. layer: 2mm pad, CsI
- gas(H, He): up to 1 bar





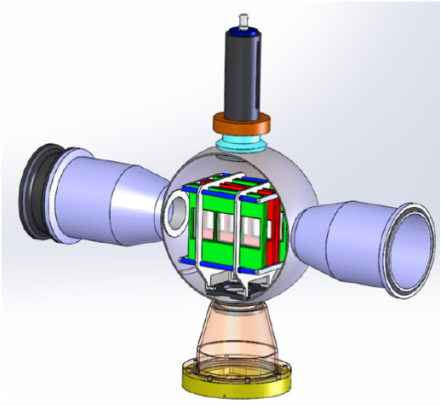
^{136}Sn(d,p) @ ARIEL (5·10^3 pps), GEANT4

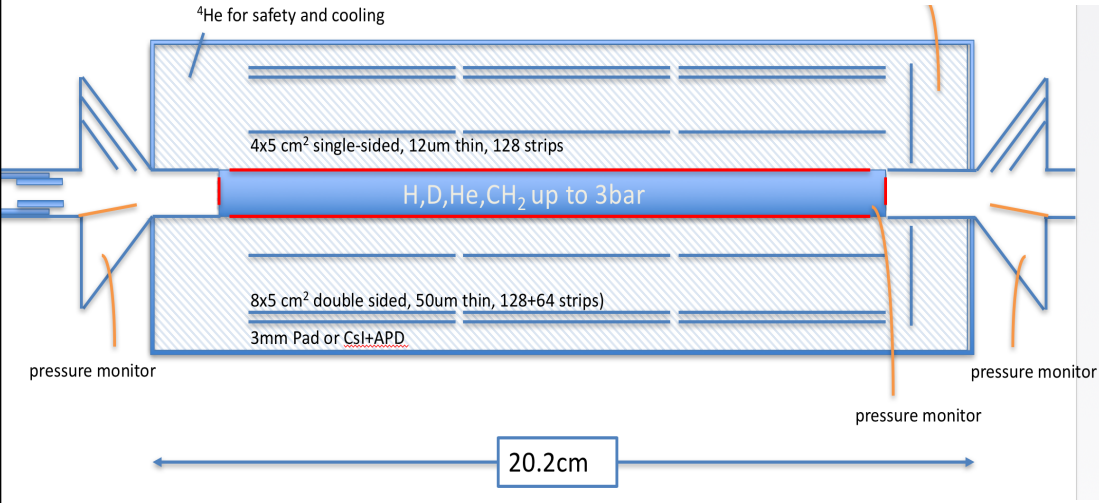


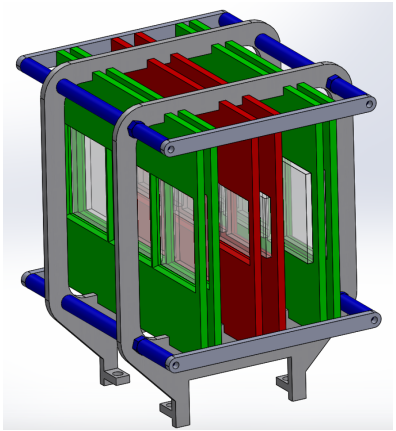


Silicon Tracker Design

- Compact design -> high segmentation:
  128 channels (first layer, single sided)
- 128 x 64 (second layer, double sided)
- Approx. 3000 channels (current design)



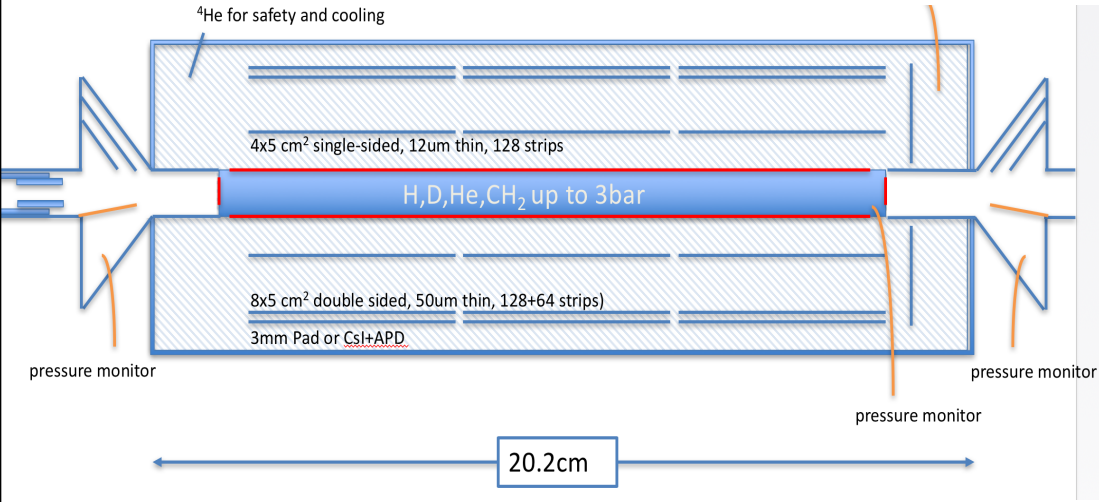


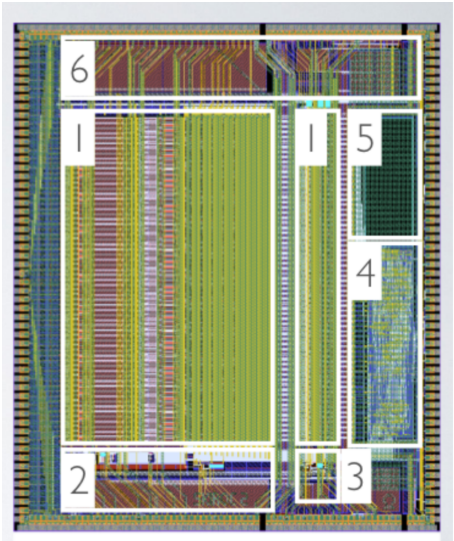


Silicon Tracker ASIC: SKIROC2

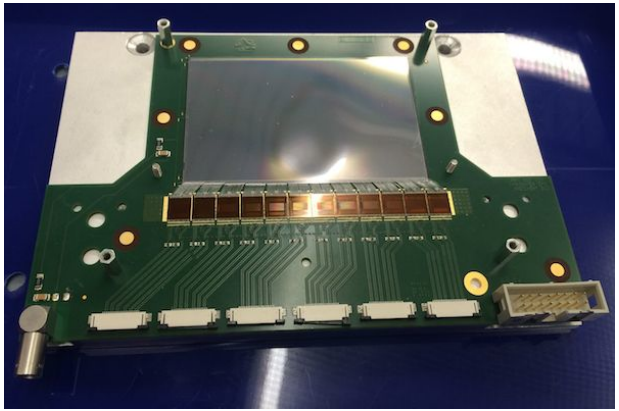
- Compact design -> high segmentation:
  128 channels (first layer, single sided)
- 128 x 64 (second layer, double sided)
- Approx. 3000 channels (current design)

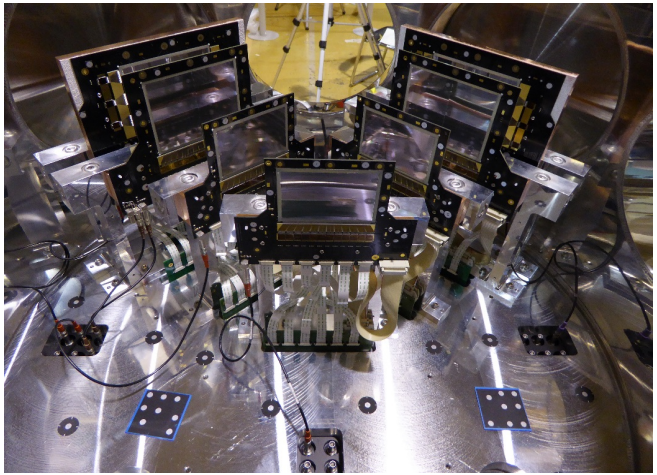
- 64 chn, designed for Si-PIN (5mm²; 20 pF)
- dyn. range: 0.1 MIP/4 fC … 2500 MIPs/10 pC
- charge PA (positive), slow & fast shaper, 15 depth SCA, TDC & ADC (12 bit), 4kbytes RAM
- PowerPulsing: ~ 25 µW/chn, ENC < 0.4 fC





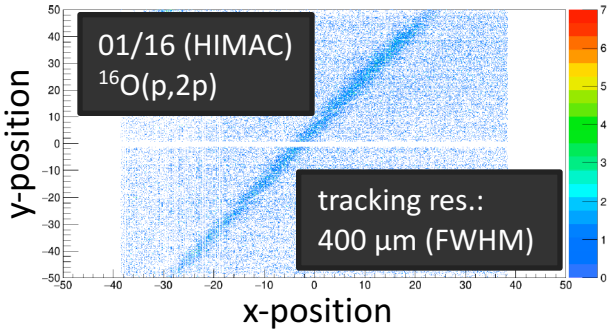
RIKEN Silicon Tracker





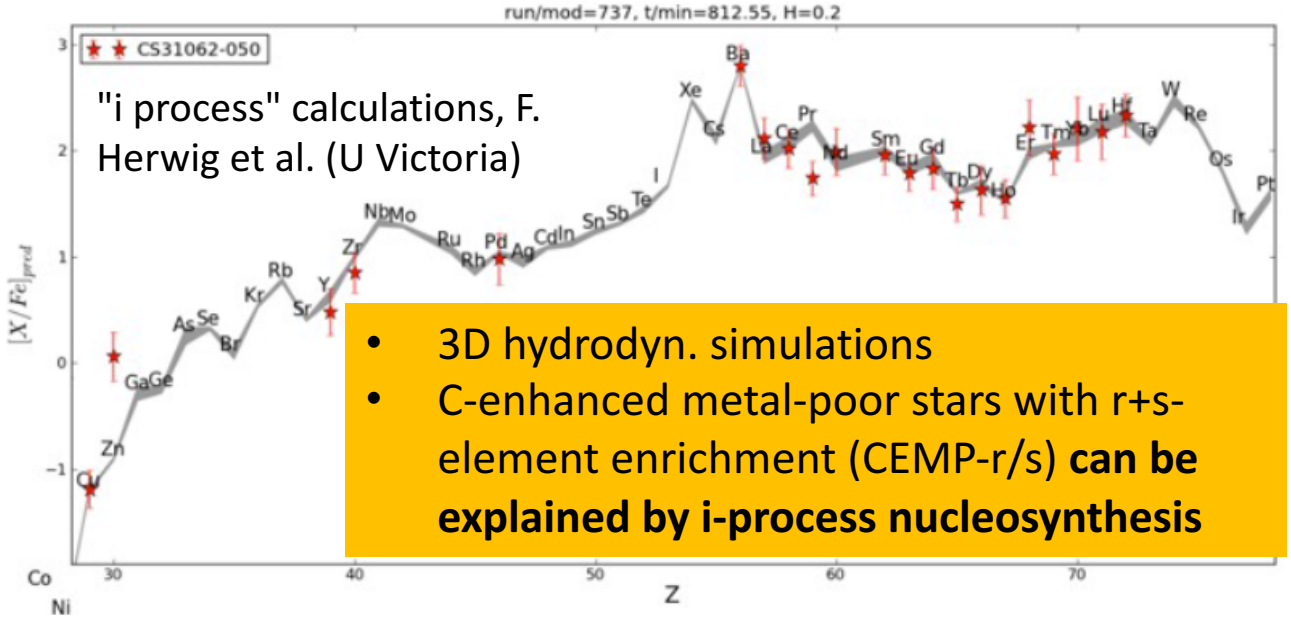
- PCB-design: M. Böhmer + E12+E18
- based on APV-25 CMS ASIC
- silicon: 100 um thickness, AC
- 100 um pitch, 8x5 cm single sided
- readout: TRB HADES (L. Maier)
- roughly 8000 channels

- collaboration TUM + RIKEN + Univ. of Guelph

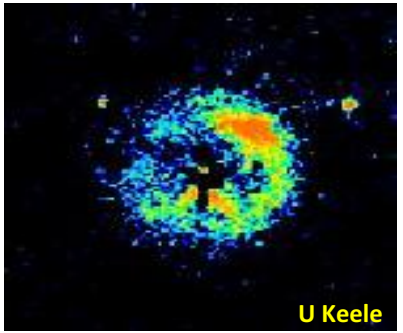


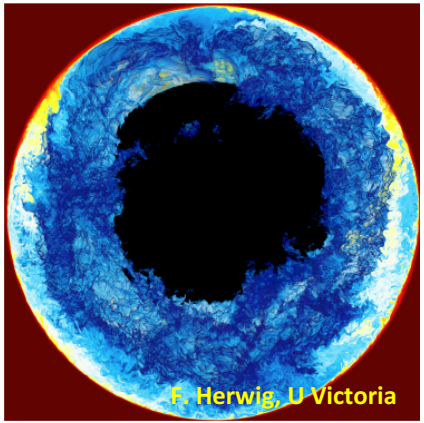
Silicon Tracker: selected applications

- shell evolution via one-neutron transfer towards and beyond N=82
- proton-neutron correlations beyond ^{132}Sn: ^{132}Sn(α,^{136}Te)γ
- i-process: (d,p) **n-rich in Kr** region and around unstable **^{135}I**



- 3D hydrodyn. simulations
- C-enhanced metal-poor stars with r+s-element enrichment (CEMP-r/s) **can be explained by i-process nucleosynthesis**





F. Herwig et al., ApJ 792, L3 (2014)

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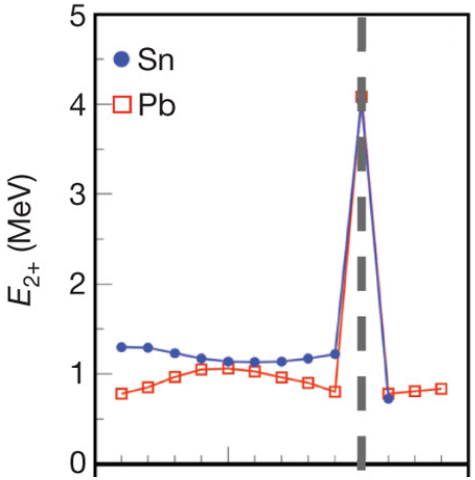
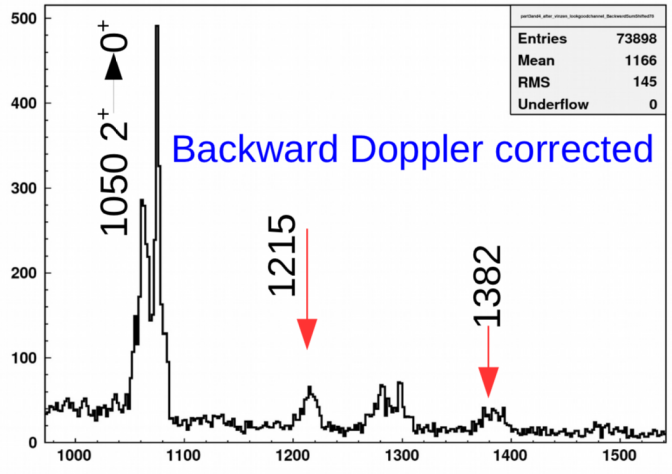
- proton-neutron correlations beyond ^{132}Sn: ^{132}Sn(α,^{136}Te)γ



- our data on **^{48}Ca(α,^{52}Ti)γ** reveal strong sensitivity on proton-neutron structure for excited 2^+ states
- can be used to study **anomaly** of 2^+ energies beyond N=82 via **^{132}Sn(α,^{136}Te)γ**

^{48}Ca(α,^{52}Ti)γ (MINIBALL)
analysis: Fuad Ali, UofG



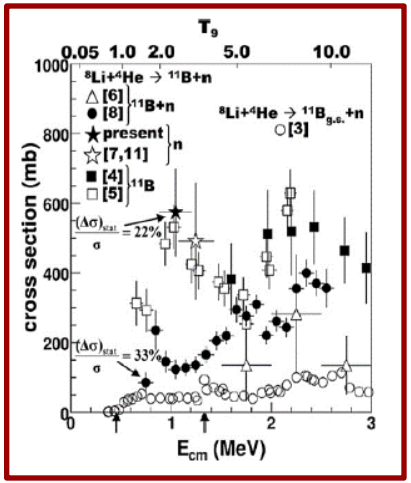
Silicon Tracker: selected applications

- shell evolution via one-neutron transfer towards and beyond N=82
- proton-neutron correlations beyond ^{132}Sn: ^{132}Sn(α,^{136}Te)γ
- i-process: (d,p) n-rich in Kr region and around unstable ^{135}I
- excitation functions in transfer reactions

- excitation energies and spectroscopic factors of resonances within the rp-process
- measurement of (p,α) and (α,p) rates for X-ray bursts studies, e.g ^{14}O(α,p)^{17}F
- S-factor for ^{8}Li(α,n)^{11}B reaction

^{8}Li(α,n)^{11}B: crucial to predictions of primordial nucleosynthesis in inhomogeneous models: first proposal using TIGRESS+DESCANT to be submitted to EEC (A. Kilic, UofG)

M.La.Cognata et al.
Physics Letter B 664 2008



Silicon Tracker: selected applications

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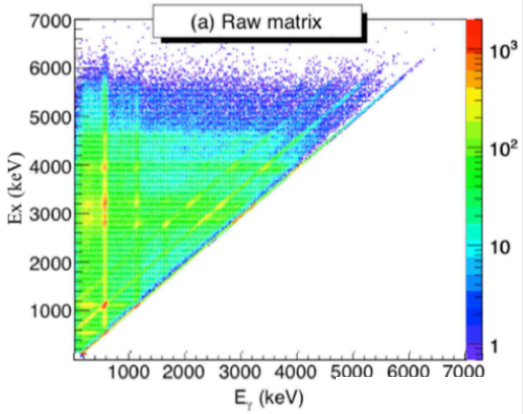
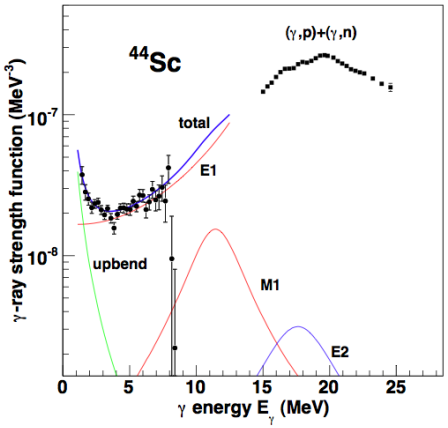
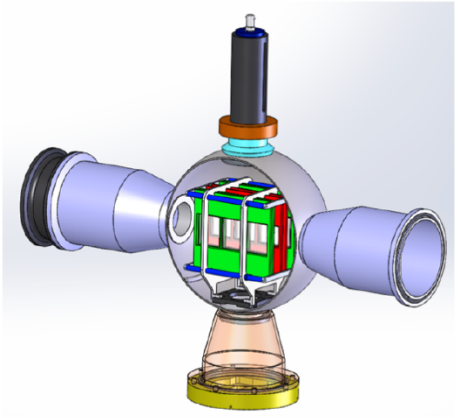
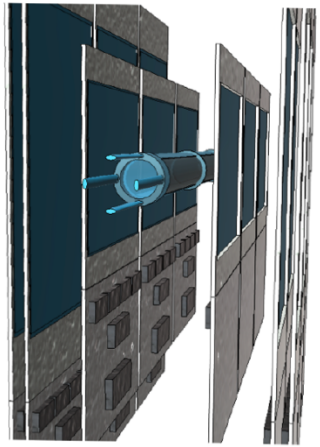
- Oslo-type experiments – level density & γ-ray strength function via (d,p) reactions: astrophysics, reactor design, waste transmutation





Silicon Tracker: Status





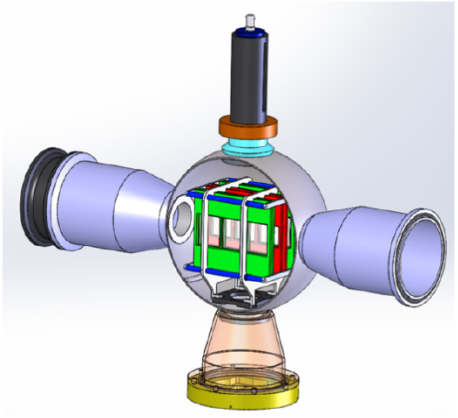
Manpower:

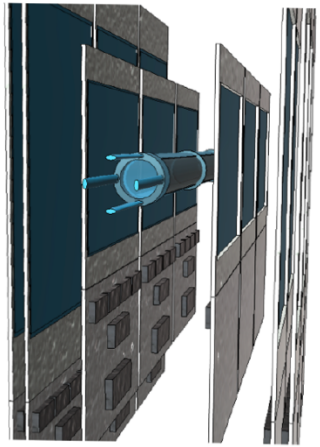
- **Design:** UofG+TRIUMF+Mines
- **Silicons:** Micron Semiconductor
- **ASIC:** Saclay, France
- **FPGA:** UofG, TRIUMF
- **PCB, pitch adapter:** TU Munich
- **Readout:** UofG + TRIUMF
- **Mechanics:** Mines, TRIUMF

- **Ali Kilic**, UofG
- **Devin Hymers**, Charlie Pham (both UofG): Geant4
- **Vinzenz Bildstein**, UofG
- **R. Gernhäuser, C. Berner, M. Böhmer** (TU Munich): ASIC
- **E. Pollacco** (CEA France): ASICs
- **F. Sarazin** (Mines)

- gate-0 at TRIUMF: ✅
- 24.10.16: meeting w. TRIUMF detector + electronics experts ✅
- mid 2017: JELF proposal (UofG internal discussion with Dean has started)
- End 2019 commissioning

Silicon Tracker: Status





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