Work at 5 MV accelerator in Aarhus

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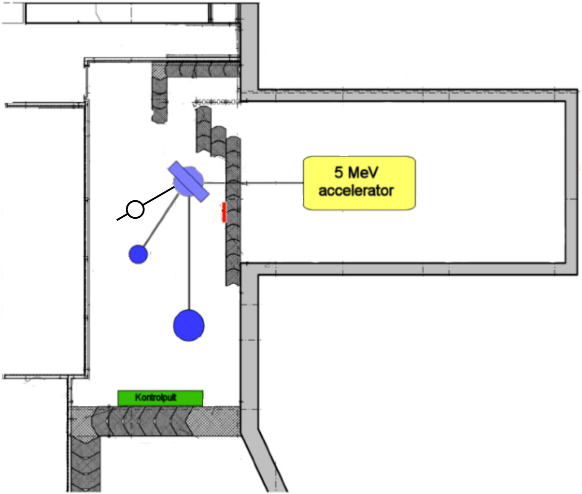
5 MV Van de Graaff accelerator

Possibilities

- ^{1}H, ^{3}He, ^{4}He
- $I_{proton} = 0.01\ nA - 100\ nA$
- E_{proton} : $700\ keV - 3500\ keV$
- Stable conditions.

Beam line



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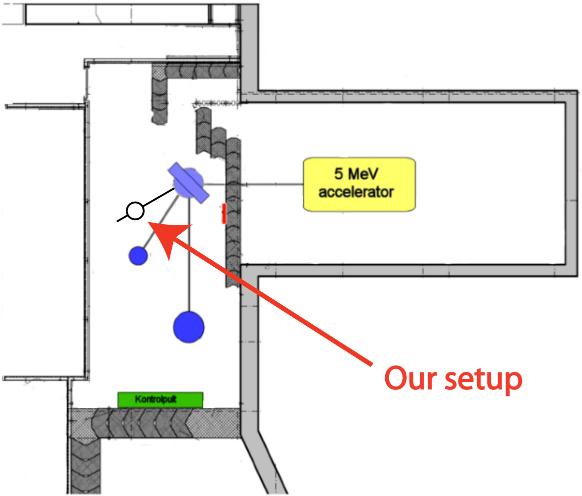

Physics motivation

Reactions through which we can study problems of astrophysical interest:

- ^{12}C-studies: ^{11}B(p,γ)3α, ^{10}B(^{3}He,p)^{12}C
- ^{16}O-studies: ^{15}N(p,γ)^{16}O, ^{14}N(^{3}He,p)^{16}O

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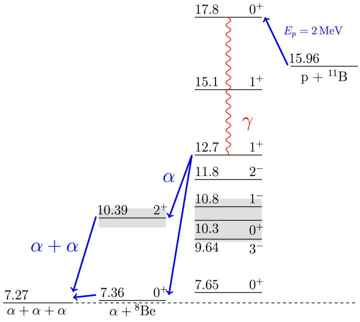
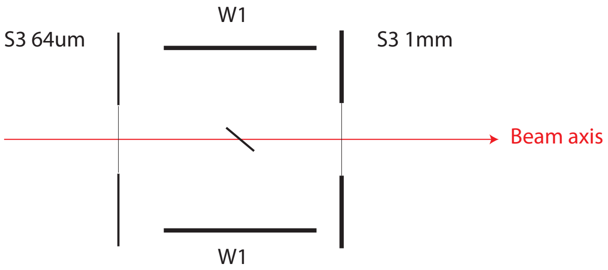
- Search for 2_2^+. Important for 3α reaction rate at temperatures above $1e9\,K$. W. R. Zimmerman et al., Phys. Rev. Lett. 110, 152502 (2013).
- Search for 4_2^+. Next step in the Hoyle state rotational band. Hints of this state: M. Freer *et al.*, Phys. Rev. C 83, 034314 (2011)



Detector setup

- DSSSDs: $(2 \times 16) + (2 \times 16) + (32 + 24) + (32 + 24) = 176$ strips
- Mesytec preamps and amps (STM16+ and MSCF-16)
- VME modules: CAEN ADC (785) and TDC (1190)



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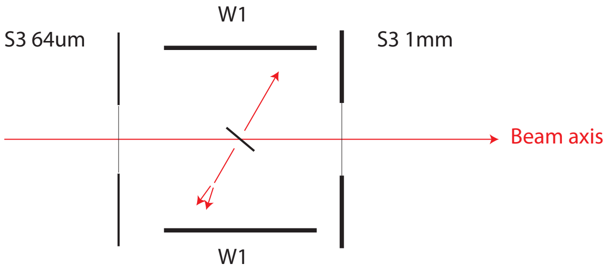
- Solid angle coverage $\approx 40\%$

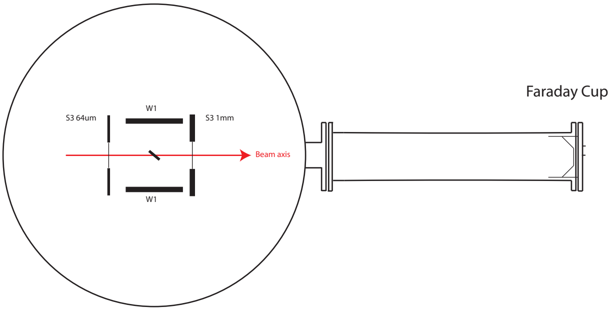


Detector setup

Backscattering from Faraday Cup

Faraday cup placed after 0.5 m nipple.

- Necessary due to backscattering from Faraday cup (stainless steel)



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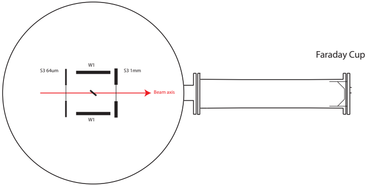

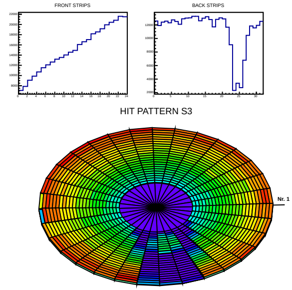

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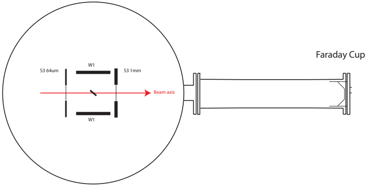
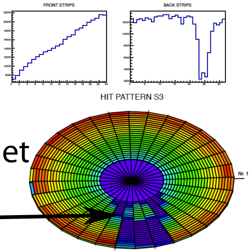


Hole in target ladder



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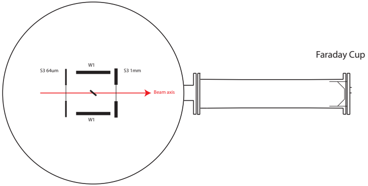
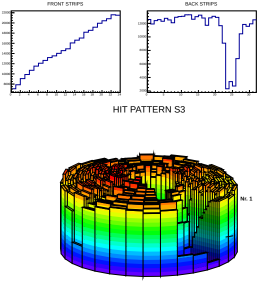
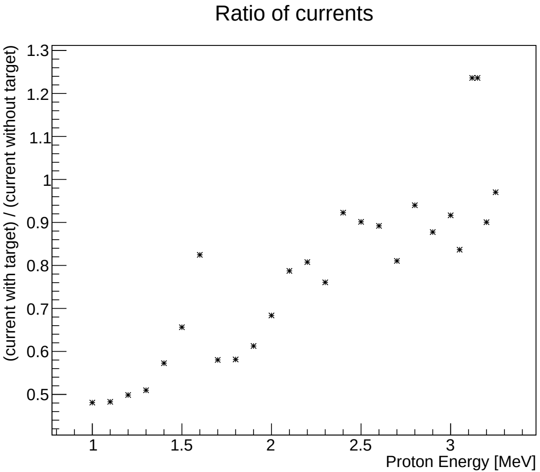


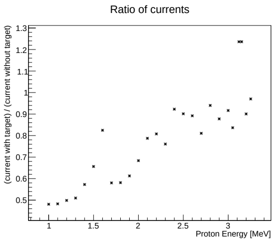


More Faraday cup problems...



Estimate fraction of protons scattered out of FC:

- Distance for target to FC $\sim 75\,\mathrm{cm}$
- Diameter of FC $\sim 1\,\mathrm{cm}$
- $E_{\mathrm{proton}} = 1\,\mathrm{MeV}$ on $^{11}\mathrm{B}$



Quick calculation for probability of "missing" the FC (using CM Rutherford crosssection)

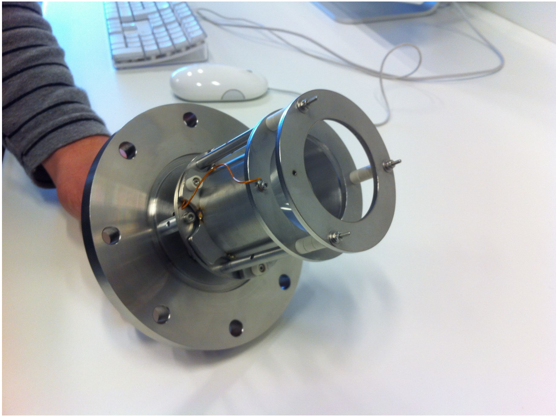
$$P = \left(\frac{Z_1\,Z_2\,\alpha\,\hbar\,c}{4\,E}\right)^2 \times \left(2\,\pi \int_{\theta_{\mathrm{FC}}}^{\pi} \frac{\sin(\theta)}{\sin^4(\theta/2)}\mathrm{d}\theta\right) \times \left(\frac{d_{\mathrm{target\ thick}} * N_A}{M_{^{11}\mathrm{B}}\ \cos(\theta_{\mathrm{target}})}\right) \approx 0.10$$

- Faraday cup does not collect all beam particles
- Energy dependence: Multiple scattering, CM

Faraday cup problem: solution

Construction of new FC

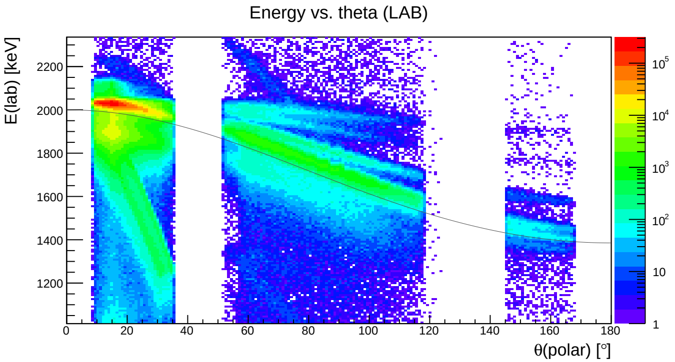
- 4 times larger collection area



Accelerator calibration

Calibration of the generating voltage meter (GV reading):

- Early analysis suggested that the GV reading is $\sim 50\,\text{keV}$ lower than the true acceleration voltage at $2\,\text{MeV}$



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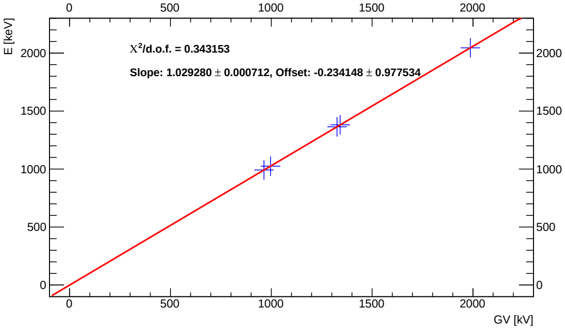


Intro

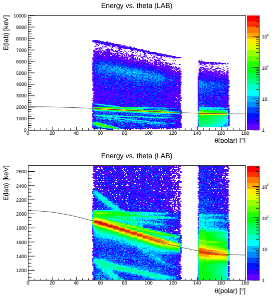
Experiment was carried out in March and aimed at determination of elastic scattering cross-section.

Motivation:

- Test of our setup
- Background for ^{11}B(p,3α)

Experiment:

- ^{10}B(p,p), ^{11}B(p,p) (^{12}C backing)
- 3 detector (no downstream S3)
  - Angular coverage: $53° - 127°$ and $142° - 166°$
- Energies: 0.3 - 3.4 MeV in step of 100 keV
- $I_{\text{proton}} \sim 1\,\text{nA}$
- 5 min on each energy



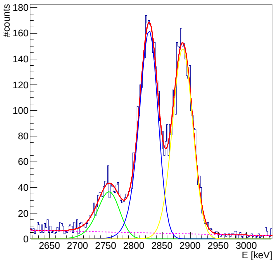
Analysis

Cross-section calculation:

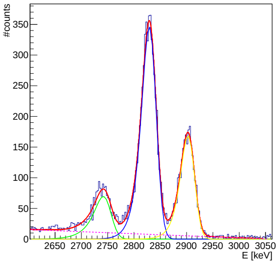
$$\frac{d\sigma}{d\Omega}^{^{11}\mathrm{B}}(E,\theta) = \frac{N_{^{11}\mathrm{B}}}{N_{\mathrm{proton}} \cdot \frac{N_{\mathrm{target}}}{A_{\mathrm{target}}} \cdot d\Omega \cdot Live_{\%} \cdot Abundance_{^{11}\mathrm{B}}} \tag{1}$$

$N_{^{11}\mathrm{B}}$:

$E_{\mathrm{proton}} = 3.39\,\mathrm{MeV}$ at angles $114^\circ - 115^\circ$



$E_{\mathrm{proton}} = 3.39\,\mathrm{MeV}$ at angles $149^\circ - 150^\circ$



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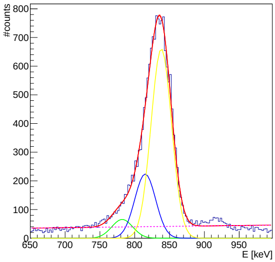
$N_{^{11}\mathrm{B}}$:

$E_{\mathrm{proton}} = 1.03\,\mathrm{MeV}$ at angles $149^\circ - 150^\circ$



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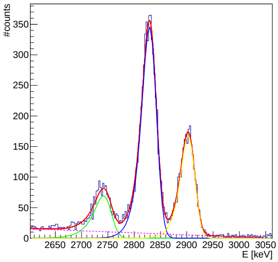

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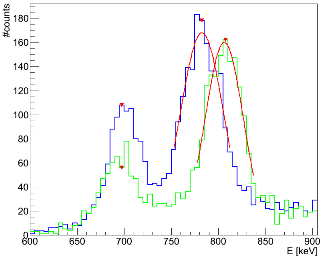
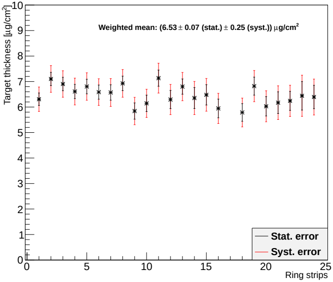
$\frac{N_{\mathrm{target}}}{A_{\mathrm{target}}}$:

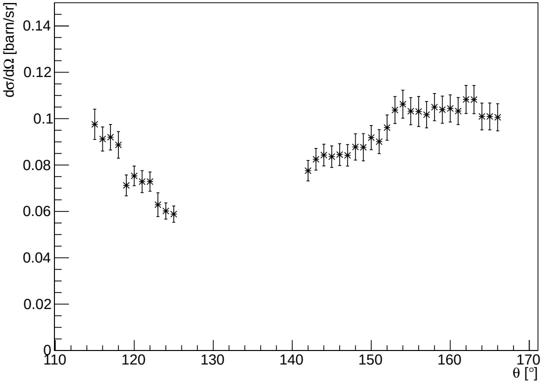
Backscattering on carbon backing. Target at 0° and 180°:





Results - ^{11}B

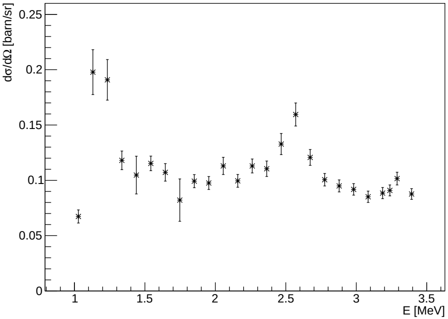
What to present ... ?
Angular distribution at 3 MeV:



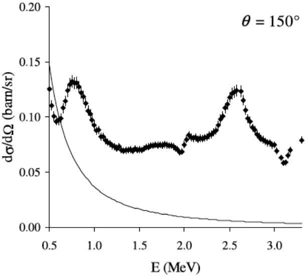
Results - ^{11}B

As function of energy at $149^\circ - 150^\circ$:

Our results:



Chiari *et al.* (2001):

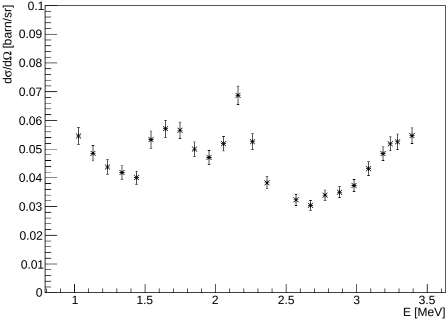


Our results lie higher

Results - ^{10}B

As function of energy at $149^\circ - 150^\circ$:

Our results:



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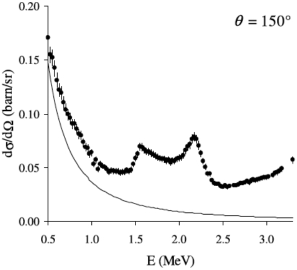
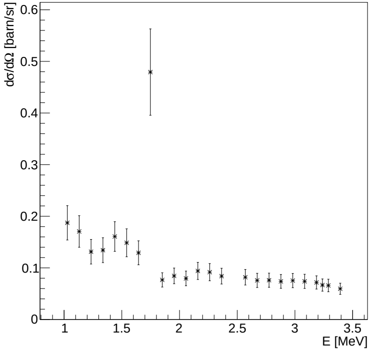


Our results seem to agree with Chiari *et al.* (2001).

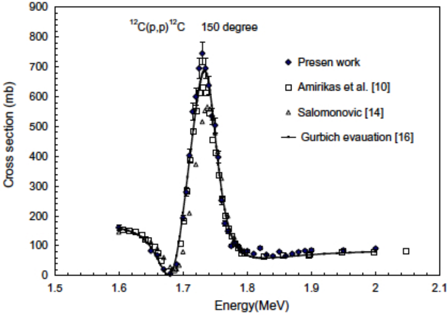
Results - ^{12}C

As function of energy at $149^\circ - 150^\circ$:

Our results:



Gul *et al.* (2011):

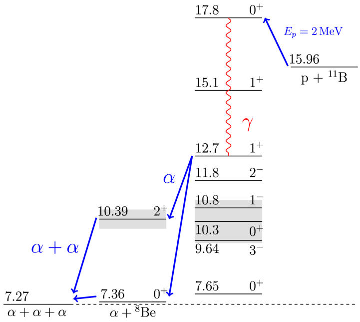


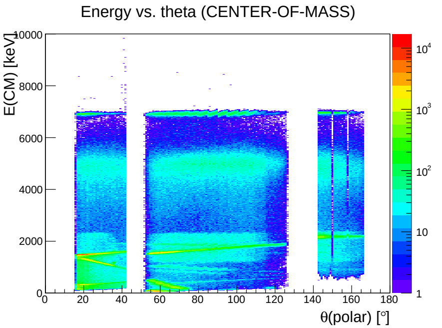
Agreement between our results and literature values.

Data: ^{11}B(p,3α)

Beam energy 2.0 MeV.

- $\sim$ 8 hours
- $\sim$ 1e6 triple coincidence events (front-back matched)





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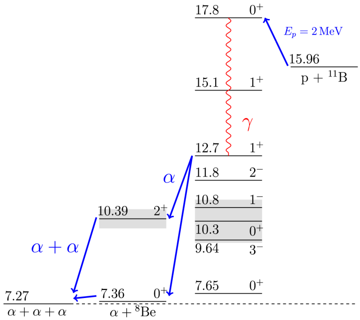
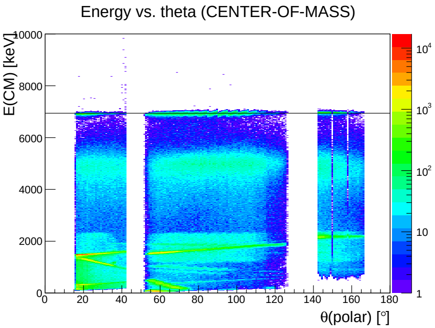
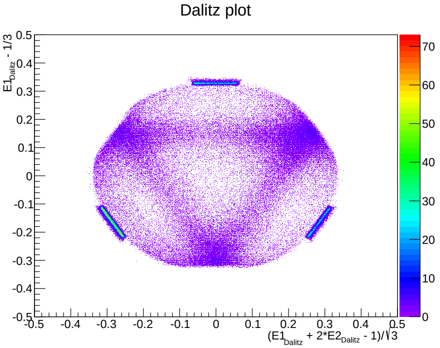




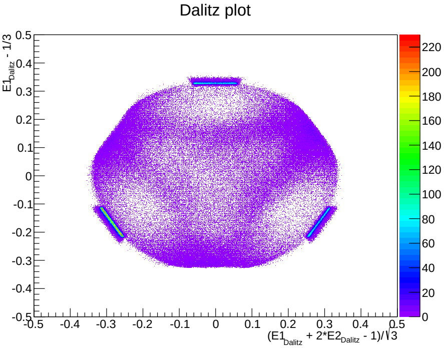
Analysis: ^{11}B(p,3α)

Dalitz plots: FURTHER ANALYSIS NEEDED

0^+ state at E_p =2.00 MeV



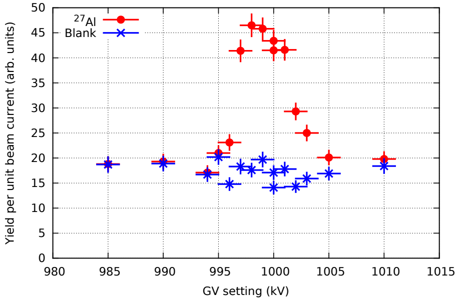
3^- state at E_p =2.65 MeV

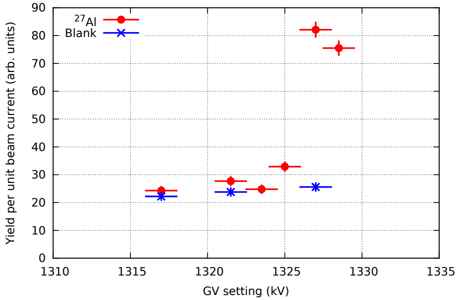


EXTRA: Accelerator calibration

Method:

- $^{27}Al(p,\gamma)^{28}Si$: Sharply defined thresholds at 992 KeV and 1317 KeV
  (idea from Nuclear Instruments and Methods in Physics Research A340 (1994) 436-441)
- Used NaI detector. Integrate γ counts from 3 MeV to 13 MeV





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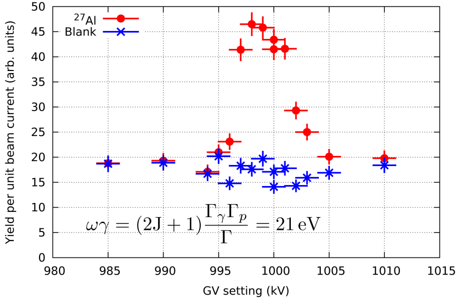

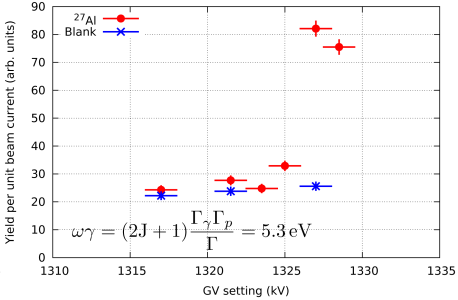

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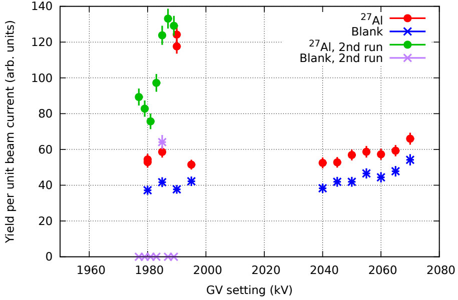

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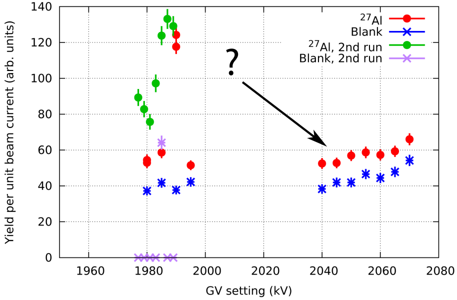

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