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# Fast(ish) beams

## *Further reach, overcome Q values, reaction mechanisms*

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# *What is the purpose of this talk?*

Raise the possibility of using a solenoidal spectrometer as an instrument for use with fast beams to:

- ➡ *carry out [insert favorite here] reactions at the FRIB frontiers*
- ➡ *overcome the Q-value barrier for certain reactions*
- ➡ *exploit reactions that demand high incident energies*

Caveat: some compromises and challenges

# *Examples — frontiers*

$^{54}$Ca: 1.1$^{4}$ Hz, 5.9$^{2}$ Hz*

… *($T_{1/2}$ = 79 ms, $E_{primary}$ = 237 MeV/u)*

***Others:***

$^{76}$Ni: 1.2$^{4}$ Hz, 1.2$^{3}$ Hz

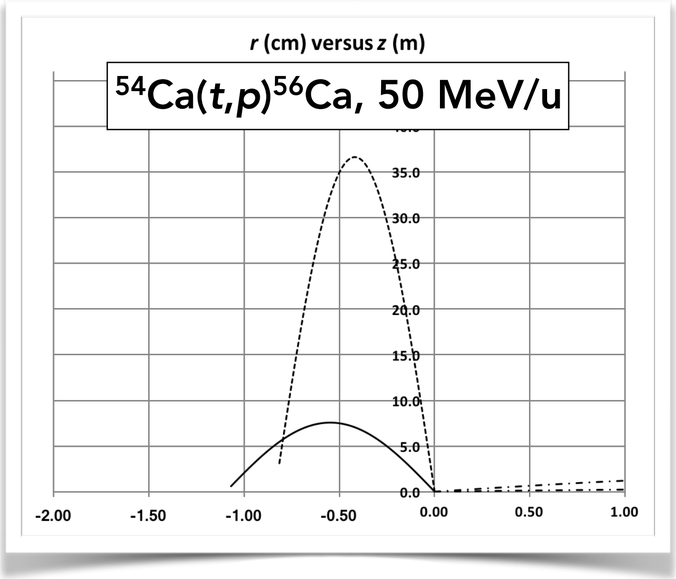
$^{102}$Sn: 1.5$^{4}$ Hz, 1.7$^{3}$ Hz

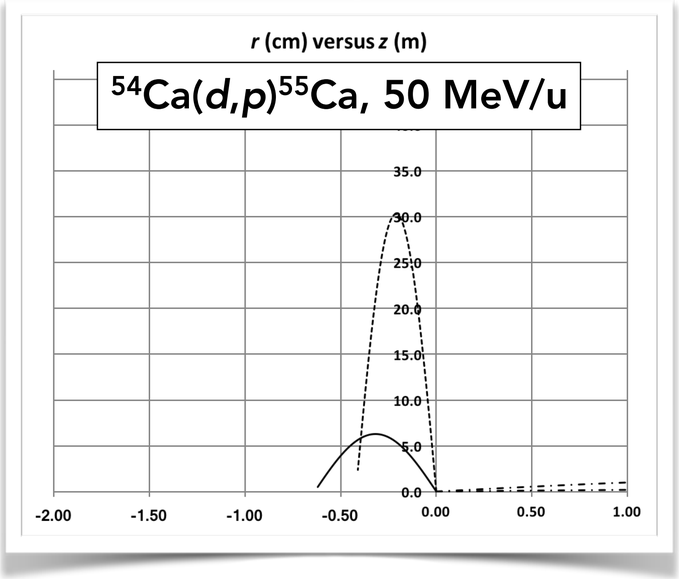
$^{204}$Pt: 7.1$^{4}$ Hz, 6.4$^{3}$ Hz

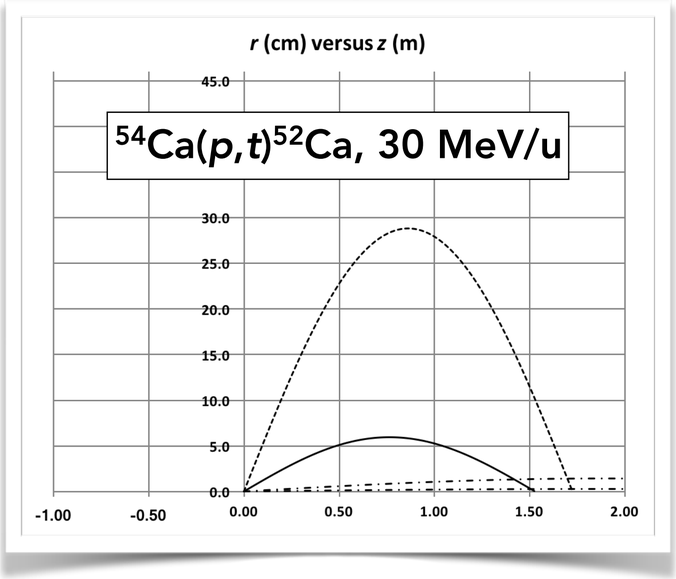
… and so on

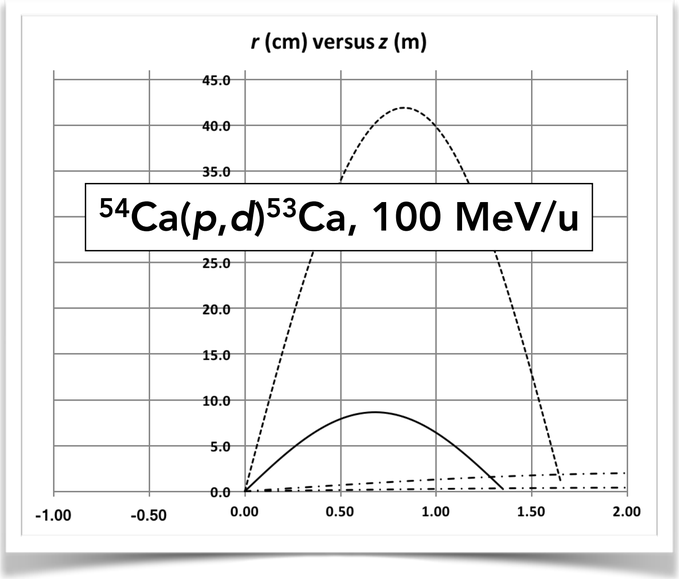
(Also ~7days vs. >100 days)

(all calculations done for 4-T field)




*https://groups.nscl.msu.edu/frib/rates/fribrates.html — Version 1.06

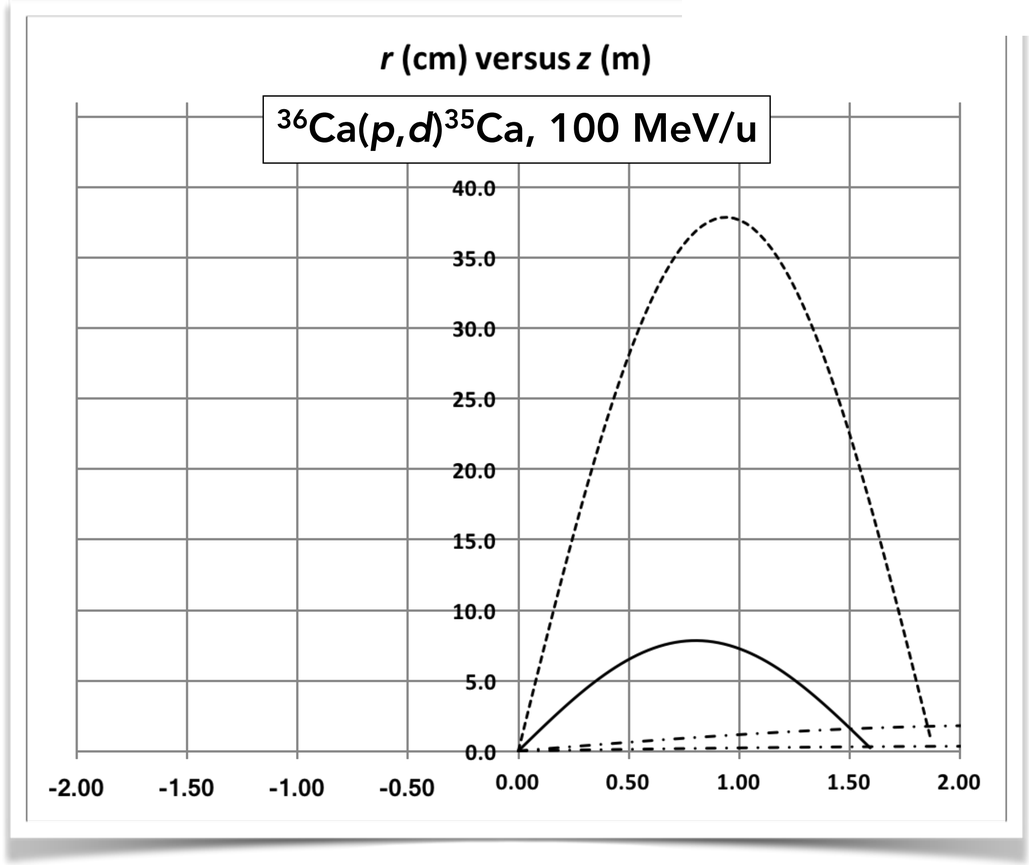
# *Examples — Q values*

**Many negative Q-value reactions that require > 10-15 MeV/u incident beam energy $^{36}$Ca: 1.6$^{7}$ Hz, 9.1$^{5}$ Hz***

***Q = -17.1 MeV***

**(Note, relatively high deuteron energies 25-30 MeV, and pushes the limits in terms of the length of the solenoid / field)**

**(all calculations done for 4-T field)**

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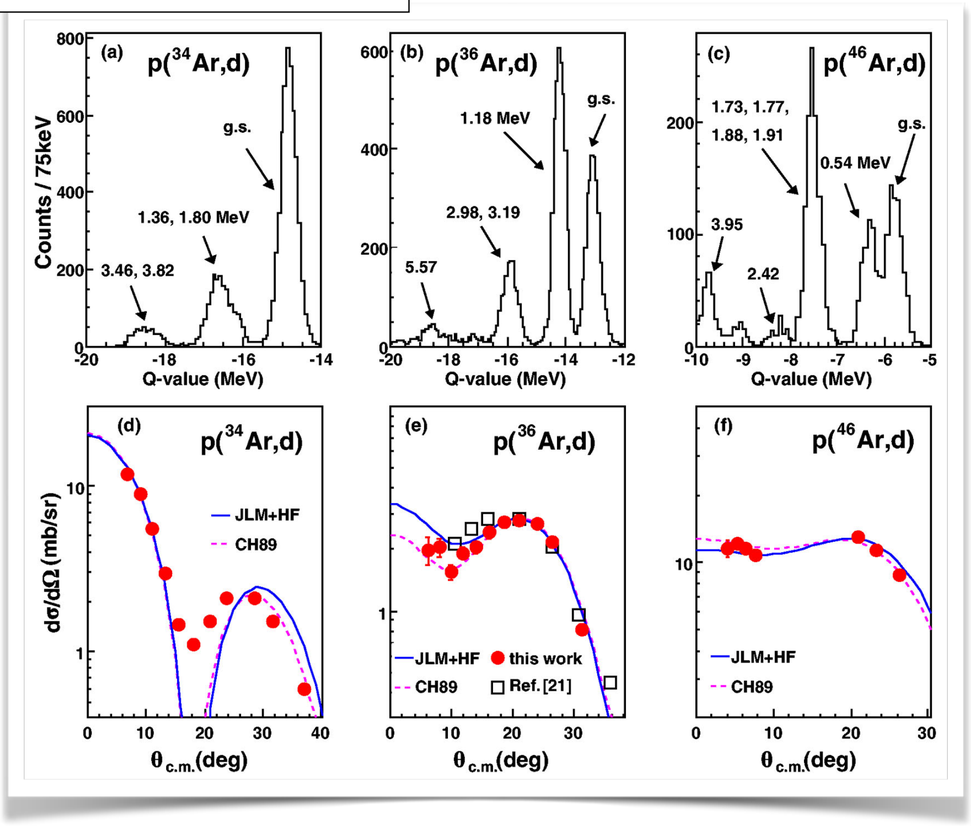
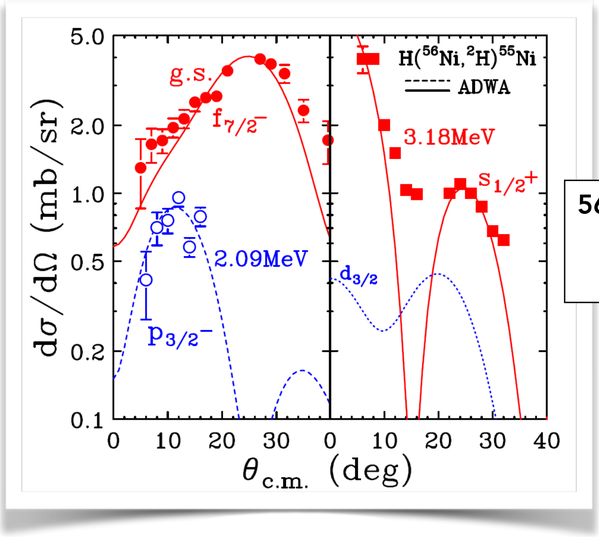
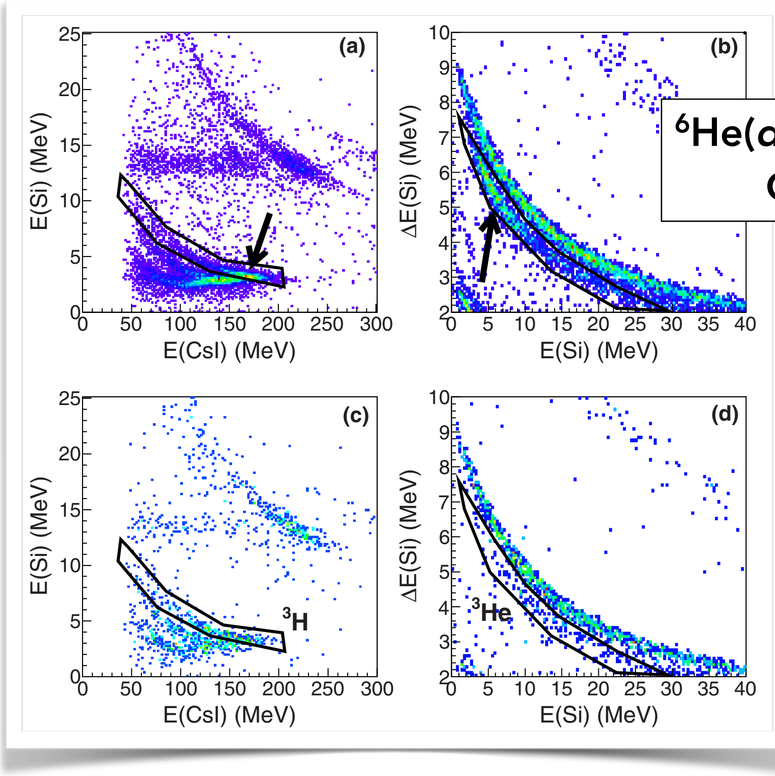
# Examples — Q values

$^{34}$Ar($p$,$d$)$^{33}$Ar, 33 MeV/u
Q = -14.8 MeV




$^{56}$Ni($p$,$d$)$^{55}$Ni, 37 MeV/u
Q = -14.4 MeV




$^{6}$He($d$,$t$/$^{3}$He)$^{5}$He/$^{5}$H, 55 MeV/u
Q = -17 MeV (d,$^{3}$He)

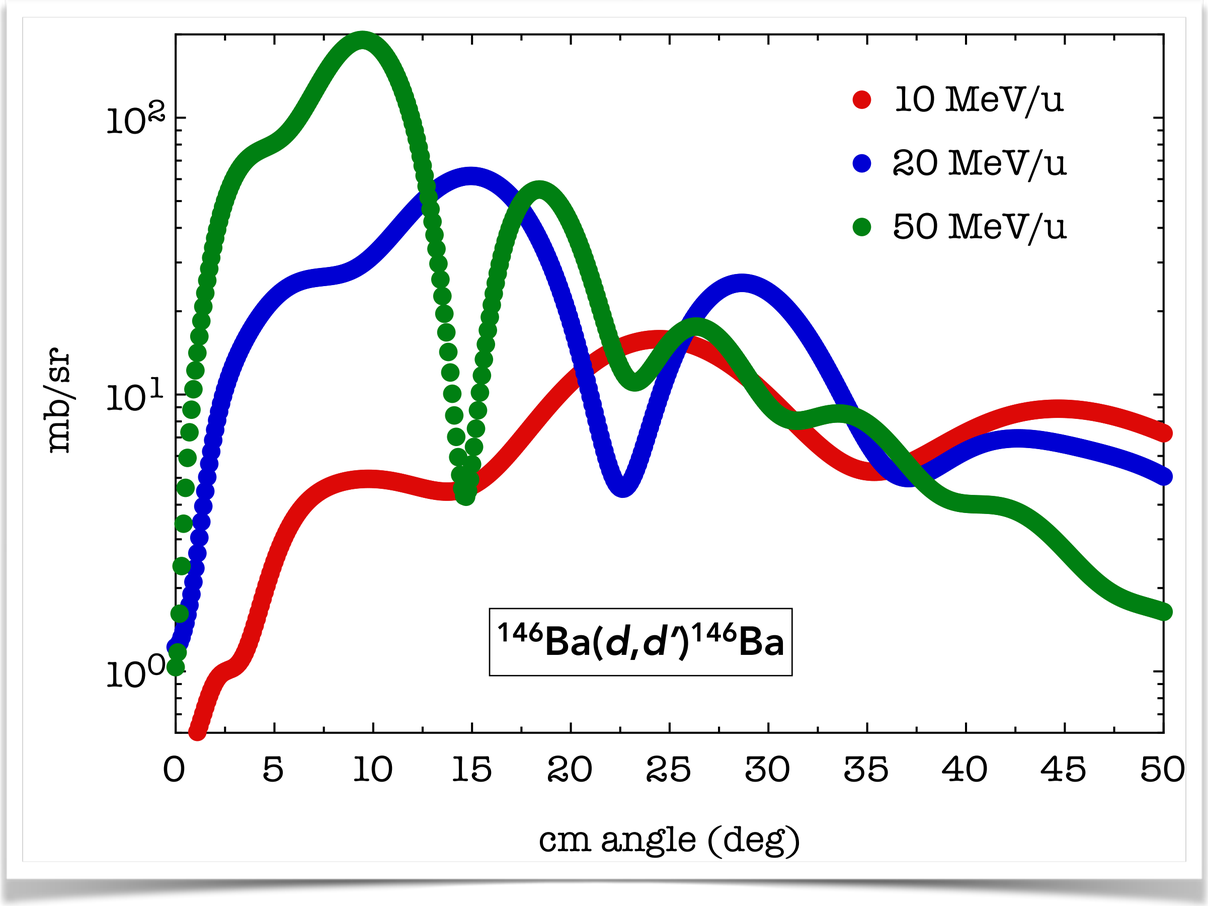

*J. Lee et al. Phys. Rev. Lett.* ***104****, 112701 (2010)*
*A. Sanetullaev et al. Phys. Lett. B* ***736****, 137 (2014)*
*A. H. Wuosmaa et al., Phys. Rec. C* ***95****, 014310 (2017)*

# *Examples — reaction that desire/require high energy*

## *For example, inelastic scattering as a complement / alternative to Coulex*

**Use $^{146}$Ba as a recent example, (*d*,*d*′) would be an ideal tool to probe the *E*3 strength … okay at 10 MeV/u, ideal at high energies**

***Many other probes e.g., (p,p′), (α,α′), charge-exchange (t,$^3$He) all at several hundred MeV/u … but forward c.m. angles challenging (low E, ~90° lab)***




*https://groups.nscl.msu.edu/frib/rates/fribrates.html — Version 1.06

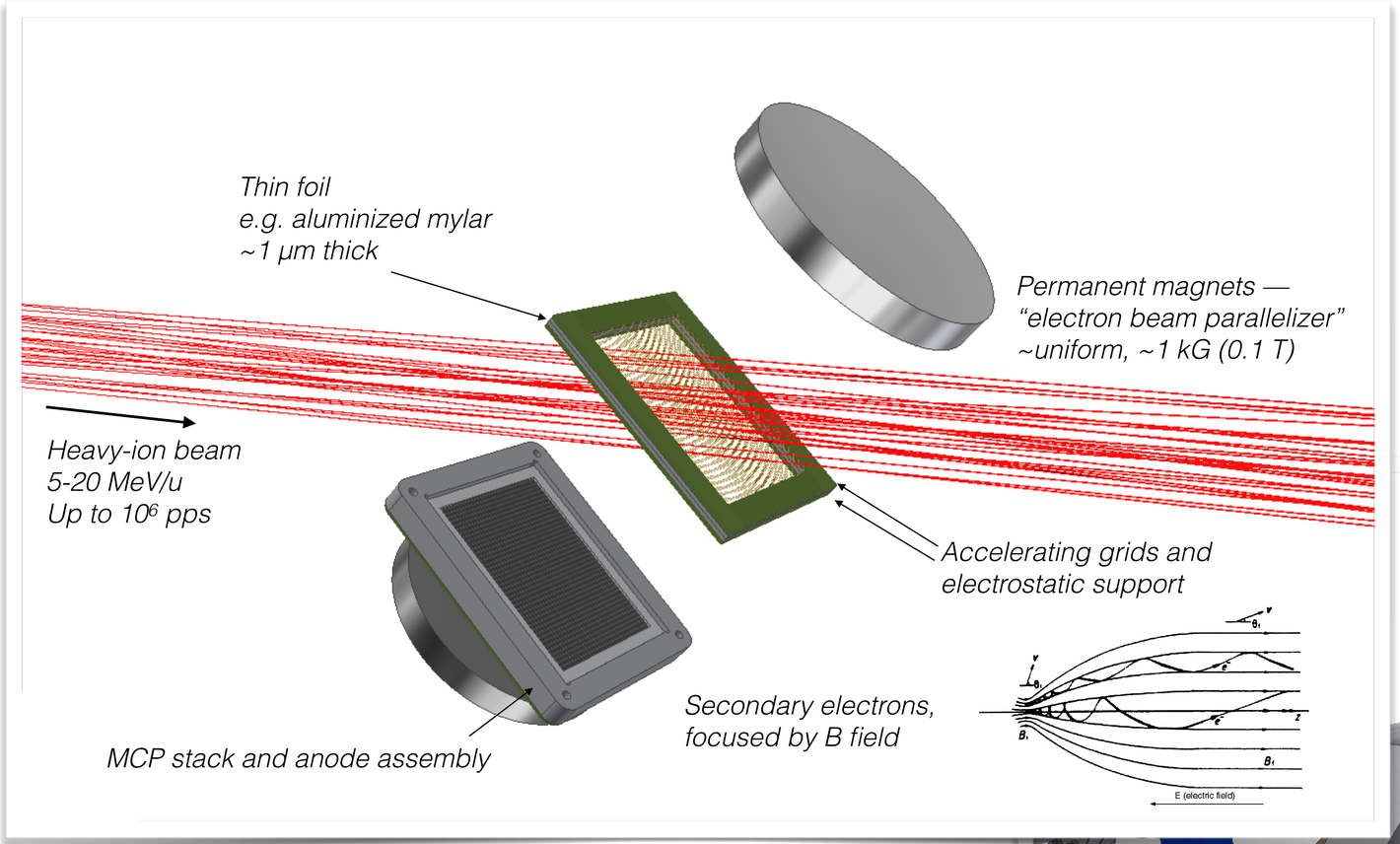
# *Beam properties, arrays*

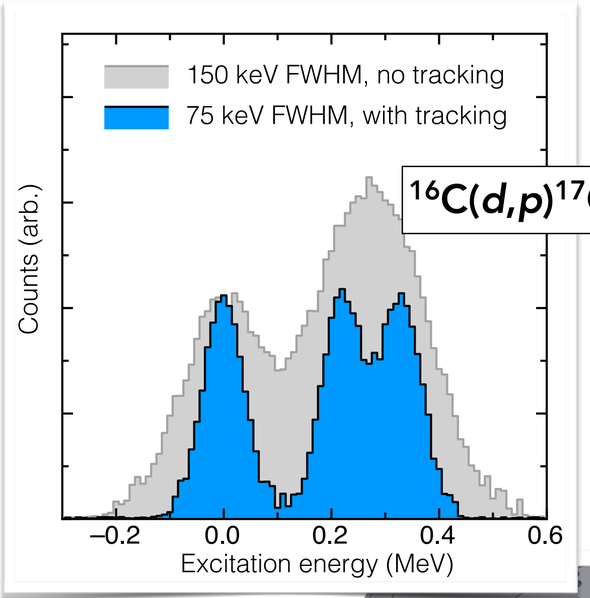
- *Fast beams will not have the same 'quality' as those from a LINAC*
- *Can readily track the beams (see e.g. HiRA, GANIL, GSI, RCNP, …, etc)*
- *Tracking, event-by-event, could removes contributions relating to beam size, longitudinal and transverse emittance*
  - ➡ *Can do with weak beams*
  - ➡ *Easier at higher energy cf. 10 MeV/u*

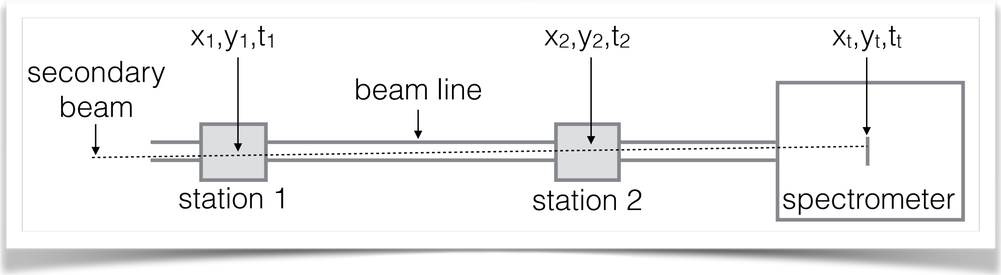
*Challenges:*

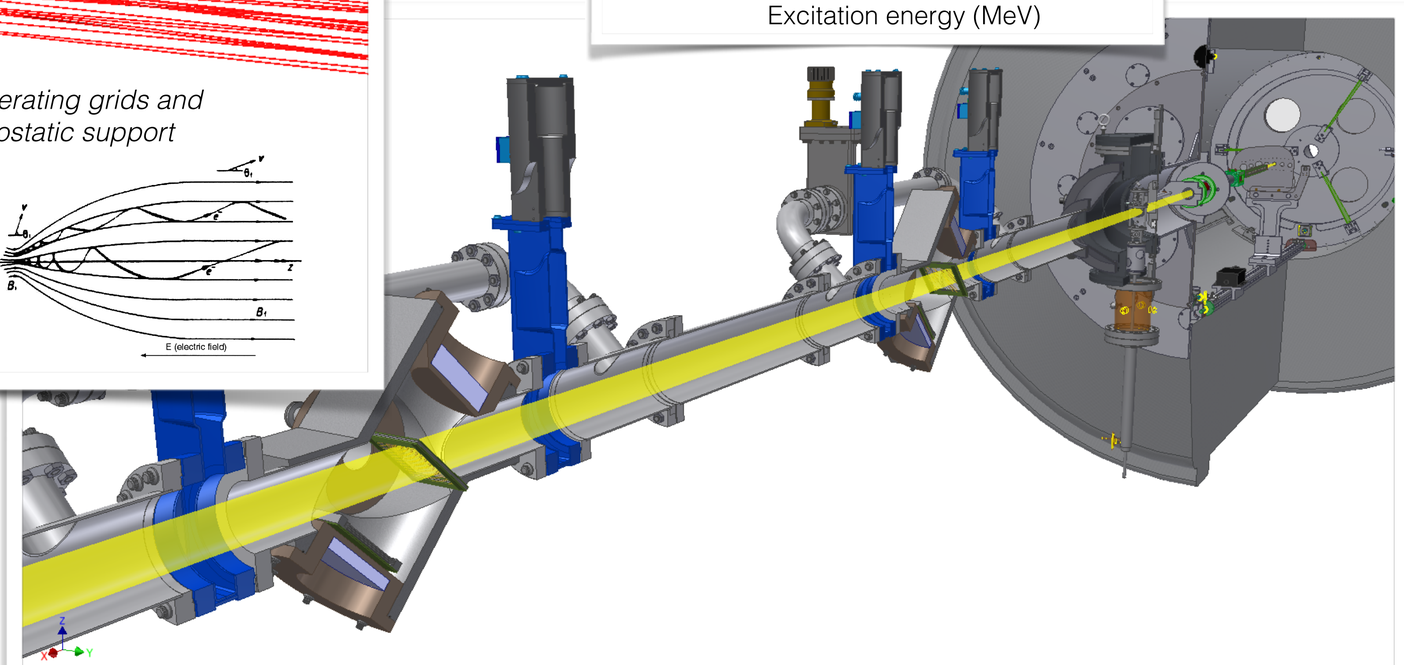
- ➡ *Mapping fields, reconstructing the position at the target*
- ➡ *Would need a larger array (some consequences)*

# E.g., beam tracking



e.g. D. Shapira *et al.*, Nucl. Instrum. Methods **A454**, 409 (2000).

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# *Pros and cons*

- *Do reactions at the frontier in terms of intensity*
- *Reactions with large negative Q values*
- *Inelastic scattering / charge-exchange*
- *Solenoidal device (focusing), large acceptance, both ‘hemispheres’*
- *…*

- *Reaction mechanisms*
- *Degrading fast beams / tracking*
- *HiRA / similar already suitable(?)*
- *Challenge of position solenoid on a fast-beam beam line (in front of HRS?) (campaign modes)*
- *Zero-degree or close is challenging (low energy, close to target)*
- *…*

# *Comment on simulations*

- *My hope is we can establish a common simulation tool / platform that is well documented, user intuitive, and supported*
- *Establish a repository of examples / geometries / detectors*
- *The NPTool project is a promising approach*
  - ➡ *Root and GEANT4 based, supported*
  - ➡ *It already includes geometries for HELIOS @ ANL (also benchmarked against experimental data) and for ISS @ HIE-ISOLDE*
- *Should start soon, necessary for white paper, postdoc support would be ideal*

# *Summary (same as intro)*

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