Nuclear structure studies – Reactions

In-ring reactions

- Gas-jet target + array UVH detectors: **Technical challenge!**
- Good spatial resolution required for the reaction vertex:
  - In transverse directions: **Cooling necessary**
  - In beam direction: **???** Possible with the gas target?? [however this is not critical for large angles which are usually the most important, i.e. 0 deg c.m.]
- Cooling sets limits on the half lives:
  Short nuclear half lives not feasible → interesting exotic light nuclei are not really accessible
  Medium-mass and heavy nuclei potentially interesting
  (Physics cases are presented in the TSR paper)

Nuclear structure studies – Reactions

In-ring reactions (cont'd)

Luminosity – how does it compare to "typical" external-target setup?

- Ratio determined by:
  (ratio target thickness) x (revolution frequency) x (lifetime)

- About the lifetimes:
  Scheme is injection-cooling-measurement
  Injection-cooling takes 1 to few seconds
  → we cannot measure for much longer otherwise we lose too much primary beam
  → no need to achieve lifetimes much larger than 1 to few seconds

- Frequency and targets:
  At 10 MeV/u: revolution frequency ≈ 8×10^5 Hz
  → ratio of target thickness should not be smaller than 10^{-6}
  However such large gas-jet thickness (if achievable!) induces too high beam losses (continues on following slide)

Nuclear structure studies – Reactions

Table 1: Parameters of beams circulating in the TSR. See text for details.

Ion	Nuclear lifetime	Energy (MeV/u)	Cooling time	Beam lifetime in residual gas	H_2 target (atoms/cm^2)	Beam lifetime in target	Eff. target thickness (μg/cm^2)
^{7}Be 3+	(53 d)	10	2.3 s	370 s			
^{18}F 9+	100 m	10	0.7 s	280 s	1×10^{14}	236 s	31000
^{26m}Al 13+	6.3 s	10	0.5 s	137 s	5×10^{14}	23 s	4200
^{52}Ca 20+	4.6 s	10	0.4 s	58 s	5×10^{14}	9.6 s	3000
^{70}Ni 28+	6.0 s	10	0.25 s	30 s	2×10^{14}	12 s	1600
^{70}Ni 25+	6.0 s	10	0.3 s	26 s	2×10^{13}	2.1 s	60
^{132}Sn 30+	40 s	4	0.4 s	1.5 s	1×10^{12}	1.4 s	1.2
^{132}Sn 45+	40 s	4	0.2 s	1.4 s	5×10^{12}	1.6 s	7
^{132}Sn 39+	40 s	10	0.25 s	7.4 s	2×10^{12}	3.6 s	9.5
^{132}Sn 45+	40 s	10	0.2 s	10 s	5×10^{13}	1.3 s	90
^{186}Pb 46+	4.8 s	10	0.25 s	4 s	2×10^{12}	1.5 s	4
^{186}Pb 64+	4.8 s	10	0.13 s	5 s	1×10^{13}	1.7 s	20

This “effective thickness” is essentially limited by the beam survival for charge-exchange in the gas target

Only good if the ions are fully stripped

However this cannot be achieved even with stripping at 10 MeV/u (equilibrium charge states are lower)

Maybe a gas separator needed before injection?

Nuclear structure studies – Reactions

Conclusions (to be discussed)

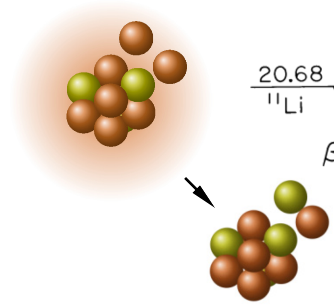
- IF a much better energy resolution can be achieved for in-ring reactions with respect to external particle-gamma setup (to be demonstrated) THEN there are cases where in-ring reactions can be of interest despite the reduce luminosity:
  - overcome high density of states in some nuclei
  - study of isomers (no gamma's)
- Otherwise, higher charge states are necessary:
  Consider a gas separator needed before injection?

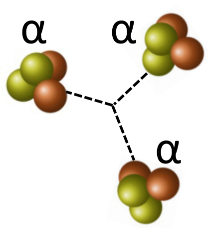
Nuclear structure studies – Decay

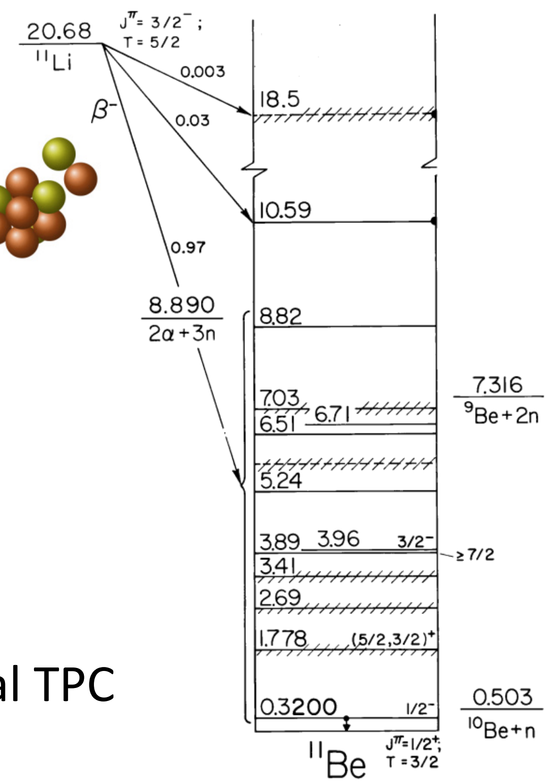
We are interested here in decay towards the continuum followed by the breakup of the daughter in two (or more) charged fragments

One needs accurate measurements of

- Branching ratios (often small!)
  $\Rightarrow$ channel identification
  $\Rightarrow$ efficiency
- Energy emitted particles
  $\Rightarrow$ low thresholds
  $\Rightarrow$ resolution
- Spatial correlations







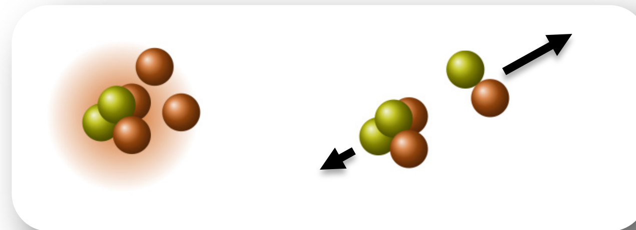
Various methods:

- External source, implantation in a Si detector, optical TPC with advantages and disadvantages

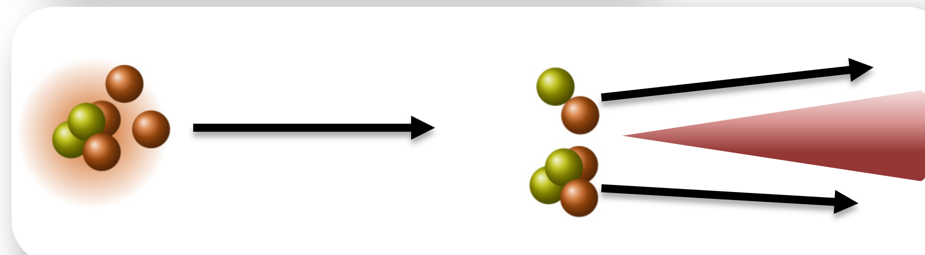
Nuclear structure studies – Decay

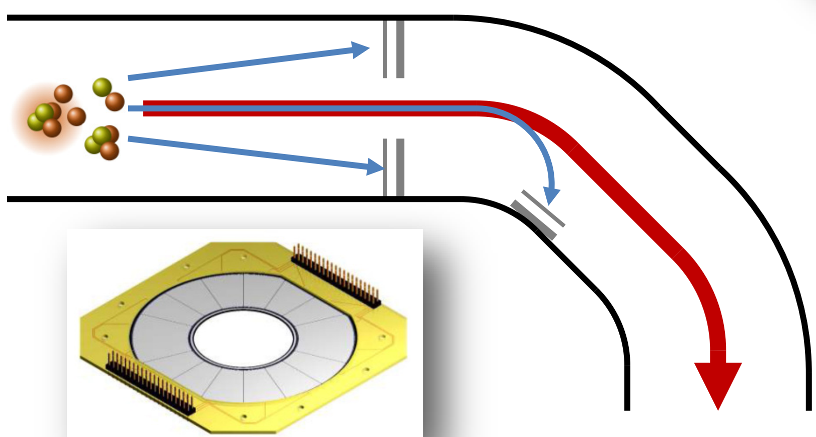
How can the TSR help? **With a very low detection threshold!**

- Decay at rest:
  Only energy of the decay is available



- Decay in flight:
  Use the momentum of the beam
  Emission in a narrow cone





- In the ring:
  Detection in annular arrays
  or after a bend
  Identification through Δ*E*-*E*

Nuclear structure studies – Decay

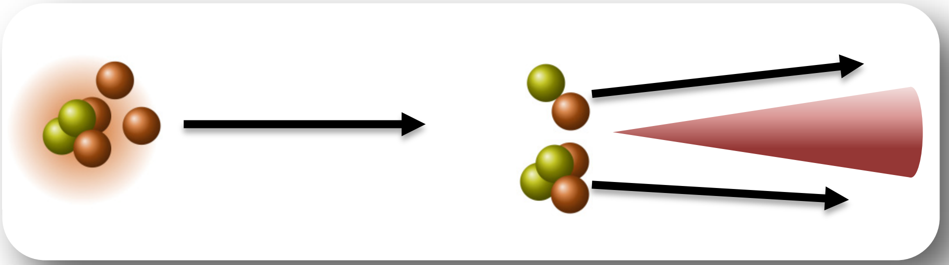
Cases of interest

^{6}He (β)→ ^{4}He+d

^{8}He (β)→ ^{6}He+d

^{11}Be (β)→ ^{10}Be+p

^{16}N (β)→ ^{12}C+α



- The emission cones are large – a few percent (transverse/longitudinal) in the worst cases
- 5 MeV/nucleon actually better
- Problem 1: measure energy very accurately (few keV at few MeV!!) AND/OR measure energy and angles → good beam definition → cooling
- Problem 2: coincidence detection preferable (particle ID affects resolution!) → probably very low efficiency