Nuclear rEaCTions At storage Rings, NECTAR

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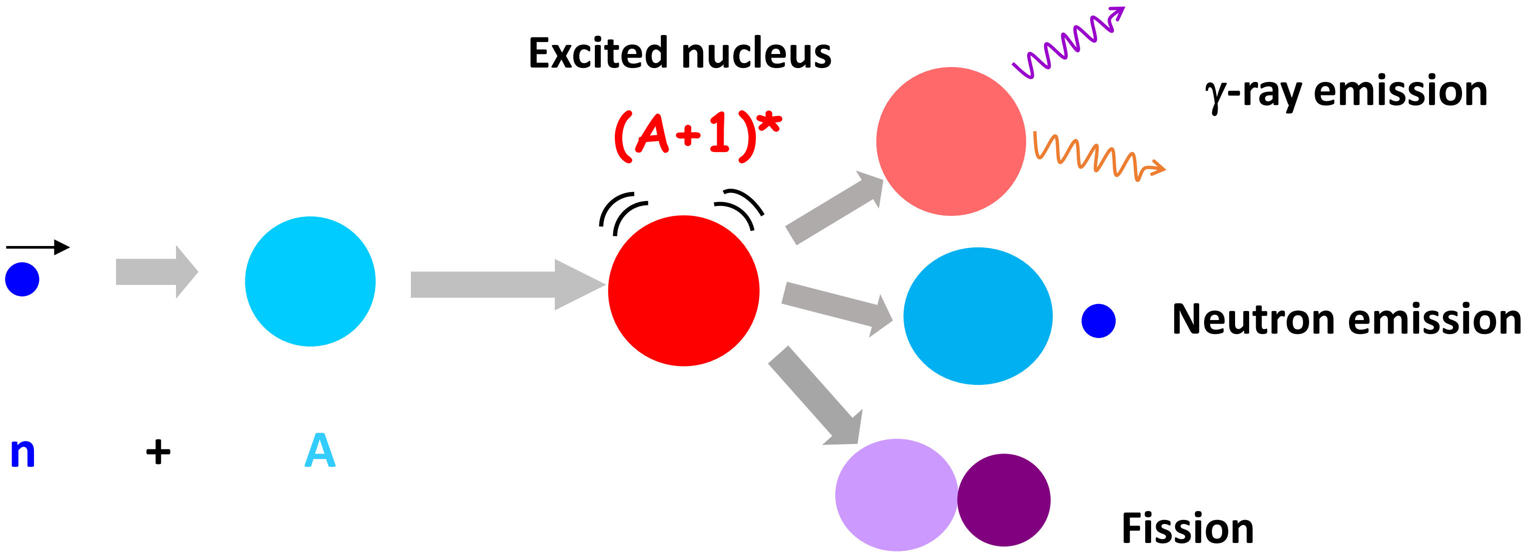
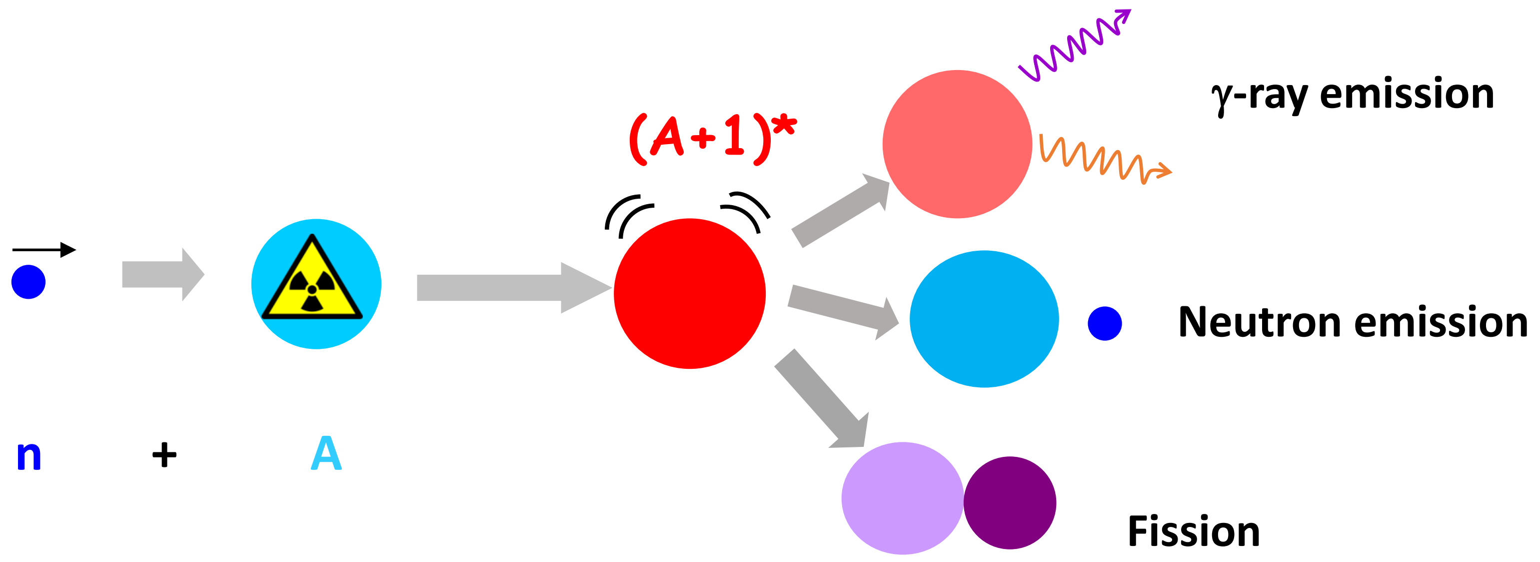
Introduction:

Neutron-induced reactions at energies below few MeV:



Motivation:

Need for neutron-induced reaction cross sections of radioactive nuclei

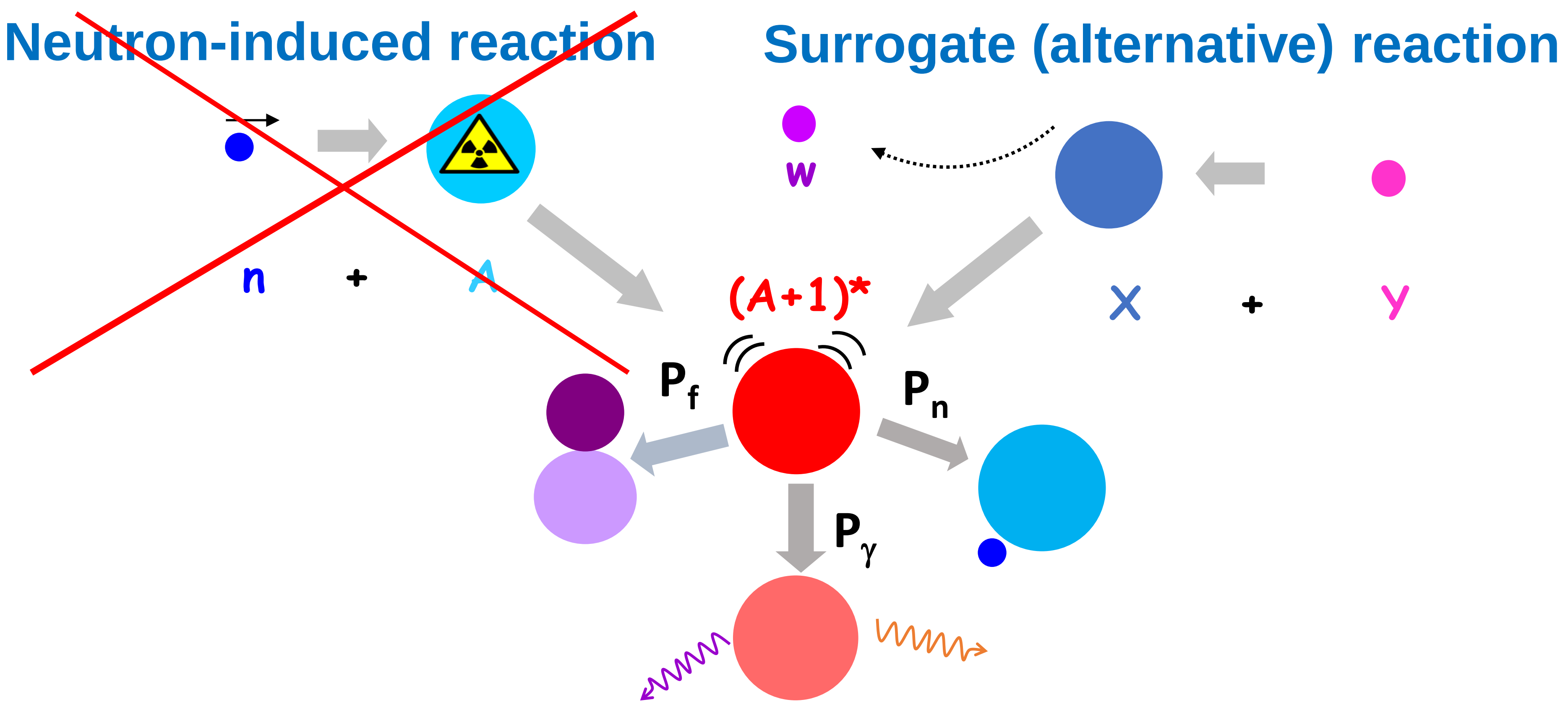


Essential for astrophysics, energy production and medicine!

→Very difficult or even impossible to measure with standard techniques because of the radioactivity of the targets.

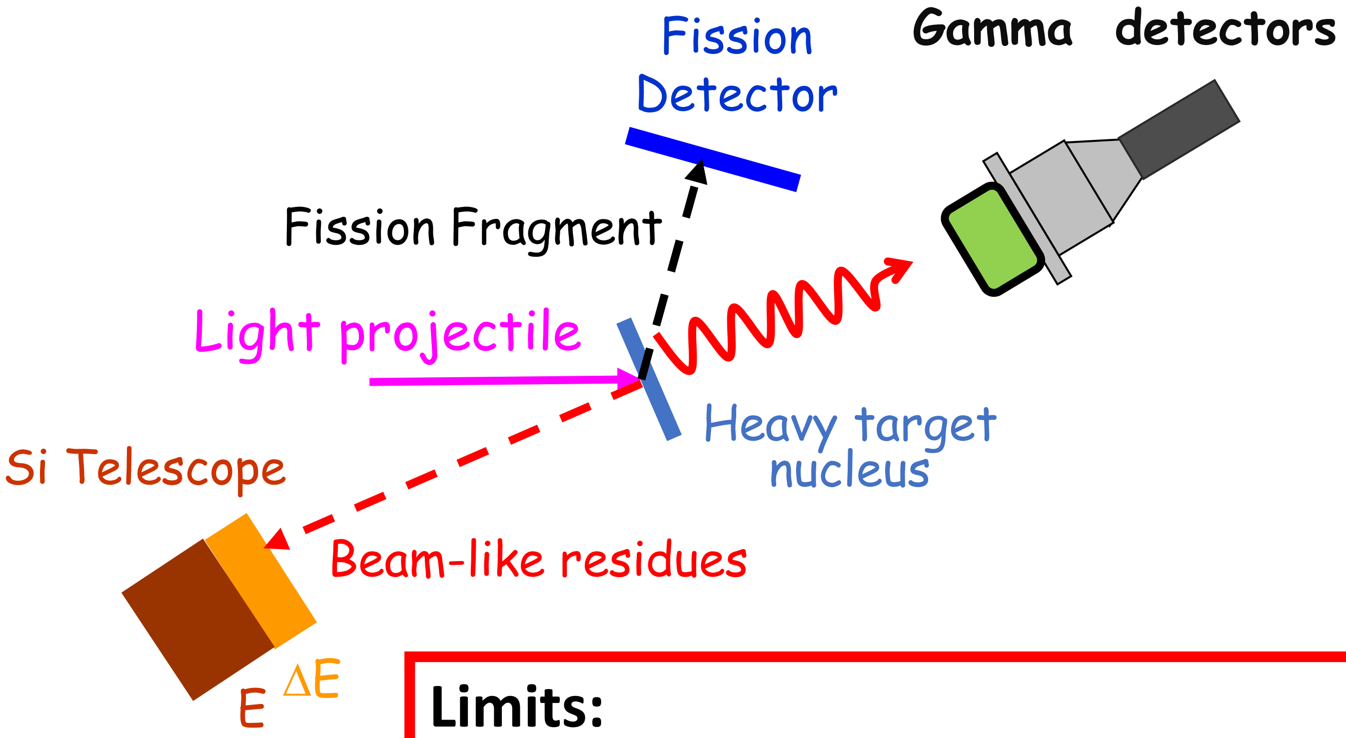
→Complicated to calculate due to the difficulty to describe the de-excitation process. Calculations can be wrong by several orders of magnitude!

Surrogate-reaction method



Decay probabilities as a function of excitation energy are precious observables to constrain models and provide much more accurate predictions for neutron-induced cross-sections of nuclei far from stability.

Setup for the study of surrogate reactions in direct kinematics



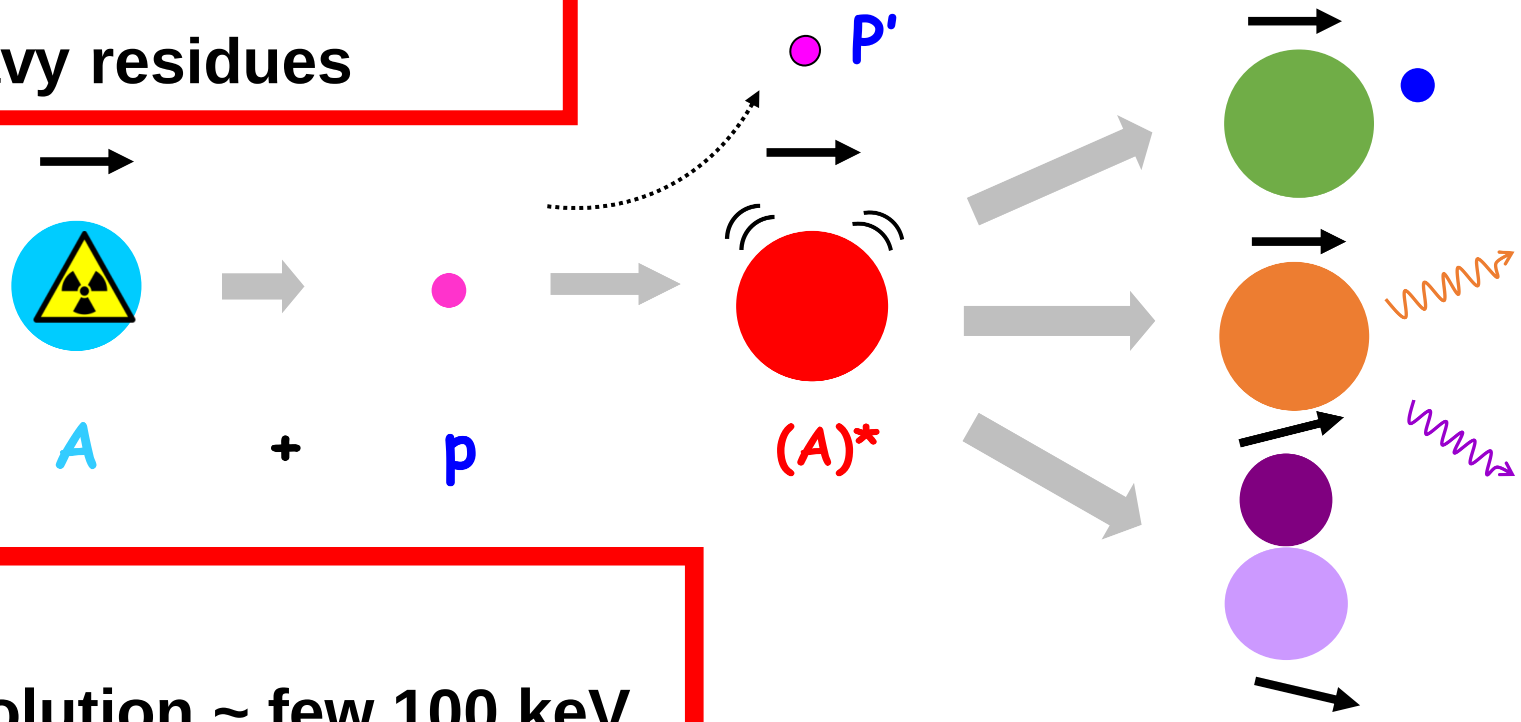
Limits:

- **Unavailability of targets (radioactive samples)**
- **Target contaminants and target support**
- **P_γ : rather low detection efficiency**
- **P_n: measurement of low-energy neutrons and neutron efficiency**

Advantages of Inverse kinematics:

-Access to very short-lived nuclei

-Detection of heavy residues



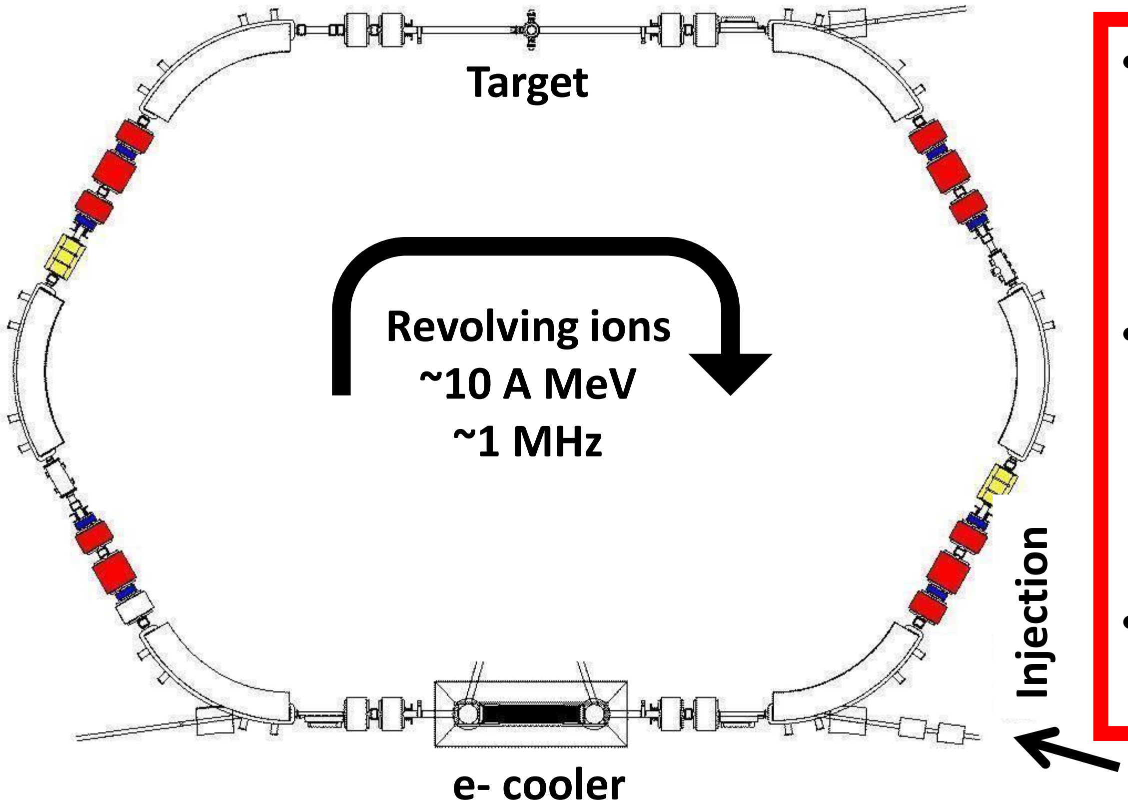
BUT!

- **Required E* resolution ~ few 100 keV, $E^*=f(E_{beam}, E_{target\_like}, \theta)$**
- **Target contaminants and target windows have to be avoided**

STORAGE RINGS!

Advantages of heavy-ion storage rings

The ESR at GSI/FAIR, Darmstadt, Germany



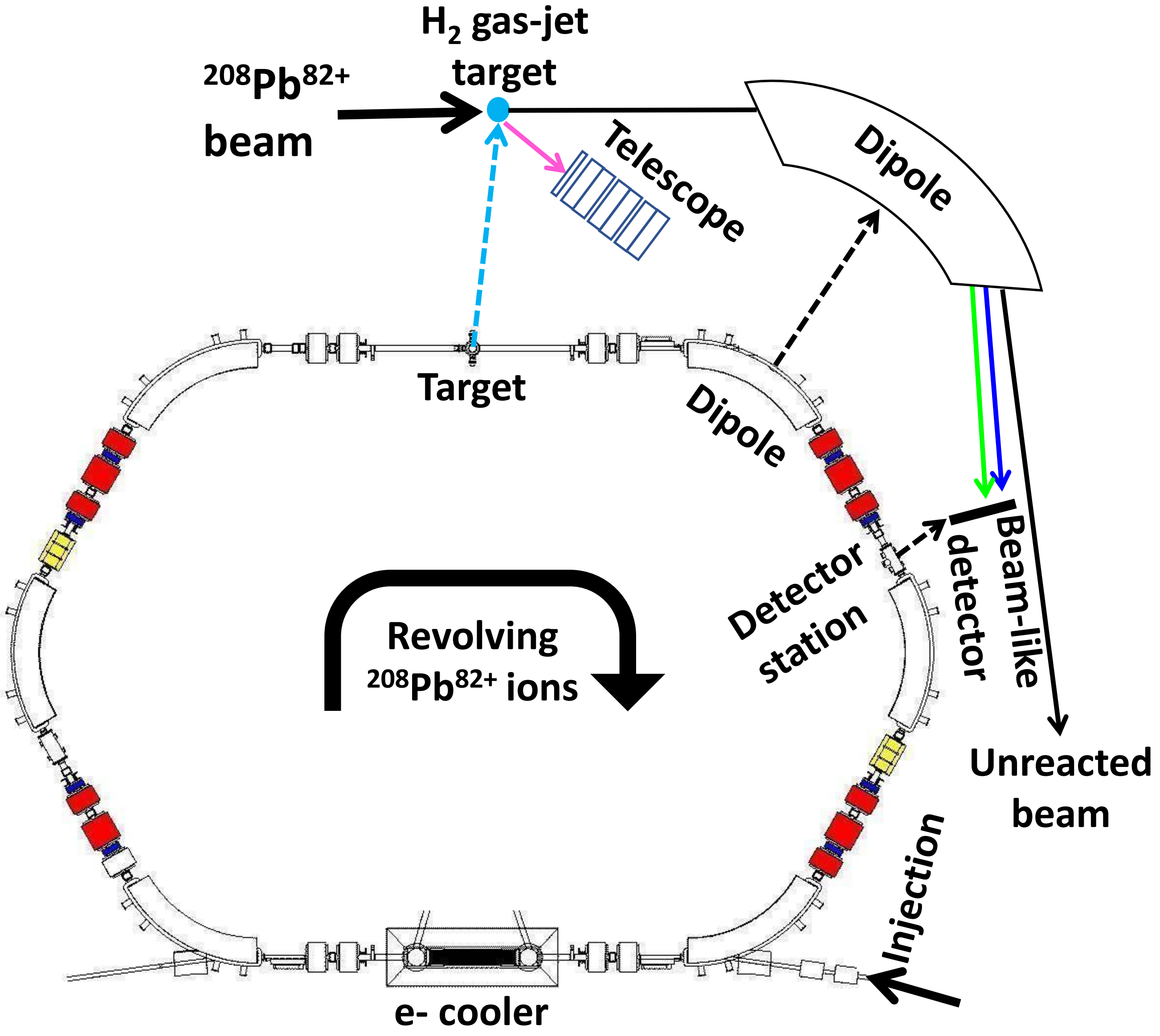
Circunference of ~ 108 m

- **Beam cooling → Excellent energy and position resolution of the beam, maintained after each passage through the target, negligible, E-loss & straggling effects**
- **Use of ultra-low density in-ring gas-jet targets ~10^{13}/cm^2.**

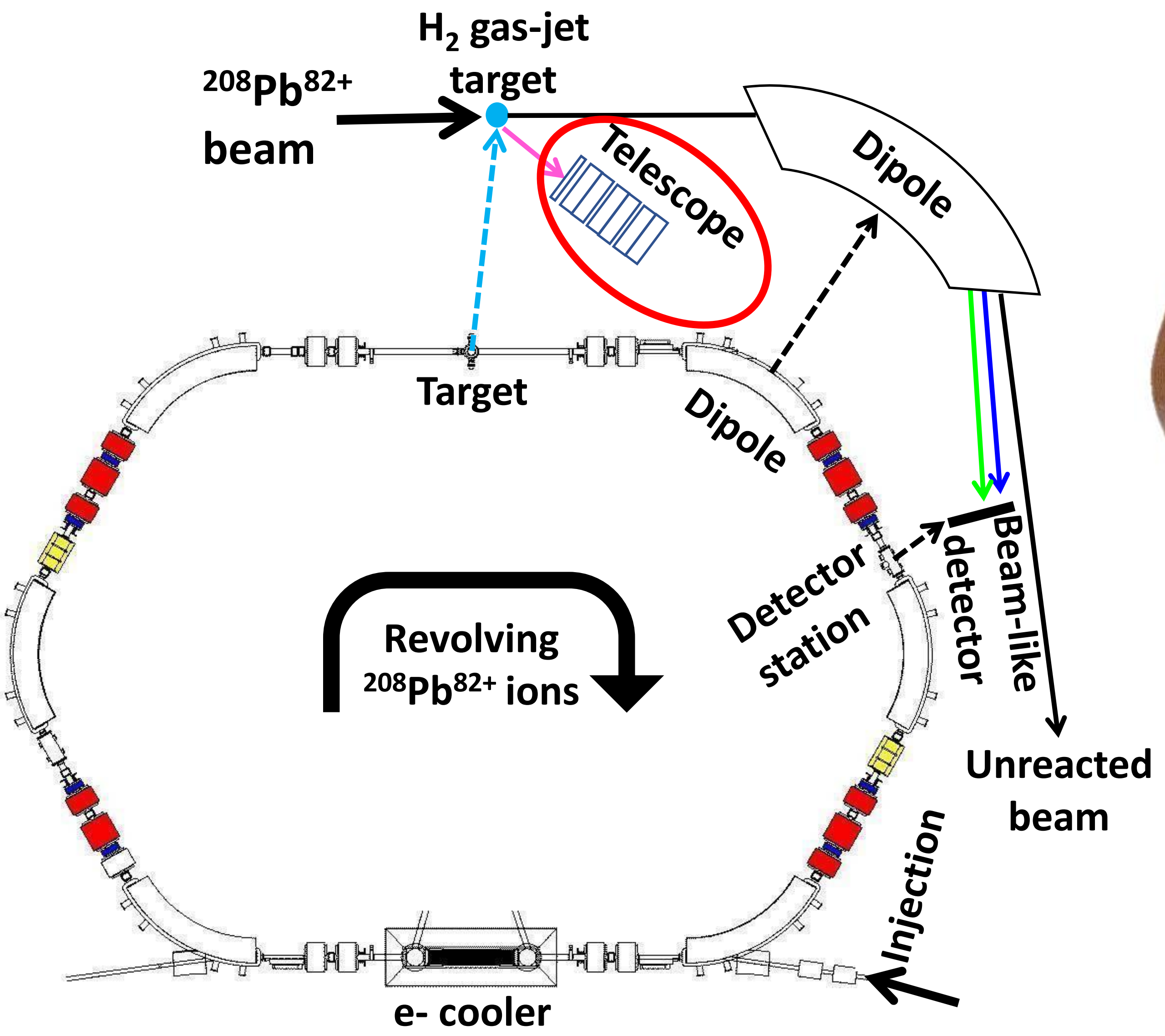
  Effective target thickness increased by ~10^6 due to revolution frequency (at 10 A MeV)
- **High-quality, pure, fully-stripped beams and pure, ultra-thin, windowless targets→ unique!**

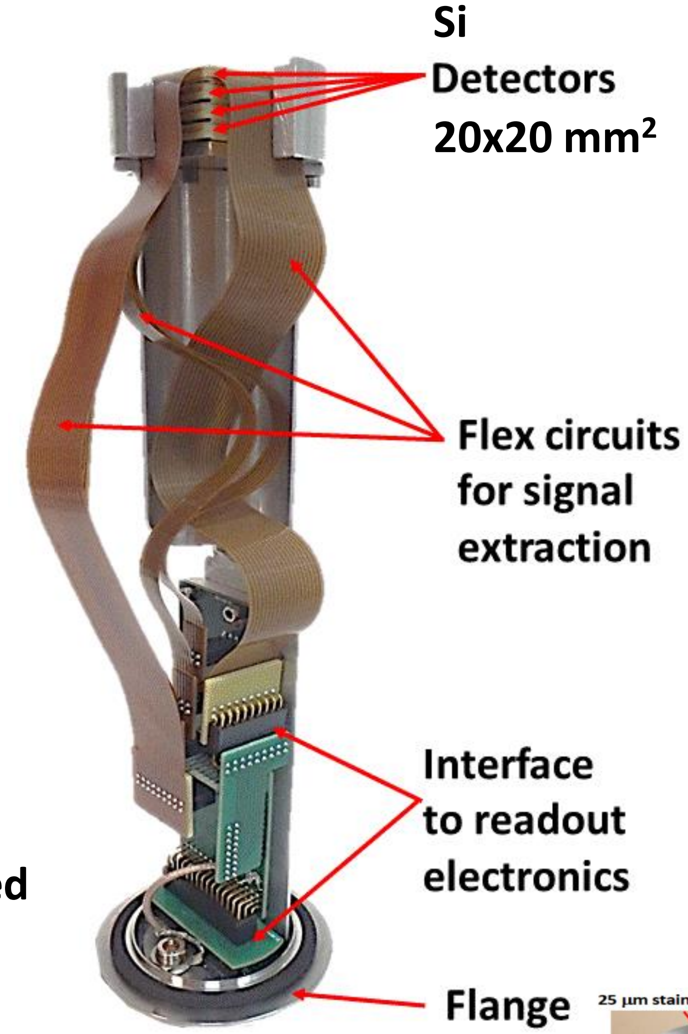
Challenge: Detectors in Ultra-High Vacuum (10^{-10}-10^{-11} mbar)!

First surrogate reaction experiment at the ESR, 20-27 June 2022
208Pb+p→208Pb*+p'

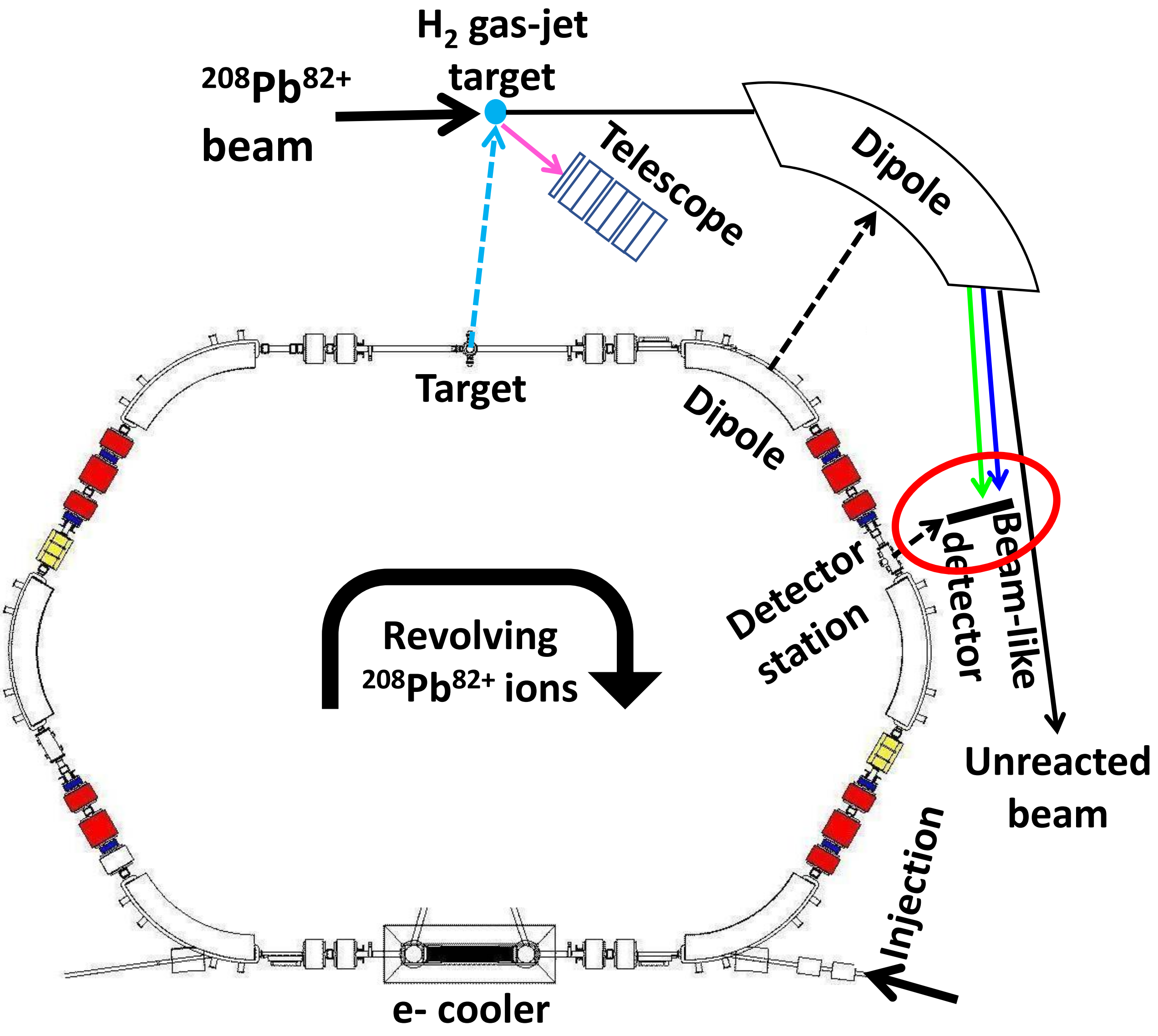


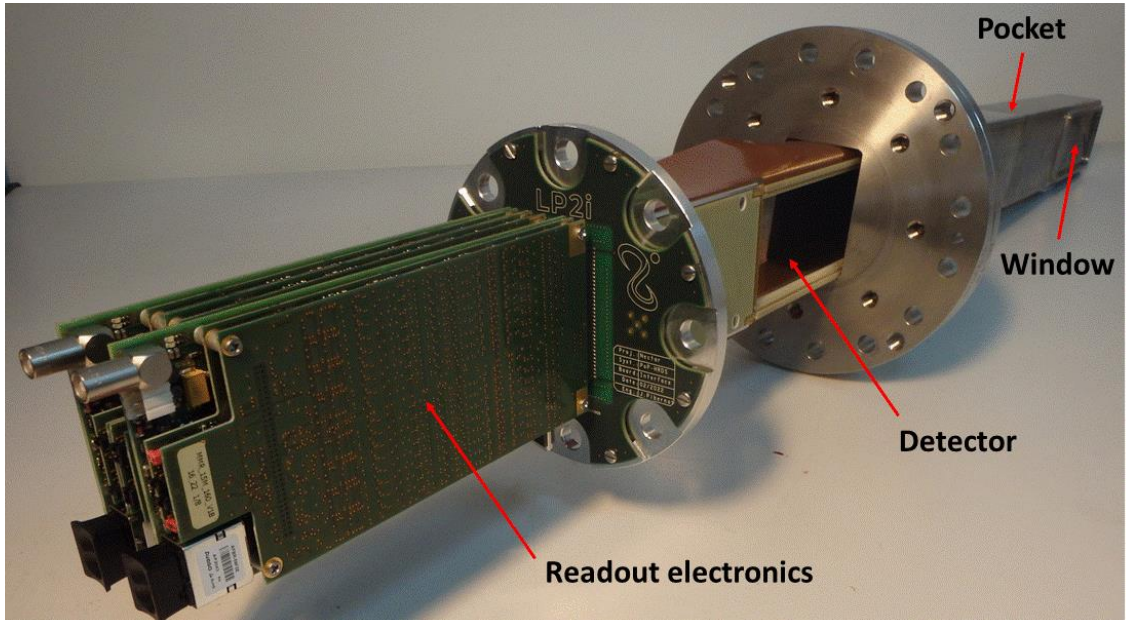
First surrogate reaction experiment at the ESR, telescope

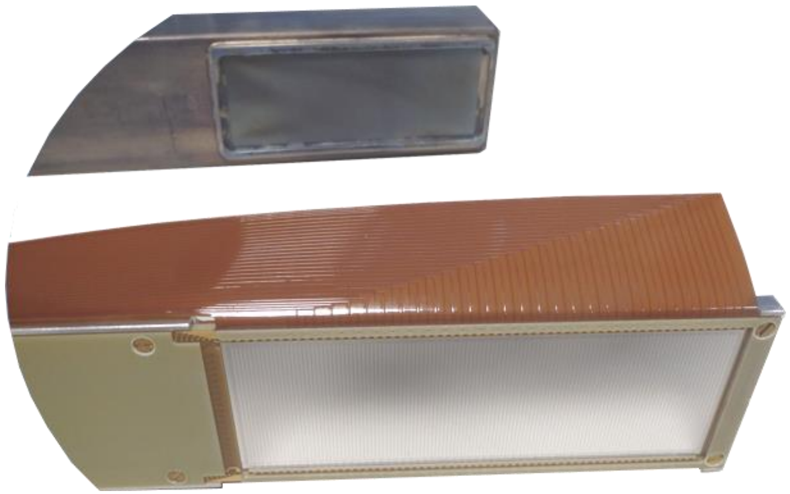




First surrogate reaction experiment at the ESR, beam-like residue detector system

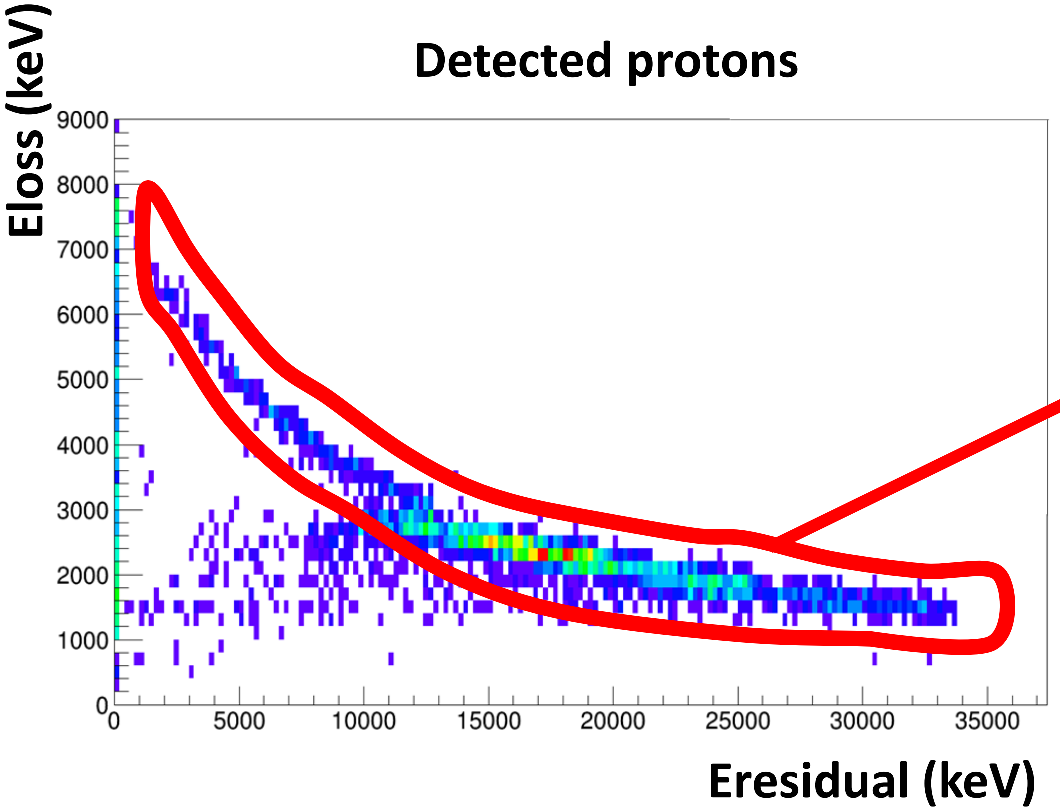


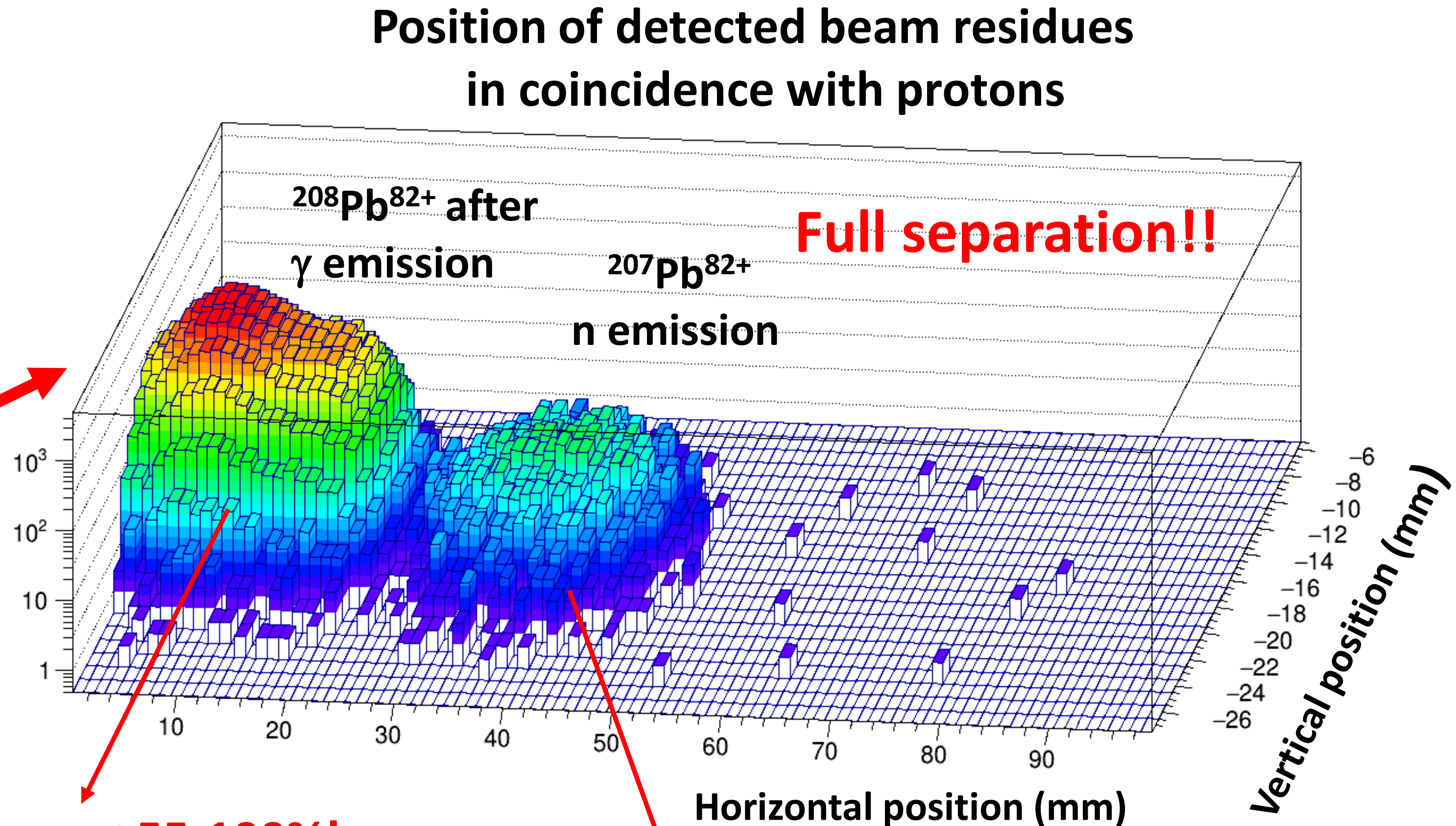




40x120 mm^2
stainless steel
window of 25 μm!
Double sided Si
strip detector

Preliminary results, detection of beam-like residues





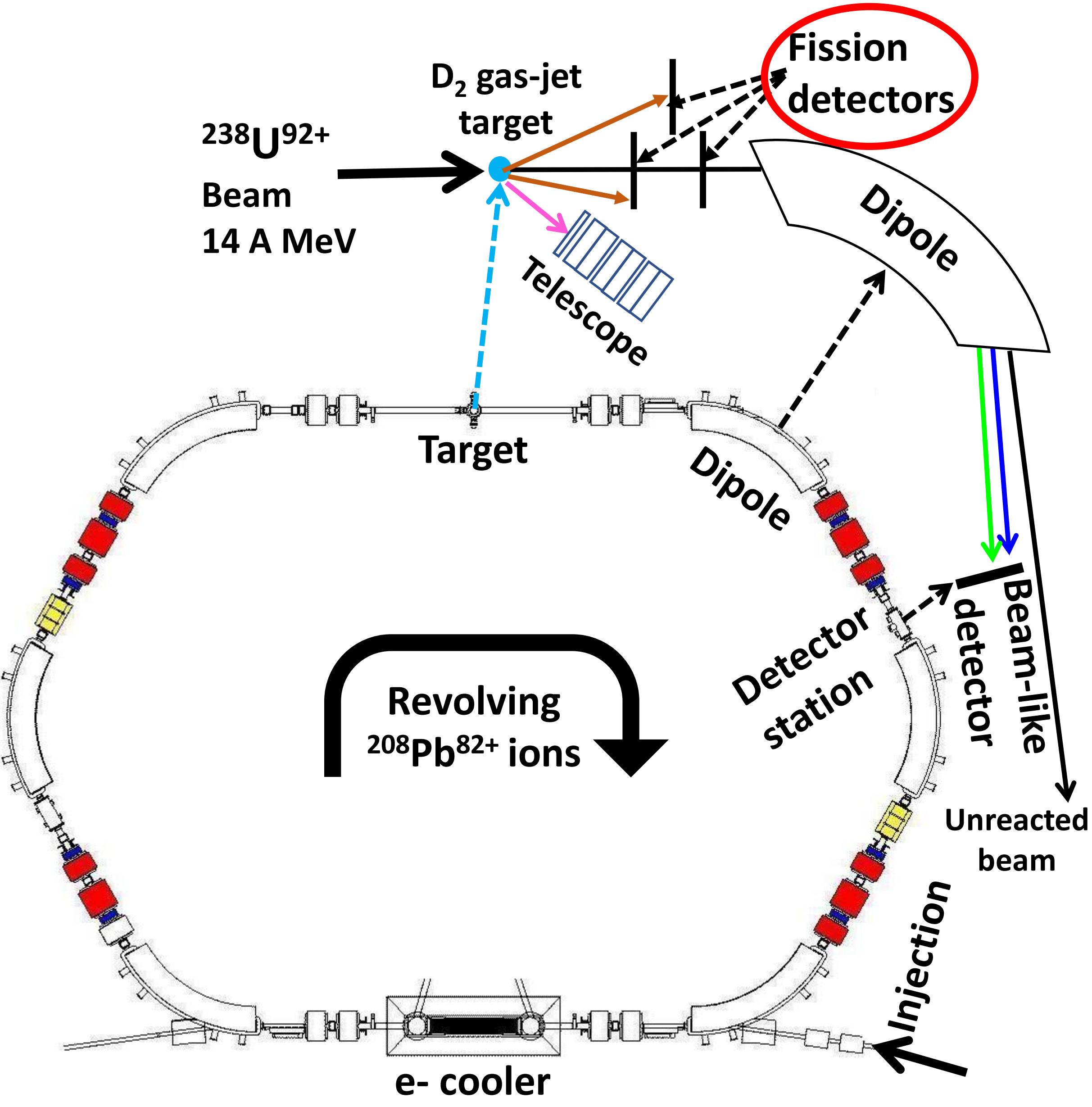
Efficiency ~55-100%!
≈ 5% in direct kinematics…

Efficiency 100%!
0% in direct kinematics…

PhD Thesis of Michele Sguazzin

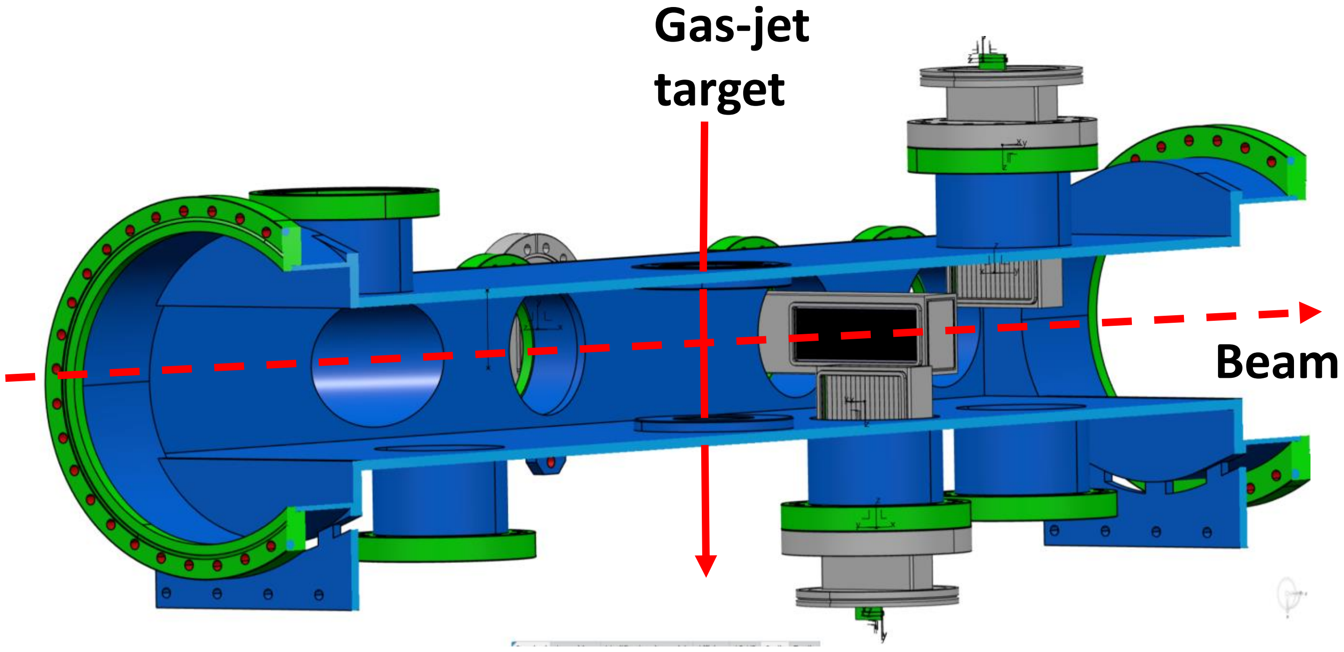
Perspectives

Next experiment (June 2024), measure simultaneously fission, neutron and gamma-emission probabilities

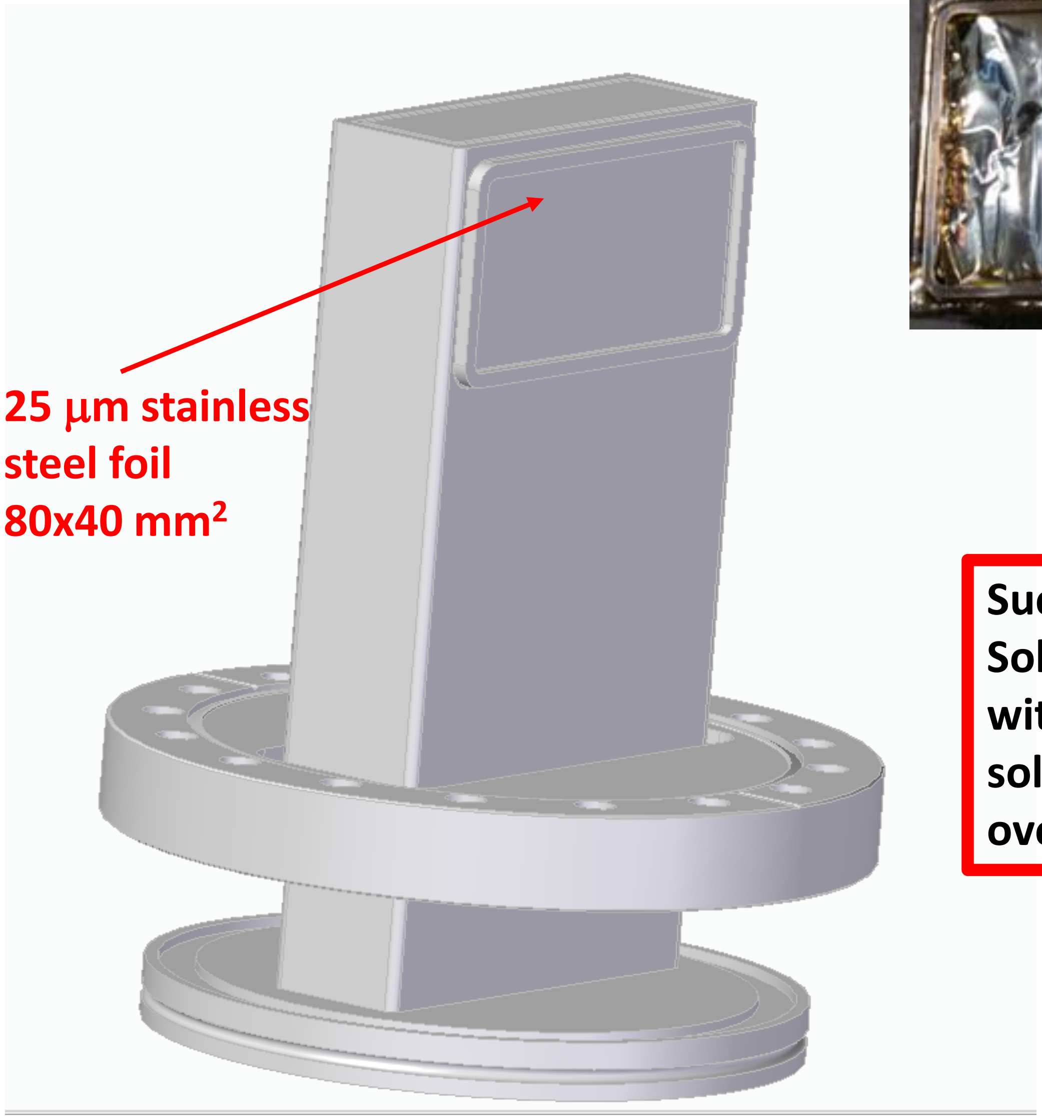


Add fission detectors.

First time that fission is studied in a storage ring!

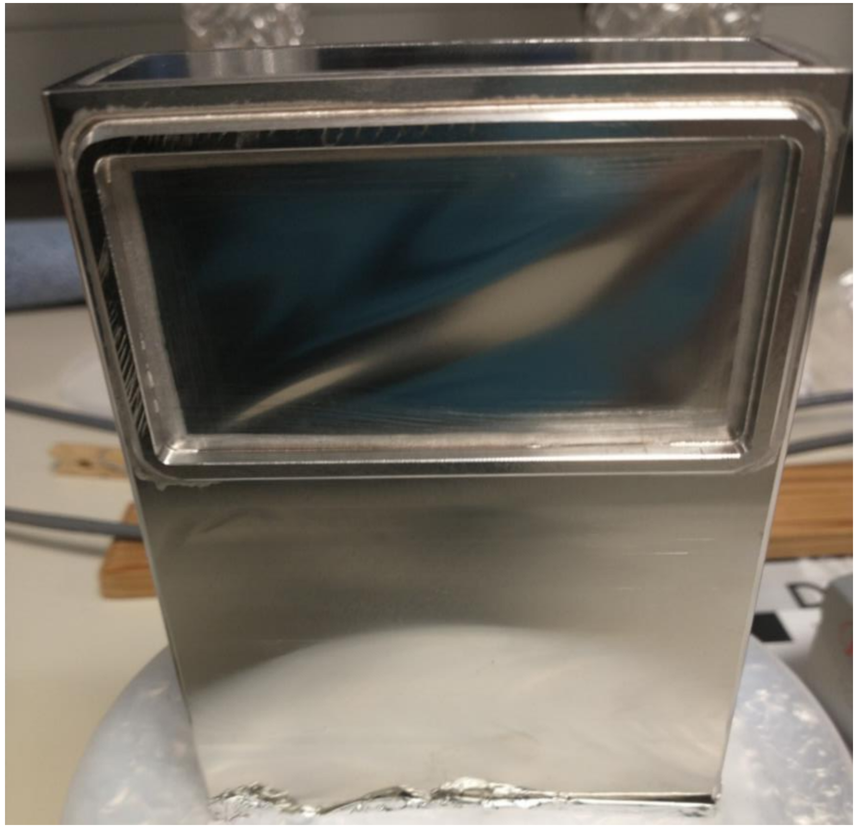


Production of pockets for fission detectors (Max-Planck-Institute for Nuclear Physics, Heidelberg)

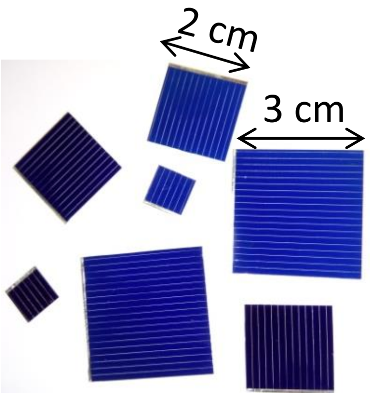


Many failures until finding the appropriate procedure for soldering the window and Making it vacuum tight!

Successful procedure:
Soldering in a vacuum oven with careful selection of soldering material and oven temperature profile!

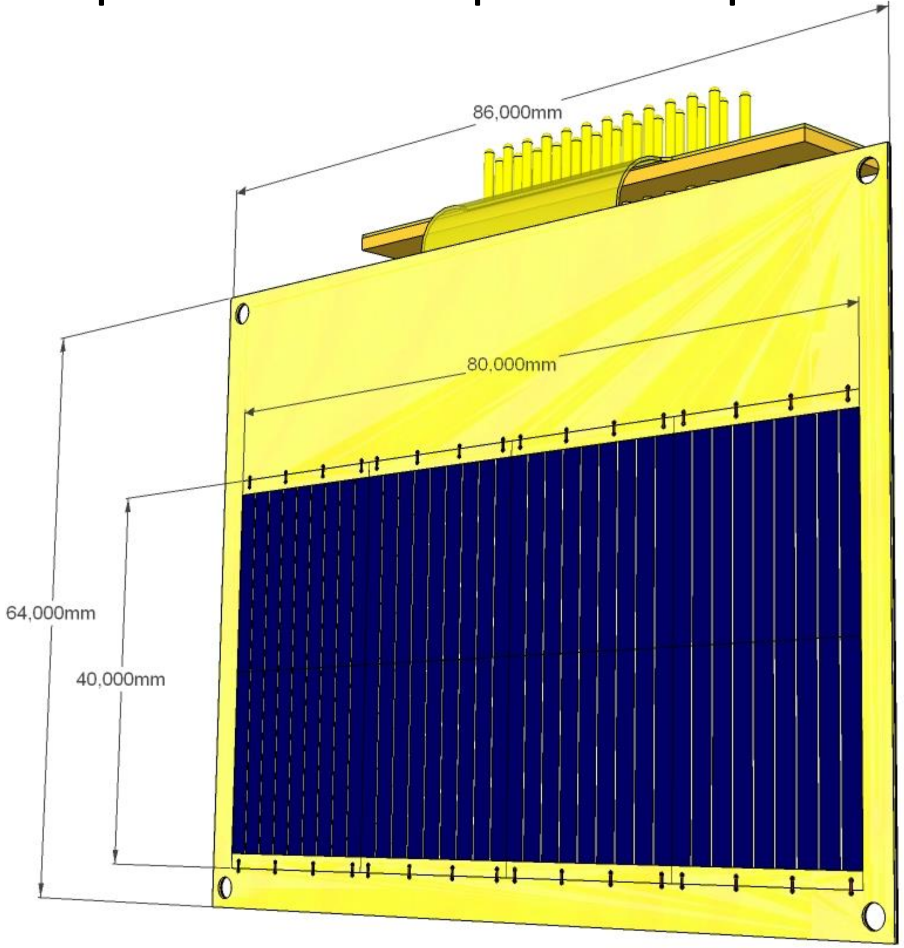


Solar cells, interesting alternative to Si detectors for heavy-ion detection



Jerome Pibernat, IR, LP2I Bordeaux

Development of specific preamps!
Development of encapsulation procedure!



Advantages:

→Good energy and time resolution!

→More resistant to radiation damage, more robust than Si detectors!

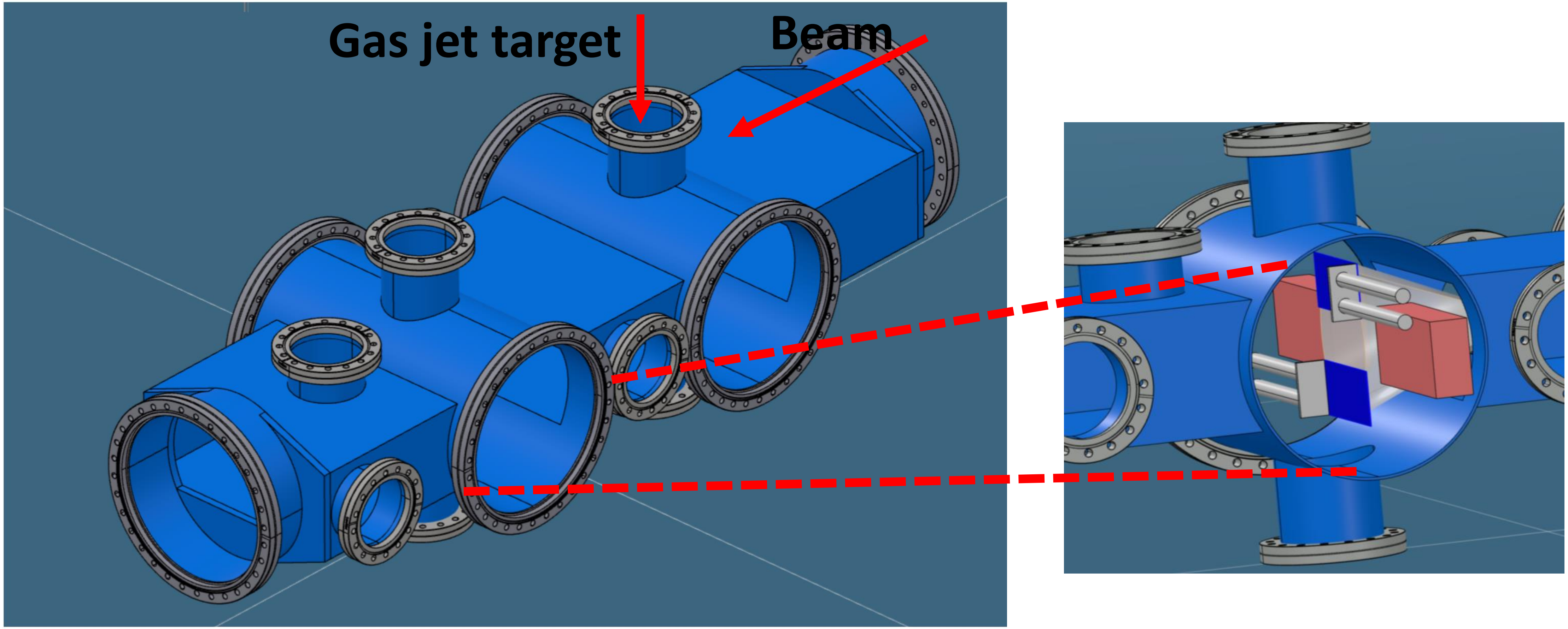
→Low cost (about 5 Euros!) compared to 2000-3000 Euros for Si detectors!

Challenges:

- **Specific electronics to cope with large capacitance.**
- **Ultra high vacuum compatibility of supports, cables, etc.**

Perspectives

Construction of a dedicated reaction chamber for the ESR, significant increase of detection efficiencies for target residues and fission fragments!



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NECTAR: Nuclear rEaCTions At storage Rings

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