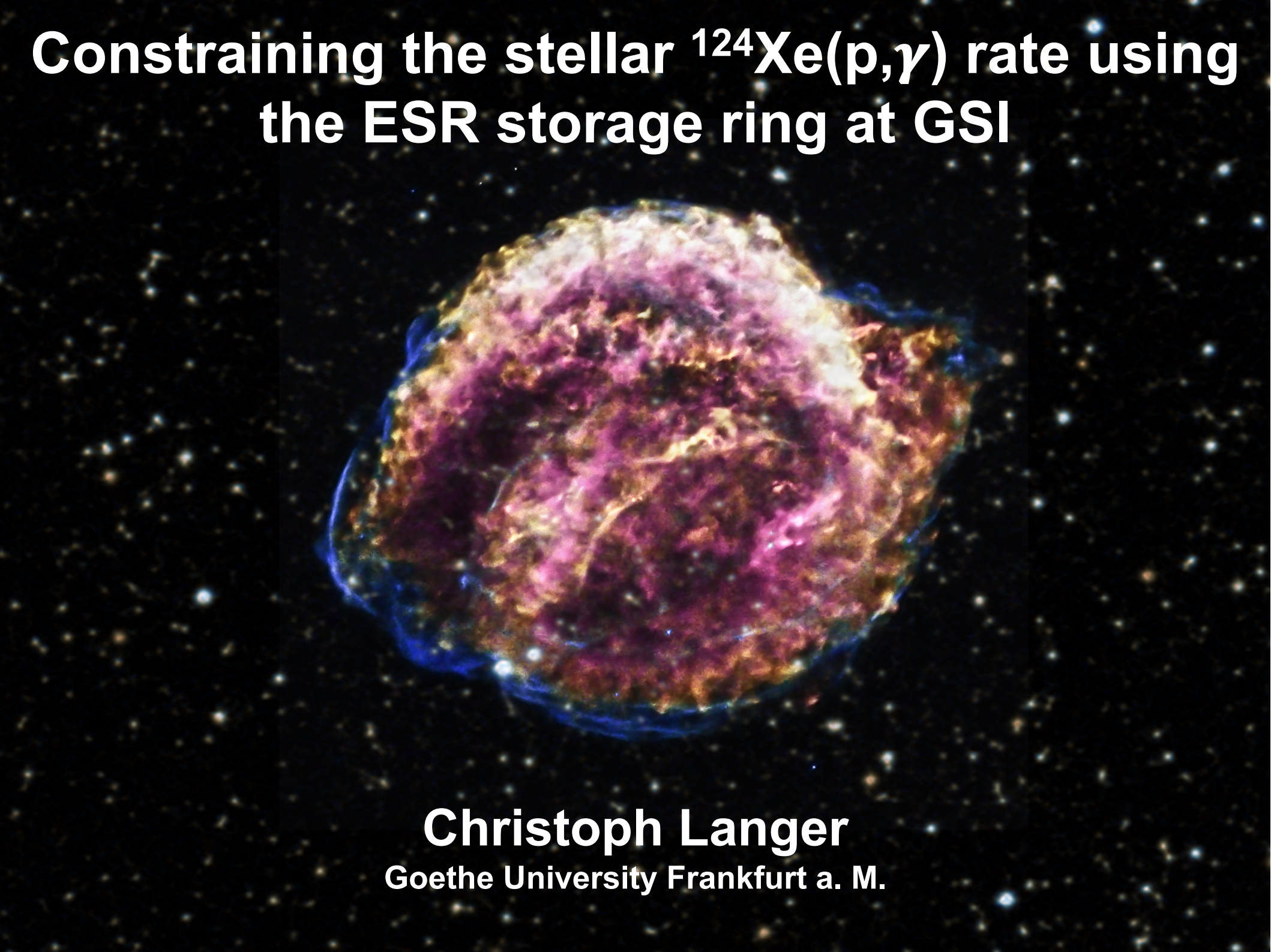
Constraining the stellar ^{124}Xe(p,γ) rate using the ESR storage ring at GSI

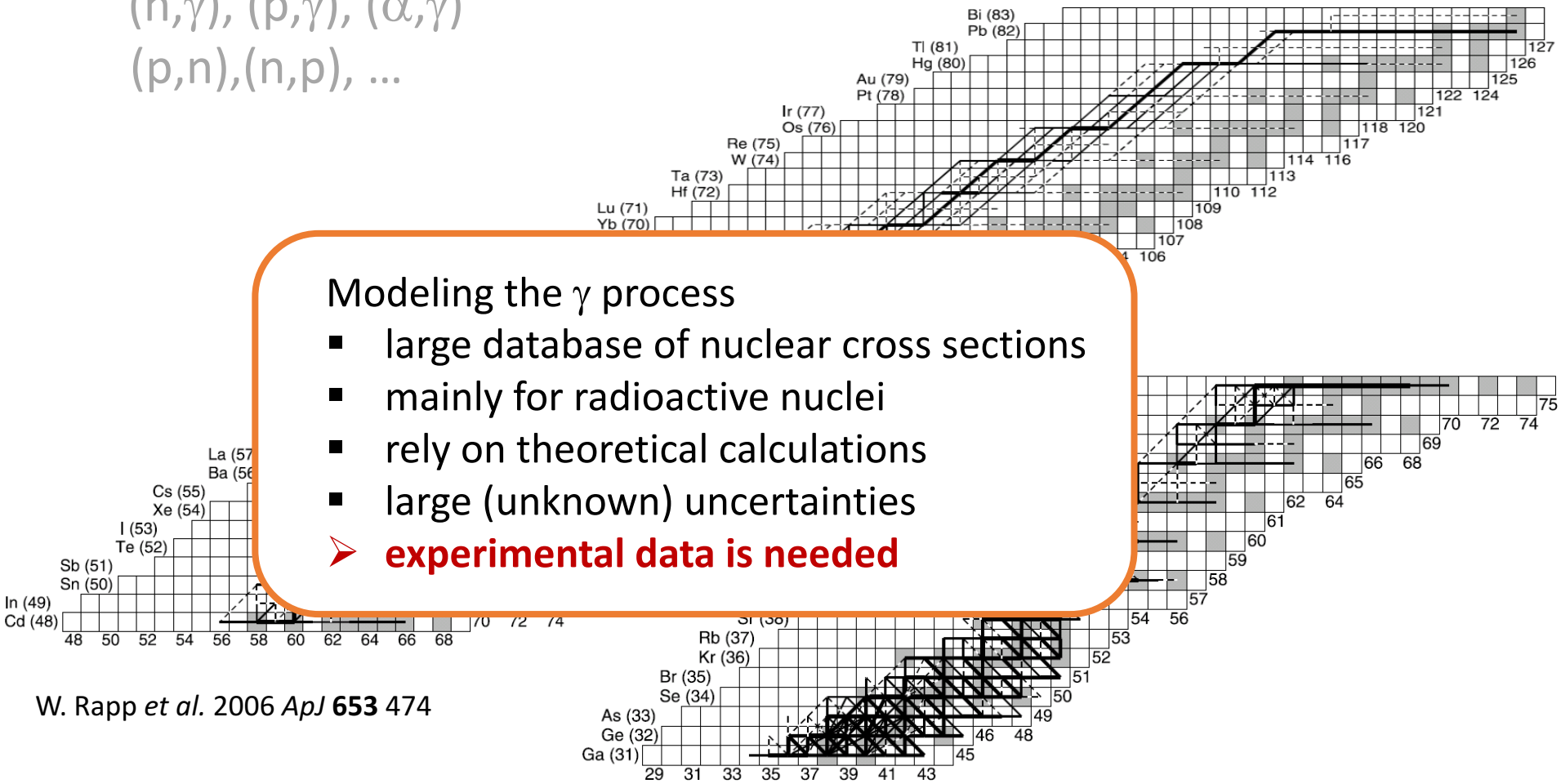


Christoph Langer

Goethe University Frankfurt a. M.

- mainly photon-induced reactions (and reverse)

  (γ,n), (γ,p), (γ,α)
  (n,γ), (p,γ), (α,γ)
  (p,n),(n,p), …



Modeling the γ process

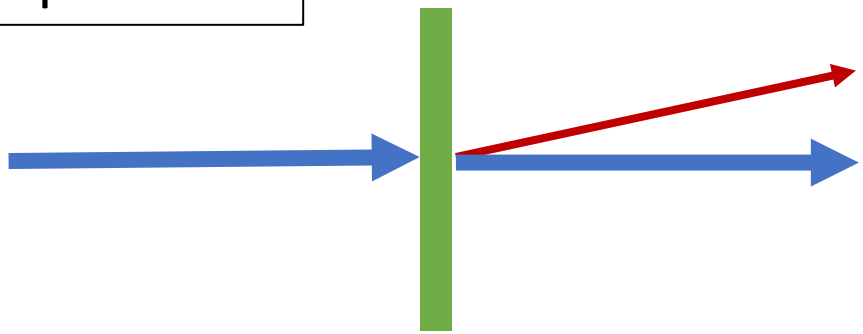
- large database of nuclear cross sections
- mainly for radioactive nuclei
- rely on theoretical calculations
- large (unknown) uncertainties

➢ **experimental data is needed**

W. Rapp *et al.* 2006 *ApJ* **653** 474

Typical problems with direct measurements

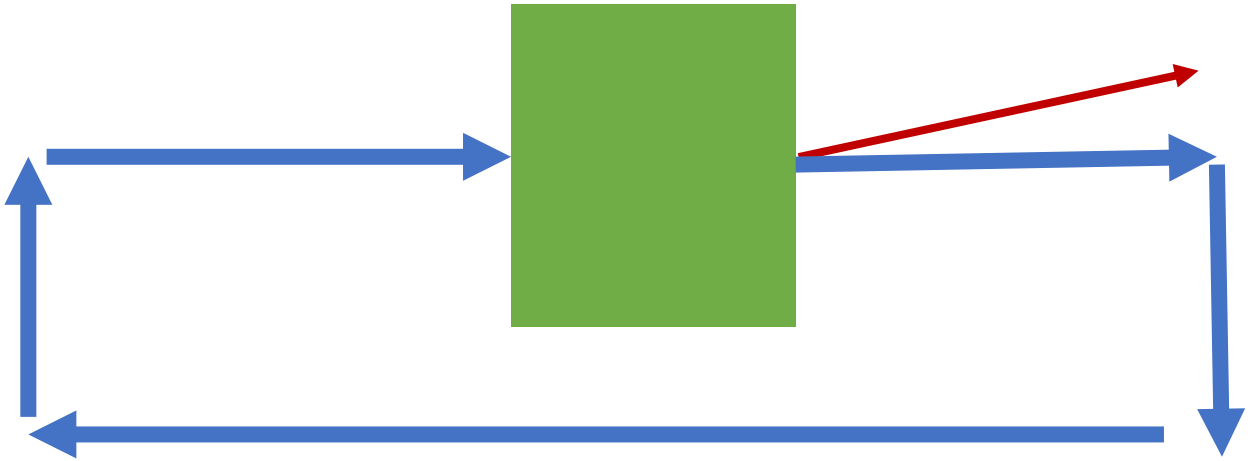
Single pass experiment



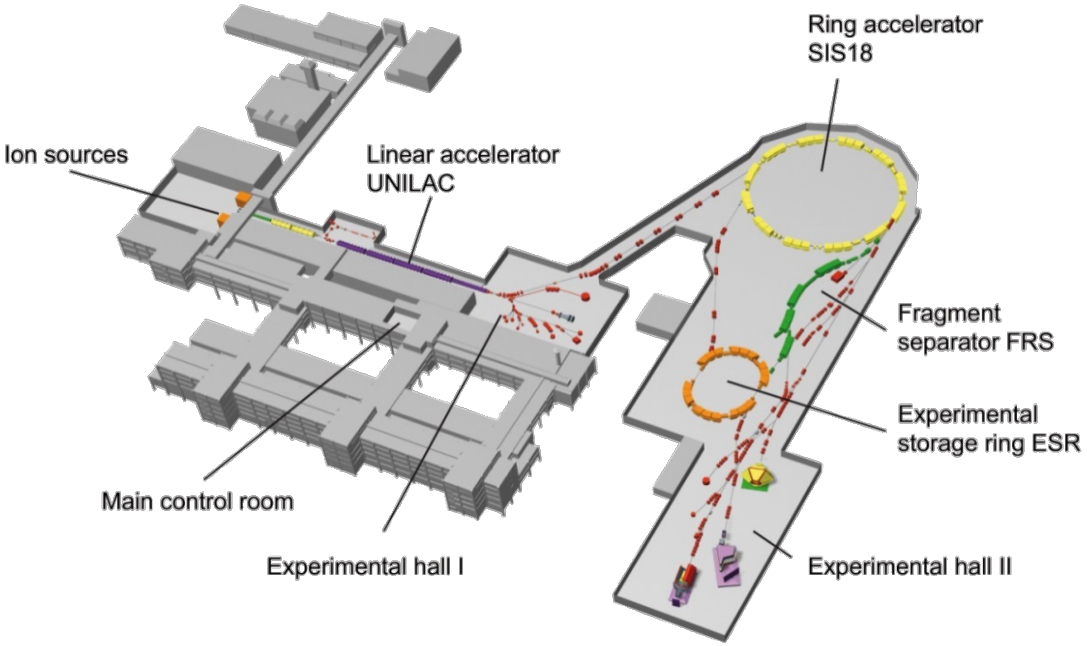
good separation required

Only 1 in 10^{12} fuses, the rest is **lost**

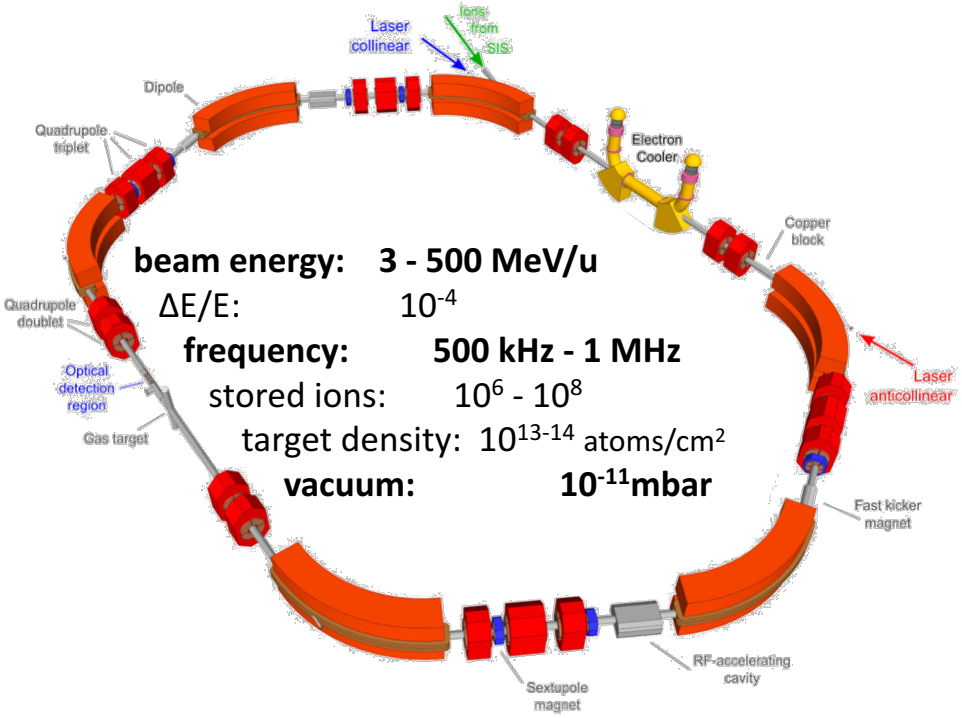
Multi pass experiment



The Experimental Storage Ring



ESR



beam energy: **3 - 500 MeV/u**

ΔE/E: 10^{-4}

frequency: **500 kHz - 1 MHz**

stored ions: 10^{6} - 10^{8}

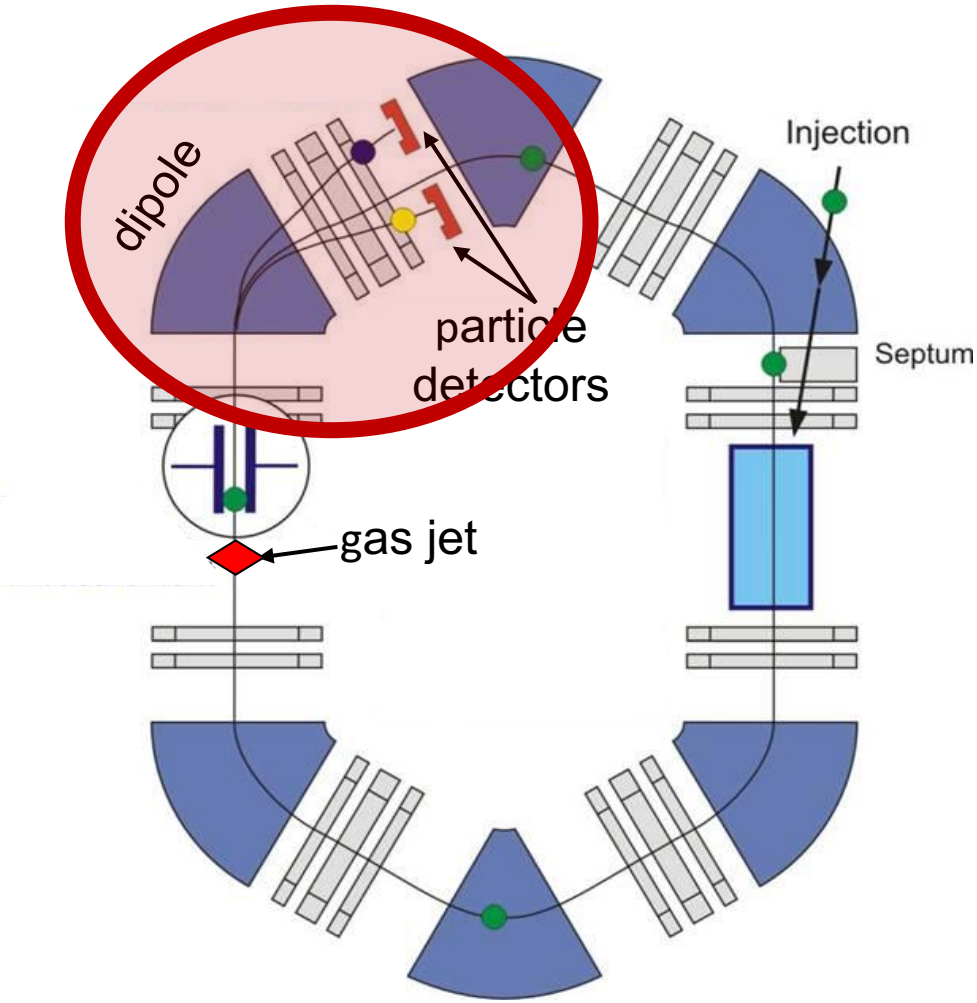
target density: $10^{13\text{-}14}$ atoms/cm^2

vacuum: **10^{-11}mbar**

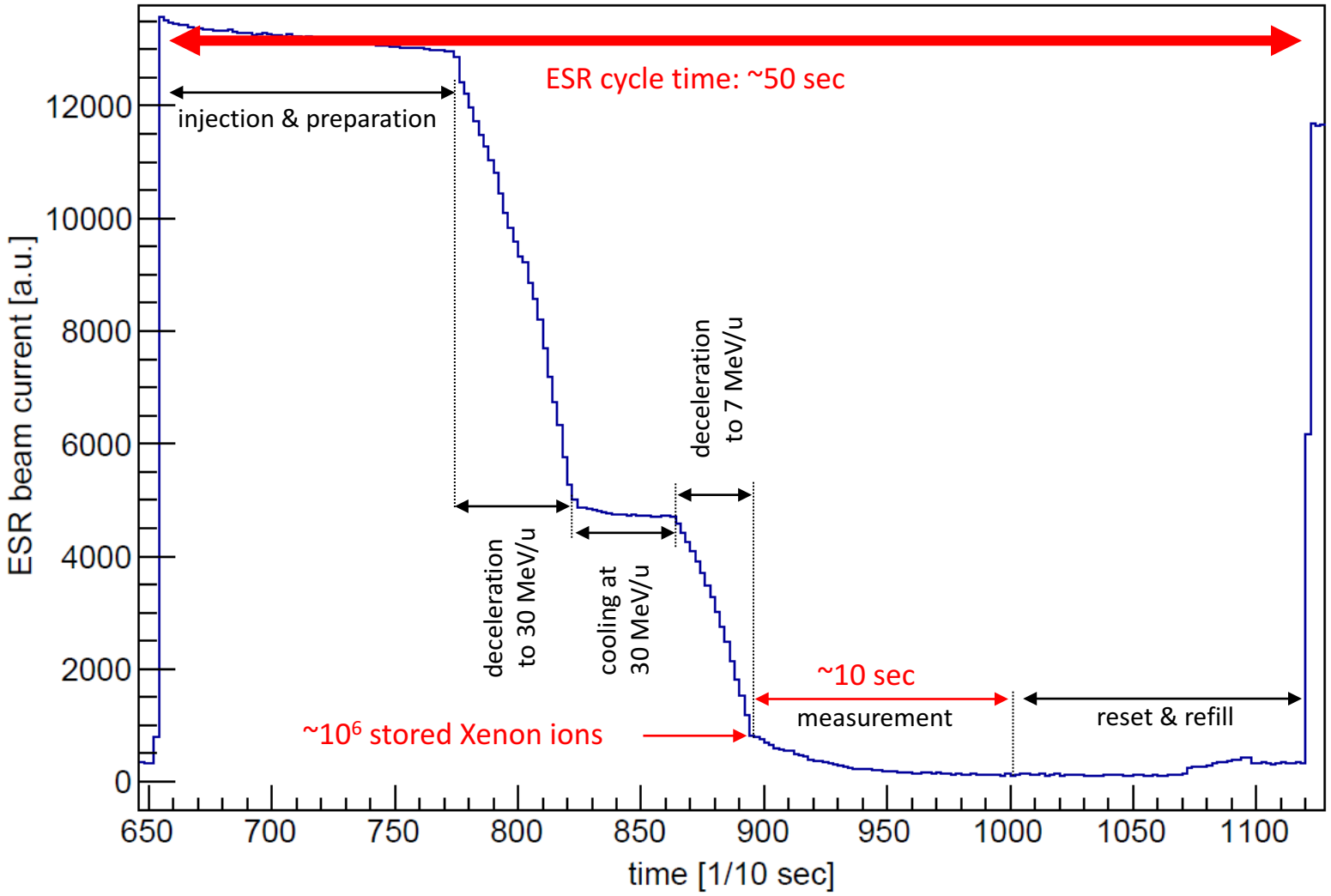
refill ring periodically

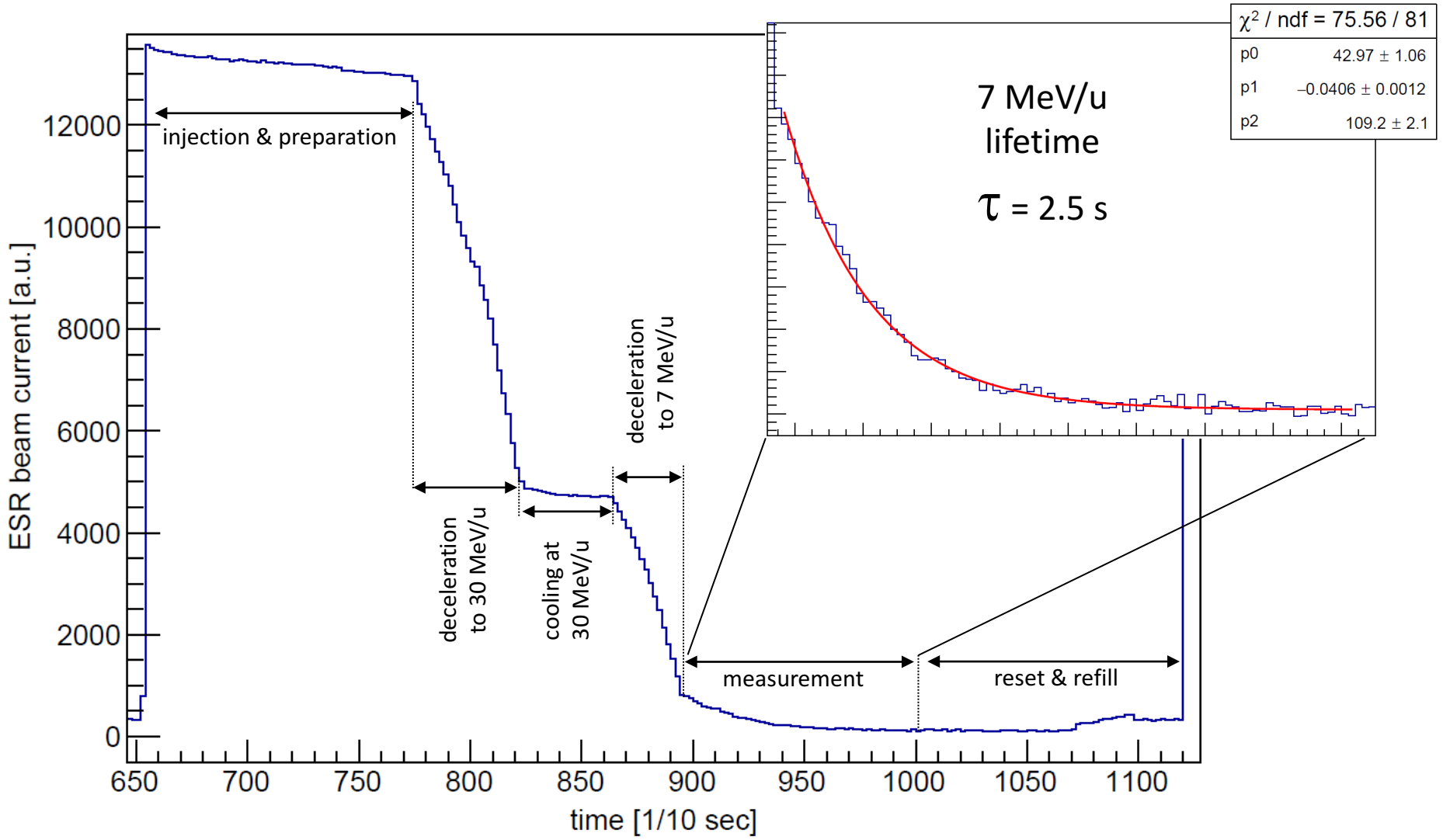
- injection of ions @ 100 MeV/u
  - ✓ **fully stripped ions**
- deceleration & e^--cooling of the beam
  - ✓ **E < 10 MeV/u**
- activate gas target [daq start]
- beam intensity drops over time

$$B\rho = \frac{p}{q}$$



ESR

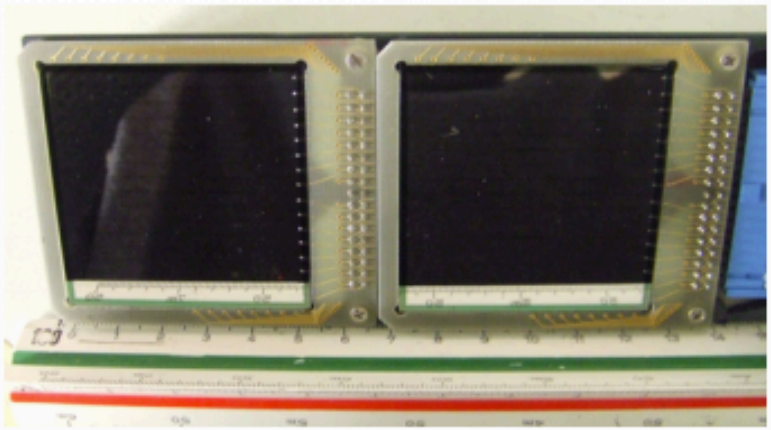

ESR cycle time: ~50 sec
injection & preparation
deceleration to 30 MeV/u
cooling at 30 MeV/u
deceleration to 7 MeV/u
~10 sec
measurement
reset & refill
~10^6 stored Xenon ions
ESR beam current [a.u.]
time [1/10 sec]
0
2000
4000
6000
8000
10000
12000
650
700
750
800
850
900
950
1000
1050
1100

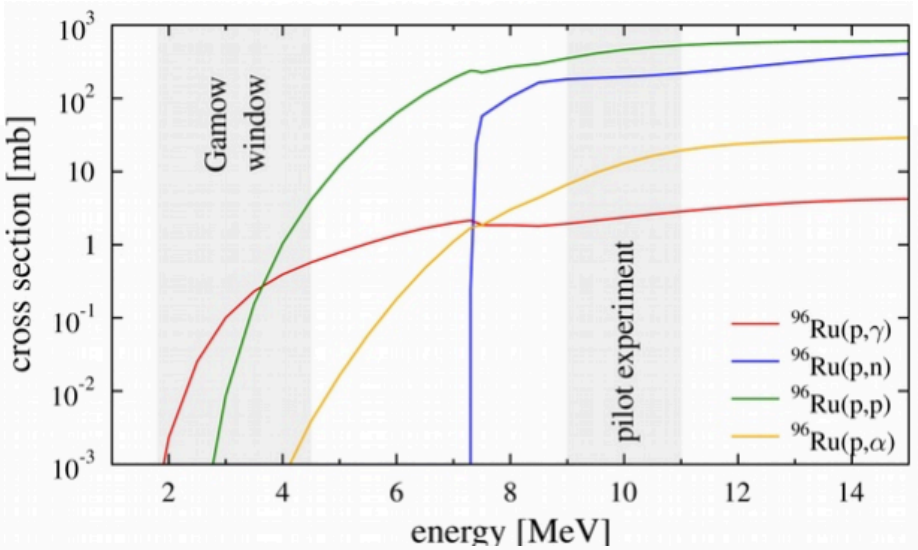

ESR beam current [a.u.]
time [1/10 sec]
injection & preparation
deceleration to 30 MeV/u
cooling at 30 MeV/u
deceleration to 7 MeV/u
measurement
reset & refill
7 MeV/u lifetime
τ = 2.5 s
χ² / ndf = 75.56 / 81
p0 42.97 ± 1.06
p1 −0.0406 ± 0.0012
p2 109.2 ± 2.1

Evolution of this method …

Pilot experiment
^{96}Ru(p, γ)^{97}Rh

2008

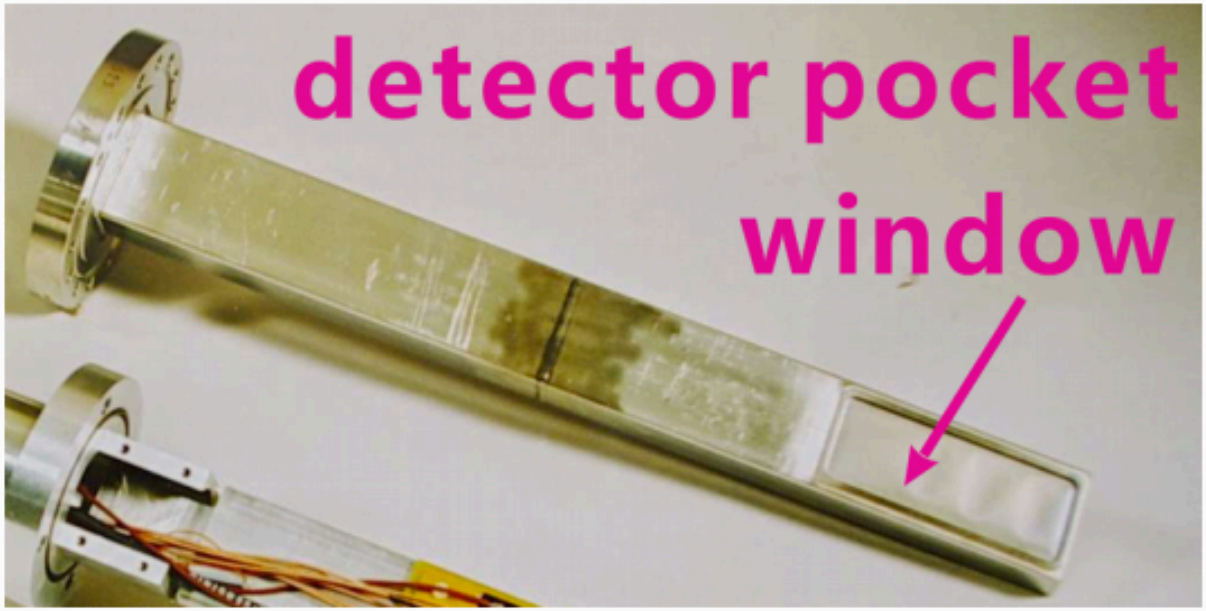


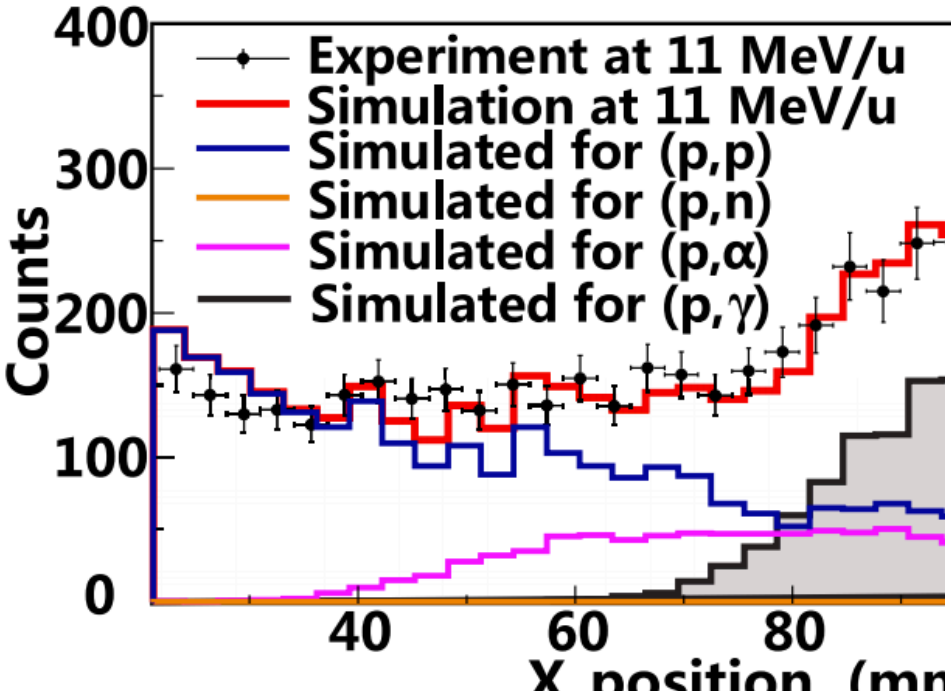


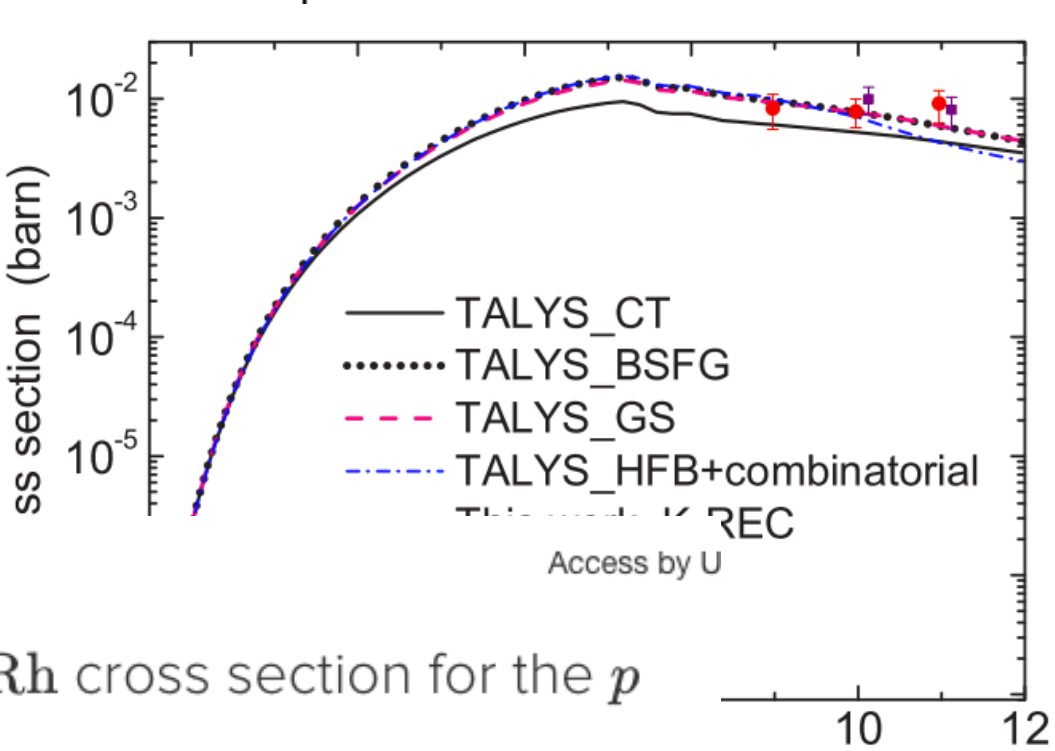
DSSSD (Double Sided Silicon Strip Detectors)

16 x 16 strips
5 x 5 cm²
not UHV compatible

position sensitive







First measurement of the $^{96}\mathrm{Ru}\left(p,\gamma\right)^{97}\mathrm{Rh}$ cross section for the p process with a storage ring

Bo Mei *et al.*
Phys. Rev. C **92**, 035803 – Published 2 September 2015

PHYSICS See Synopsis: Throwing Nuclei in the Ring

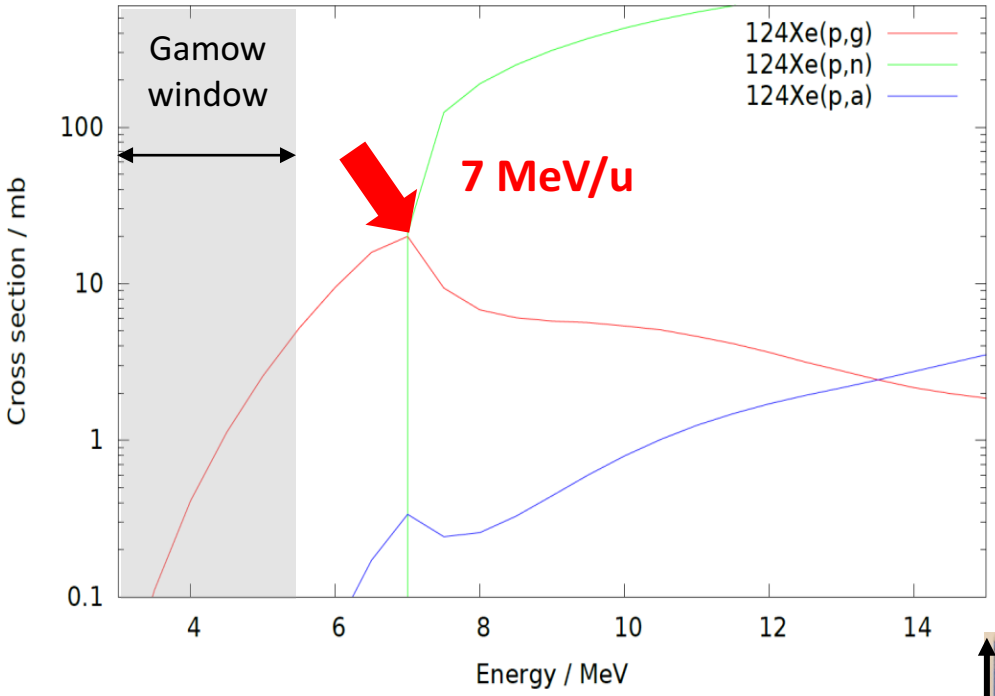
Evolution of this method …

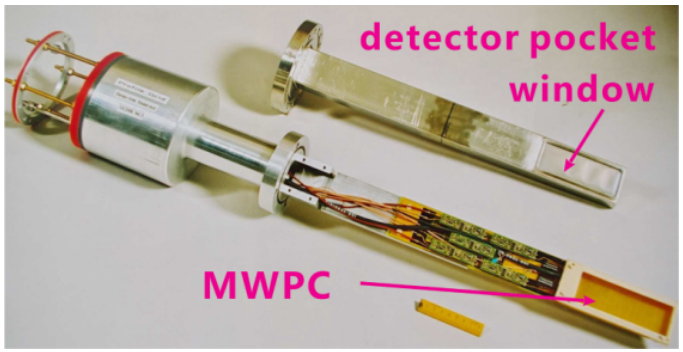
^{124}Xe(p, γ)^{125}Cs in the Gamow window

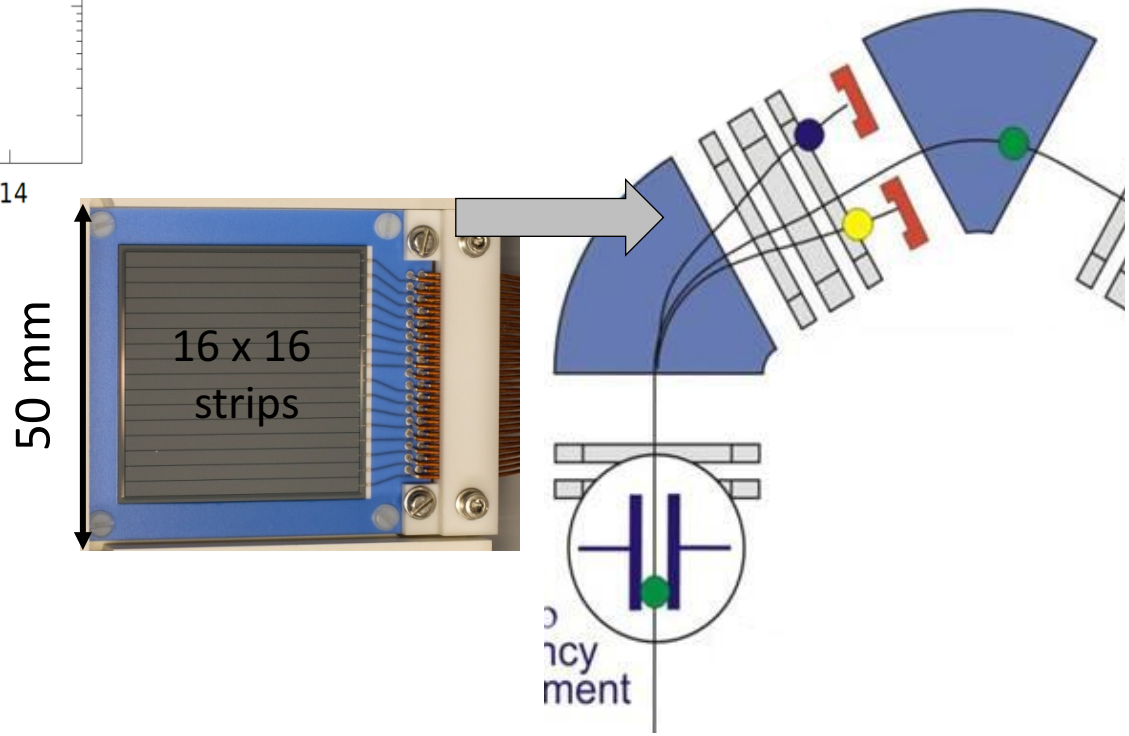
Pilot experiment ^{96}Ru(p, γ)^{97}Rh

2008 2014

TALYS code: theory cross section





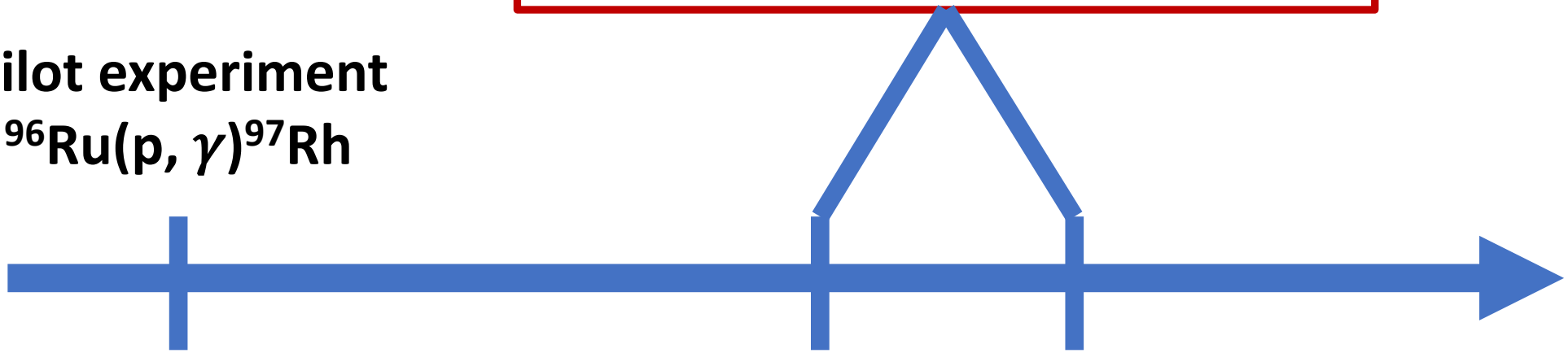



E O B !!

Evolution of this method …

^{124}Xe(p, γ)^{125}Cs in the Gamow window

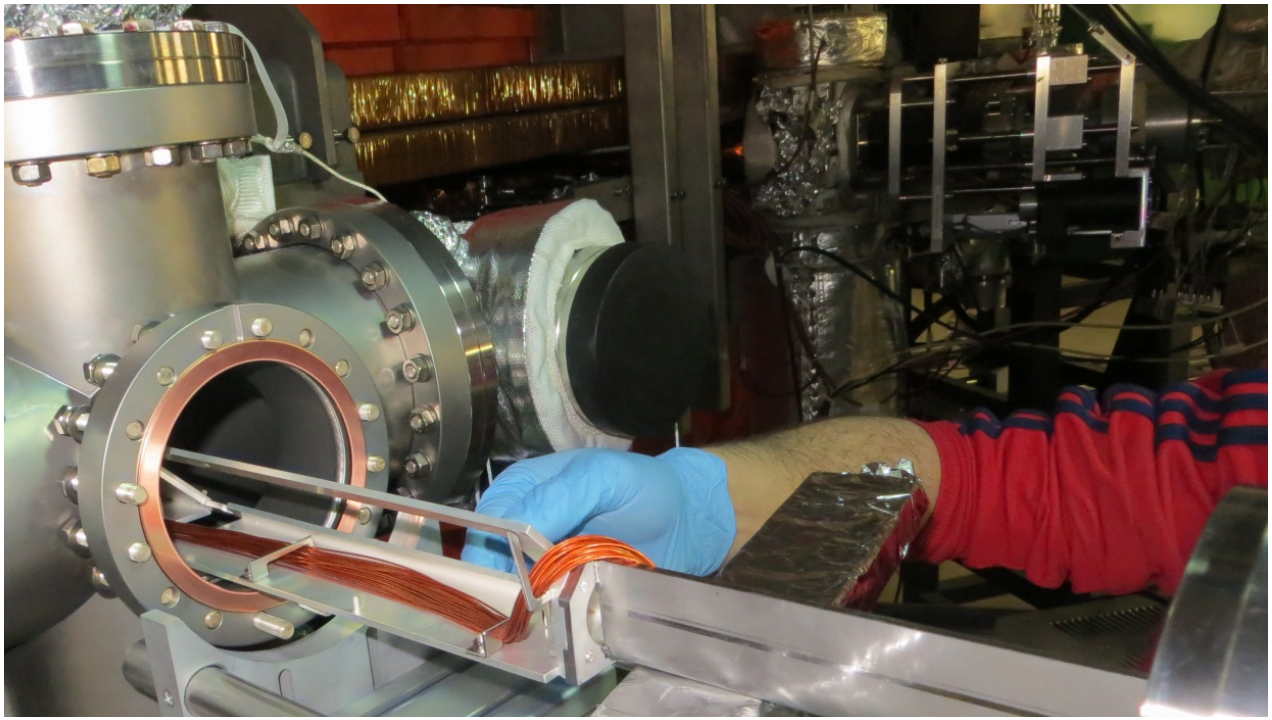
Pilot experiment ^{96}Ru(p, γ)^{97}Rh

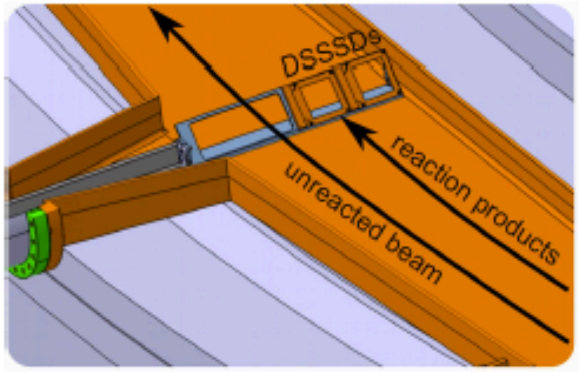


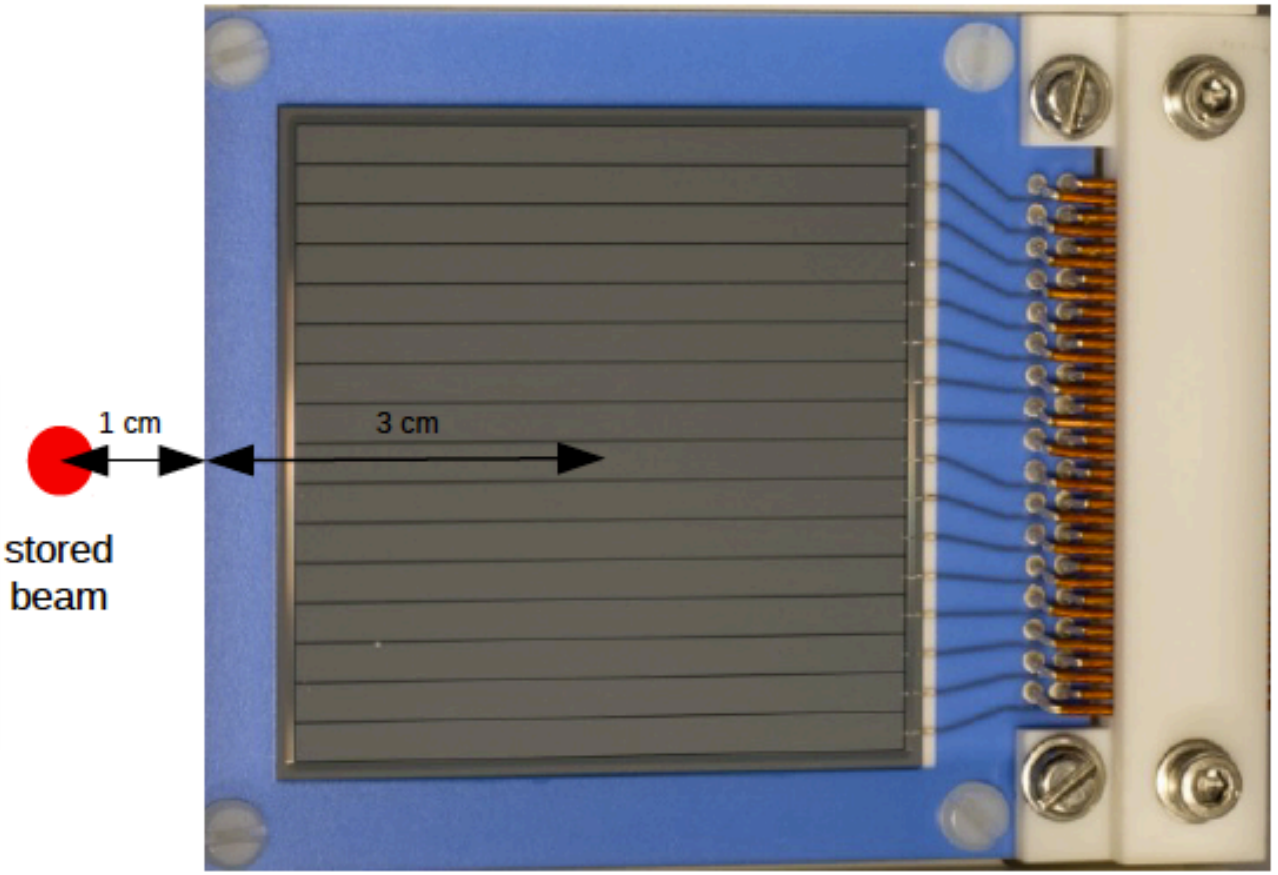
2008 2014 2016

Preparations: bring detector to ring vacuum

- goal: 10^{-11} mbar
- achieved: 5×10^{-10} mbar




DSSSDs
reaction products
unreacted beam


1 cm
3 cm
stored beam

Evolution of this method …

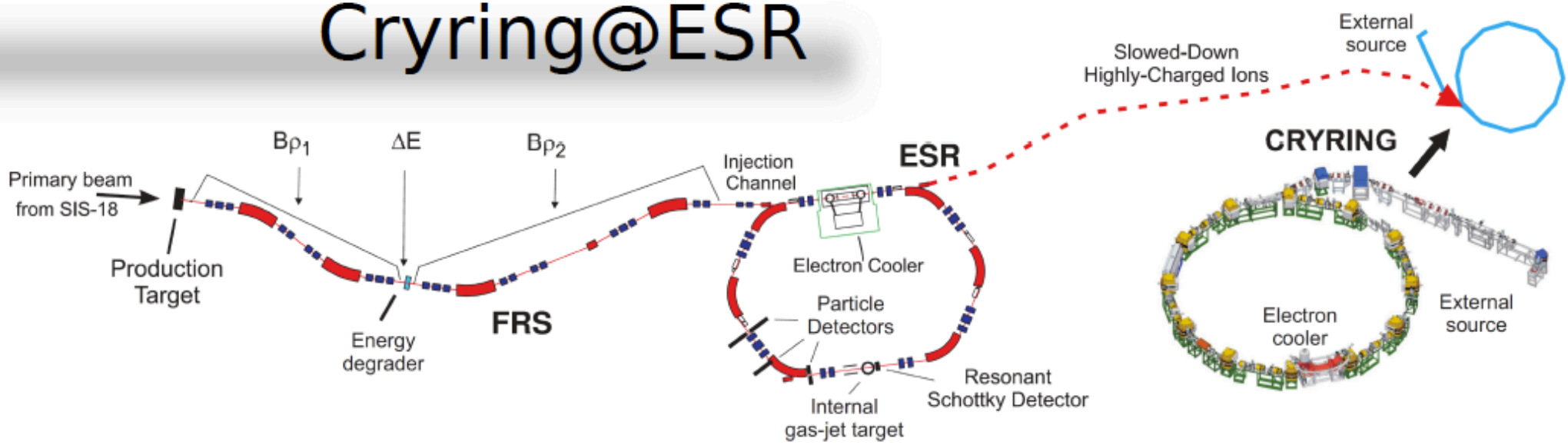
Beamtime at GSI Cryring

Pilot experiment
^{96}Ru(p, γ)^{97}Rh

^{124}Xe(p, γ)^{125}Cs
in the Gamow window

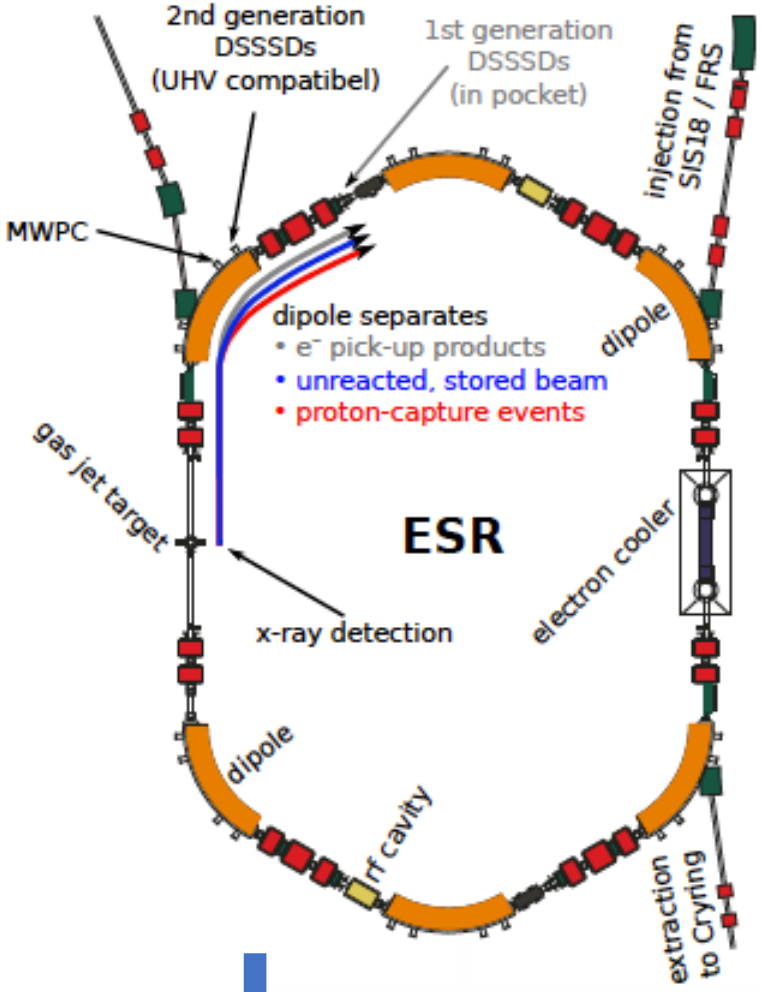
2008 2014 2016 2018 - 2019

Cryring@ESR



- low-energy extension of ESR
- can take all GSI beams at energies below 10 MeV/u
- local source available

  Beam energies down to 300 keV/u possible
- **main goal**: lower vacuum pressure as ESR [10^{-12} mbar]
  - ➢ longer lifetimes for highly charged ions at low energies



Beamtime at GSI Cryring

^{124}Xe(p, γ)^{125}Cs in the Gamow window

2008 2014 2016 2018 - 2019

www.exp-astro.de/nucar

NucAR

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NucAR: Nuclear Astrophysics at Rings

Heavy-ion storage rings can be employed for nuclear astrophysics studies. Over the last two decades the experimental storage ring ESR at GSI has played a central role for such investigations. Experimental possibilities will be extended with the commissioning of the low-energy storage ring CRYRING, which is being constructed presently downstream of the ESR. Further possibilities for experiments are the TSR@ISOLDE project, the Chinese Storage Ring and possibly more. The idea of this collaboration is to combine resources, create synergies and coherently present the latest developments concerning the experimental determination of nuclear properties with astrophysical motivation at storage rings.

Experimentelle Astrophysik | Goethe Universität Frankfurt am Main | FB Physik | IAP | Max-von-Laue-Str. 1 | 60438 Frankfurt am Main | Impressum | Contact

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— 8 Australian National University, Australia
— 9 Institute of Modern Physics, Lanzhou, China
— 10 Technische Universität Darmstadt, Germany
— 11 Helmholtz Insitute Jena, Germany
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