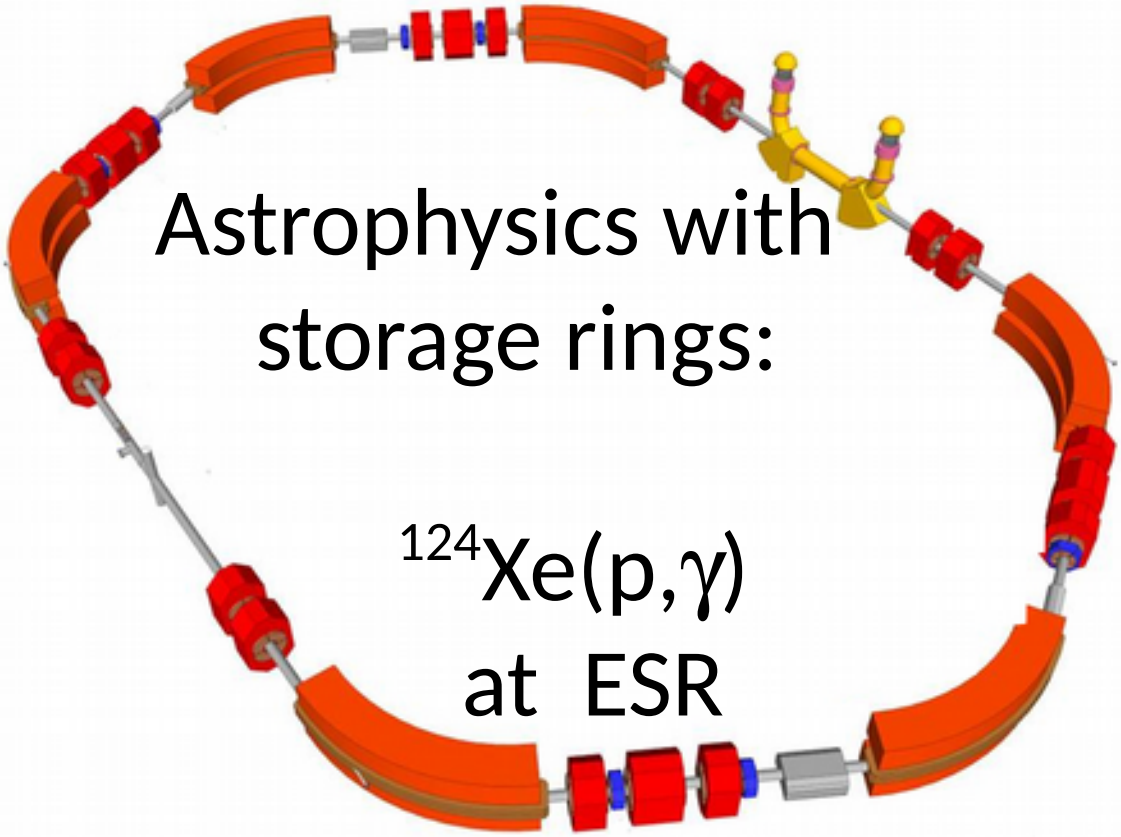
NARRS Workshop
March 13th-15th ,2018



Astrophysics with storage rings:

^{124}Xe(p,γ) at ESR

Zuzana Slavkovská[1,2], J. Glorius[1,2], C. Langer[1,2], Yu. Litvinov[2], R. Reifarth[1,2,,]
T. Davinson[3], B. Jurado[4], S. Sanjari[2,]
and many others from E108 collaboration (s. last slide)

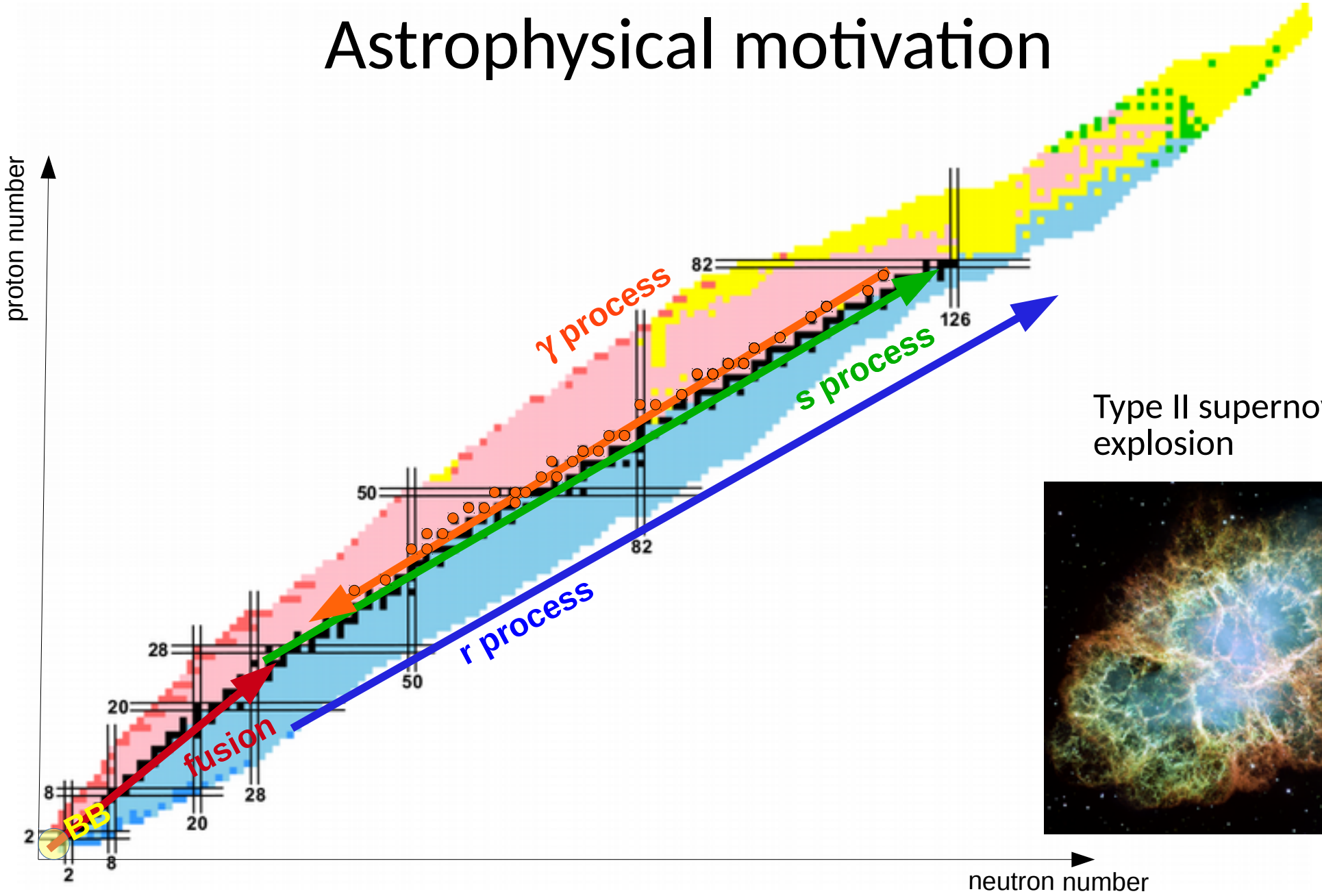
[1] GOETHE UNIVERSITÄT FRANKFURT AM MAIN

[2] GSI Helmholtzzentrum für Schwerionenforschung GmbH

[3] CENBG

[4] THE UNIVERSITY OF EDINBURGH

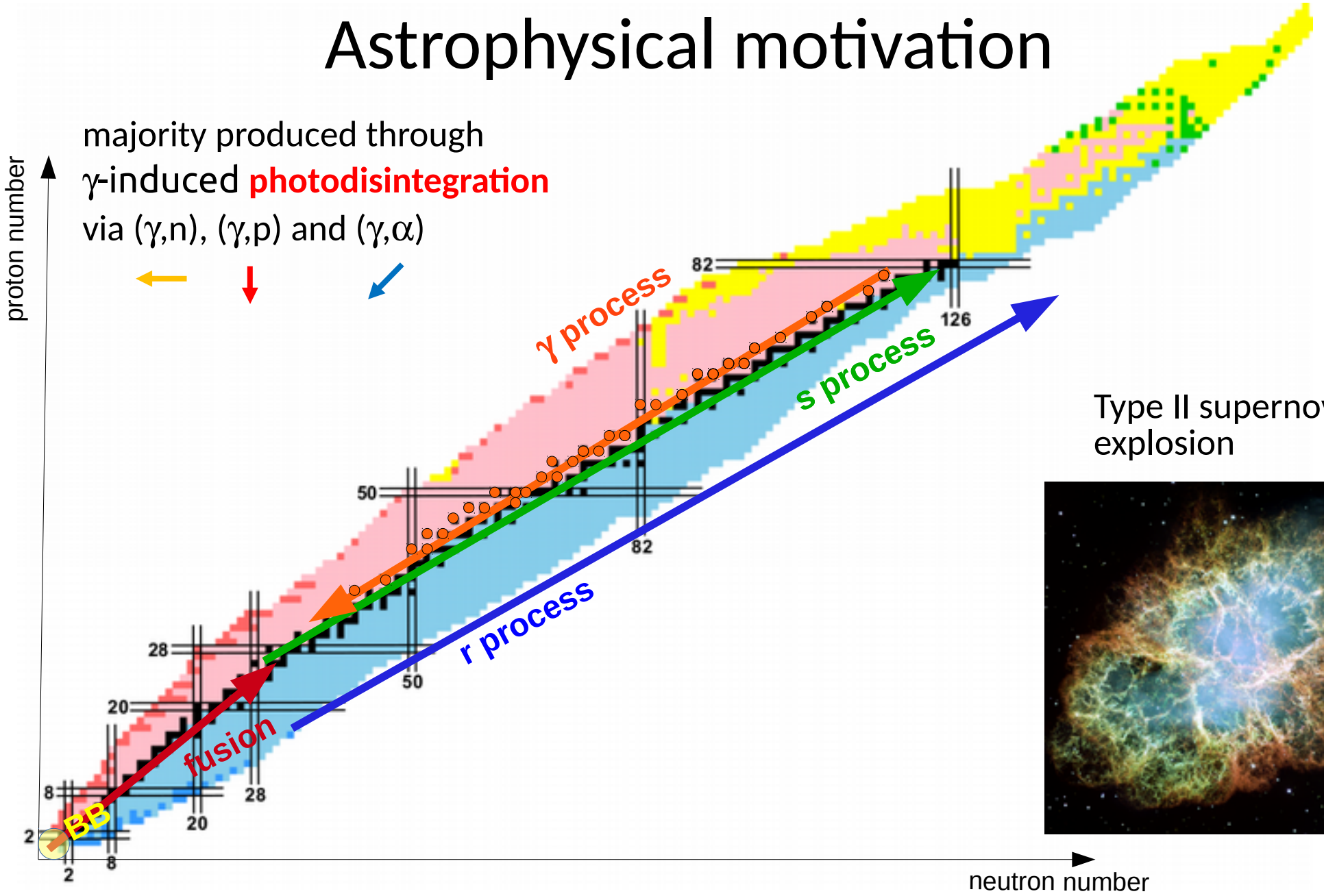
Astrophysical motivation



Type II supernova explosion

Astrophysical motivation

majority produced through
γ-induced **photodisintegration**
via (γ,n), (γ,p) and (γ,α)



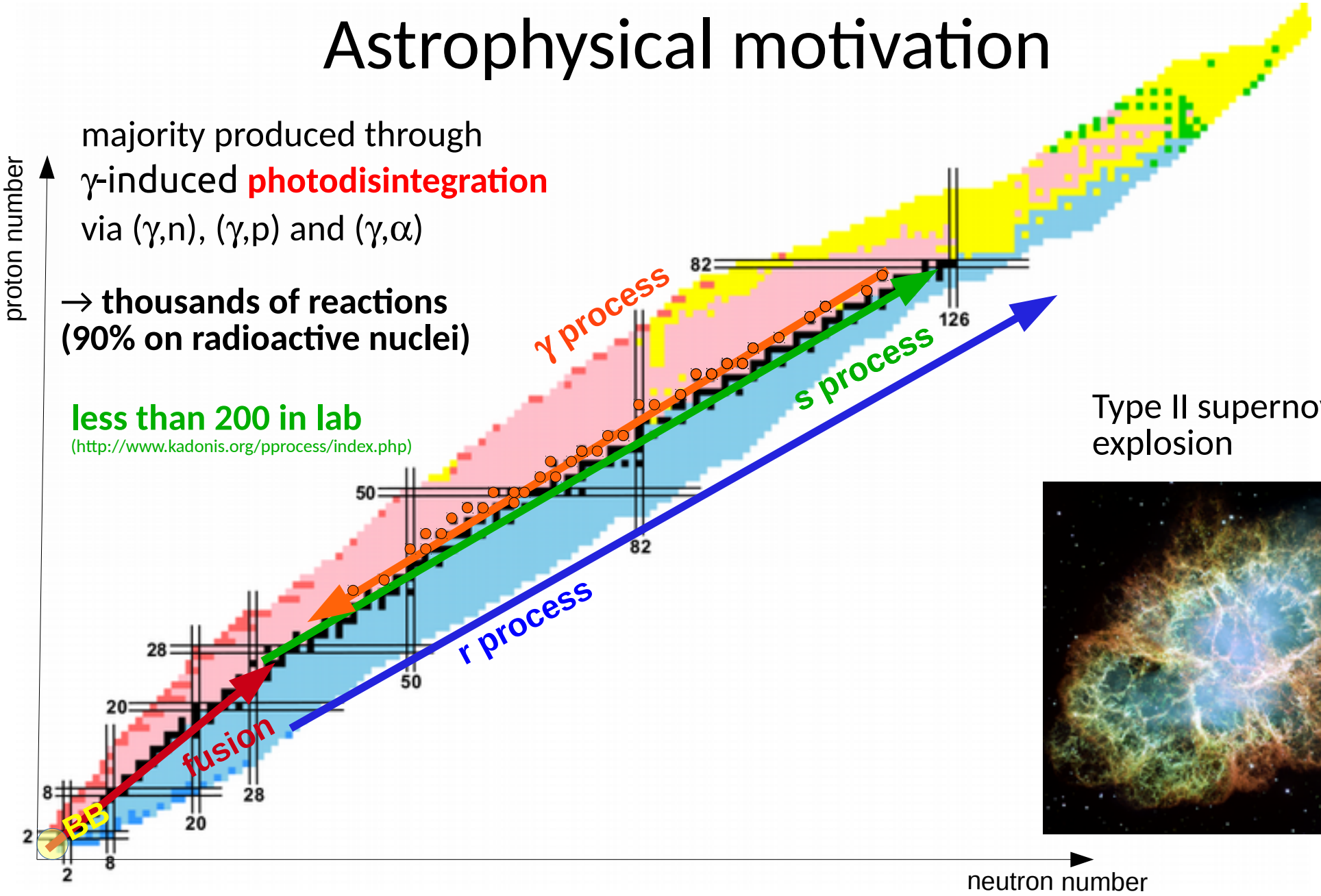
Type II supernova explosion

Astrophysical motivation

majority produced through
γ-induced **photodisintegration**
via (γ,n), (γ,p) and (γ,α)

→ **thousands of reactions**
(90% on radioactive nuclei)

less than 200 in lab
(http://www.kadonis.org/pprocess/index.php)



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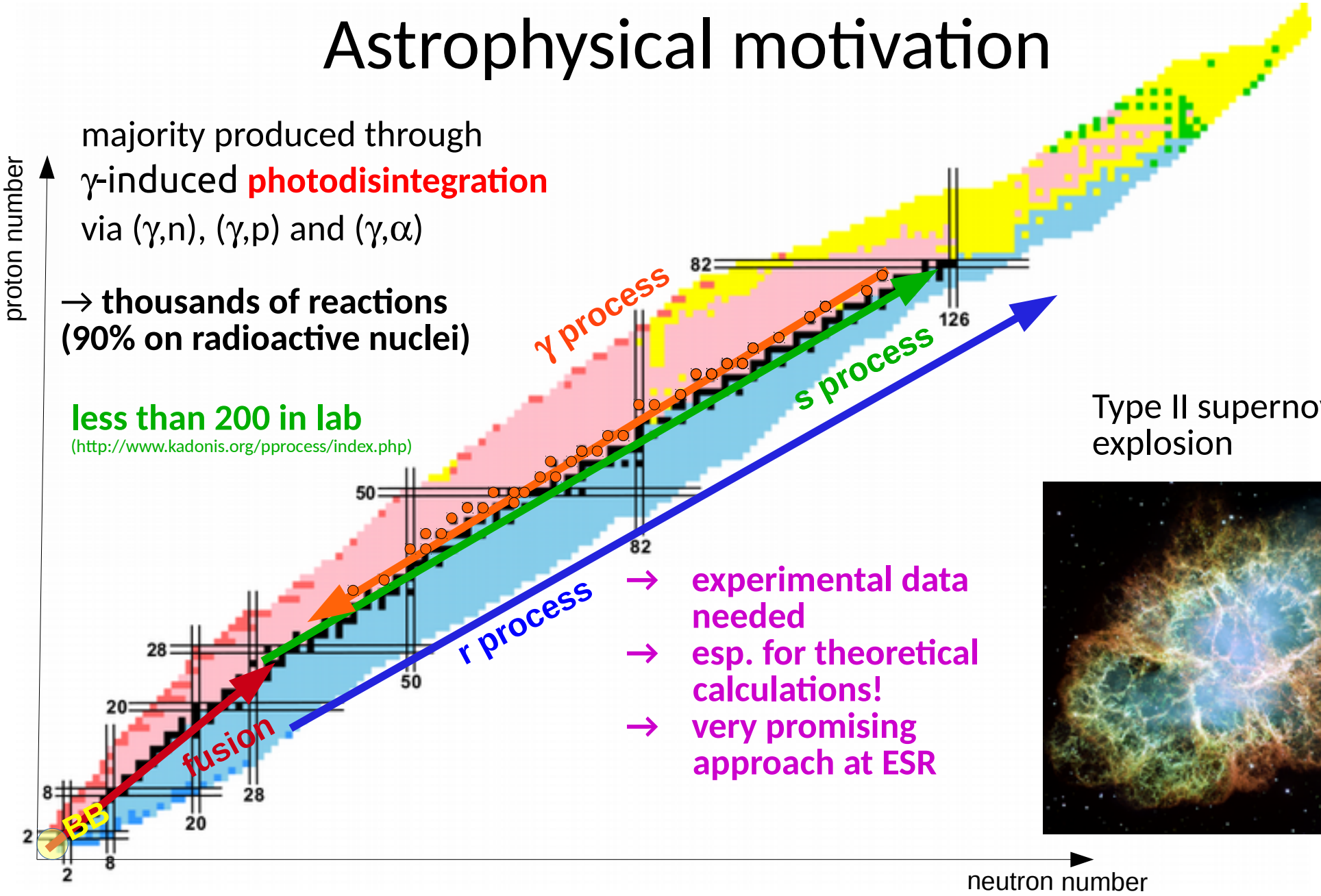
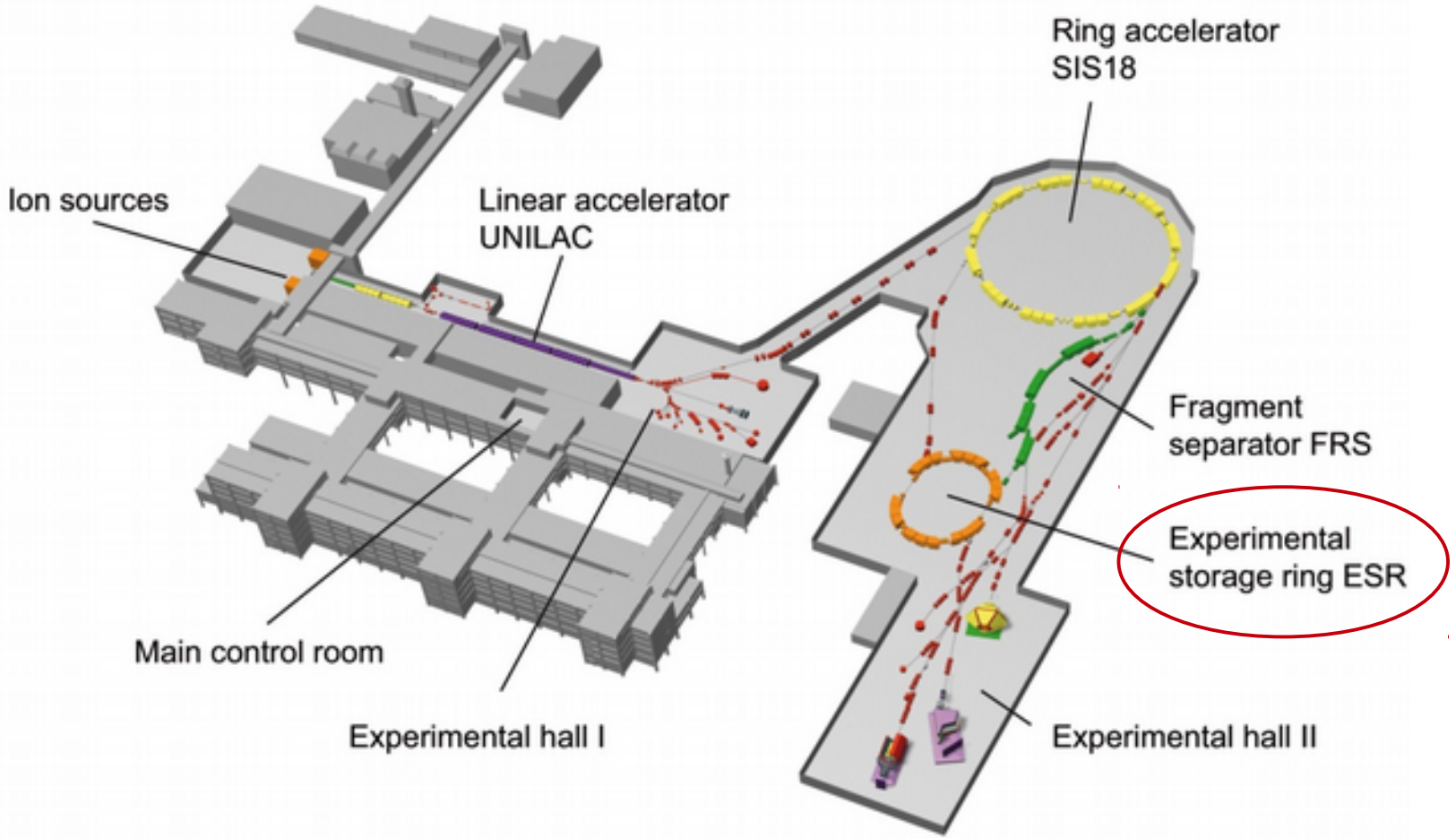


→ **experimental data needed**
→ **esp. for theoretical calculations!**
→ **very promising approach at ESR**

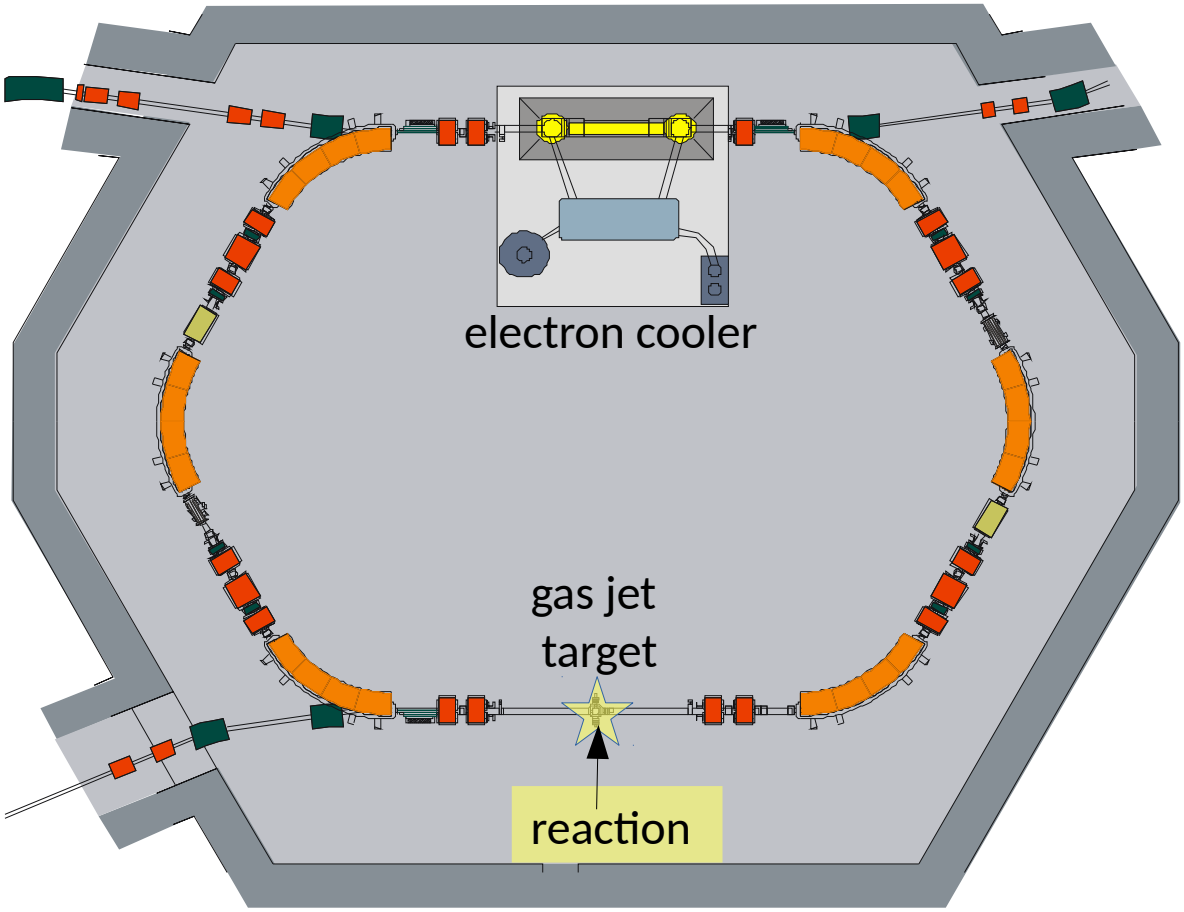
Type II supernova explosion

Helmholtzzentrum für Schwerionenforschung GmbH



Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$

Beamtime 2008



Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$

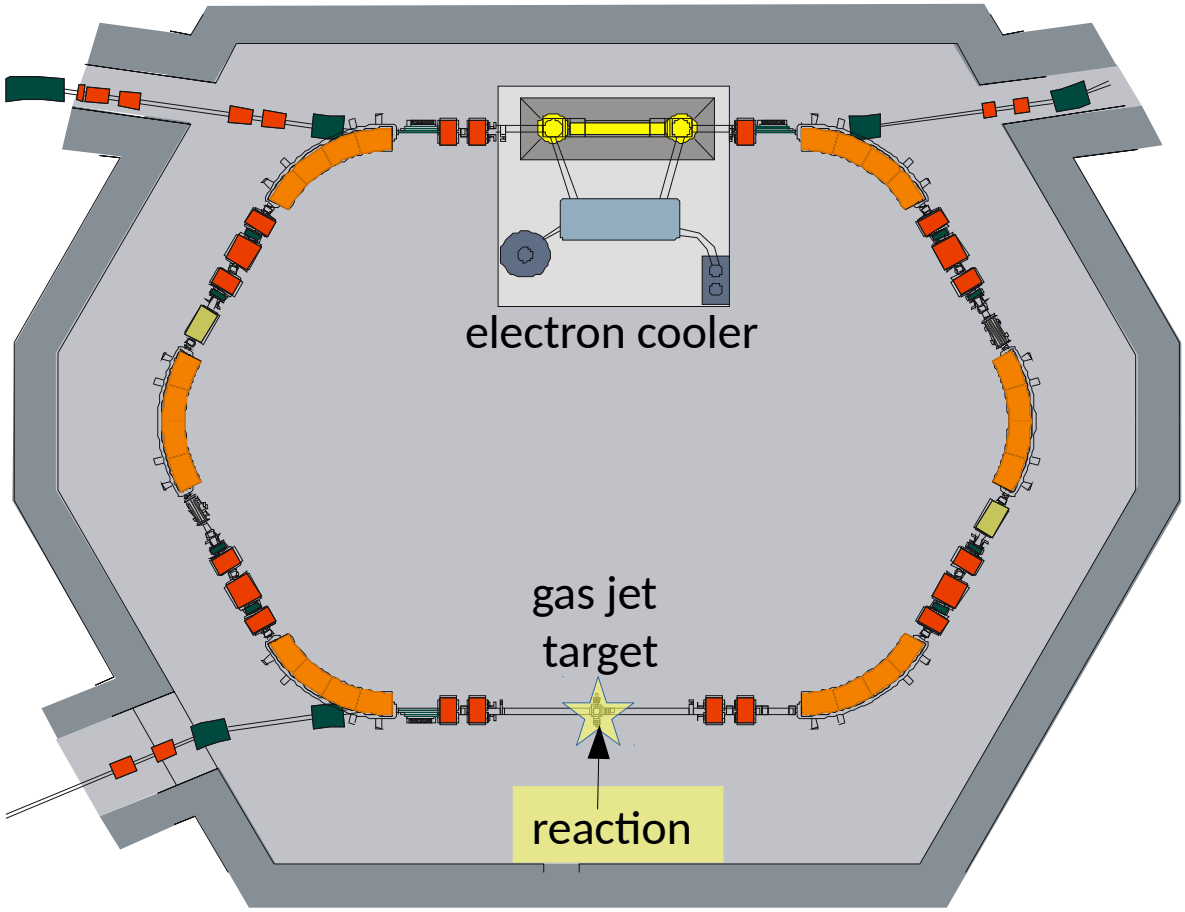
Experimental **method**:

1. fully stripped isotopes **injected into ESR** at 100 AMeV

2. beam **decelerated and cooled** to < 10 AMeV

3. activation of **gas jet target**

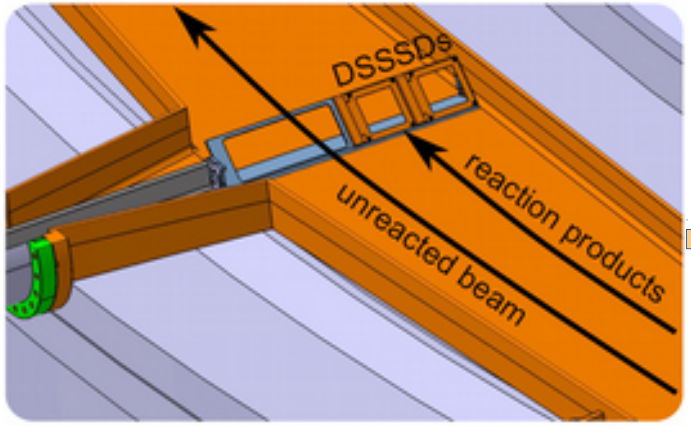
4. **detection** by position-sensitive detectors



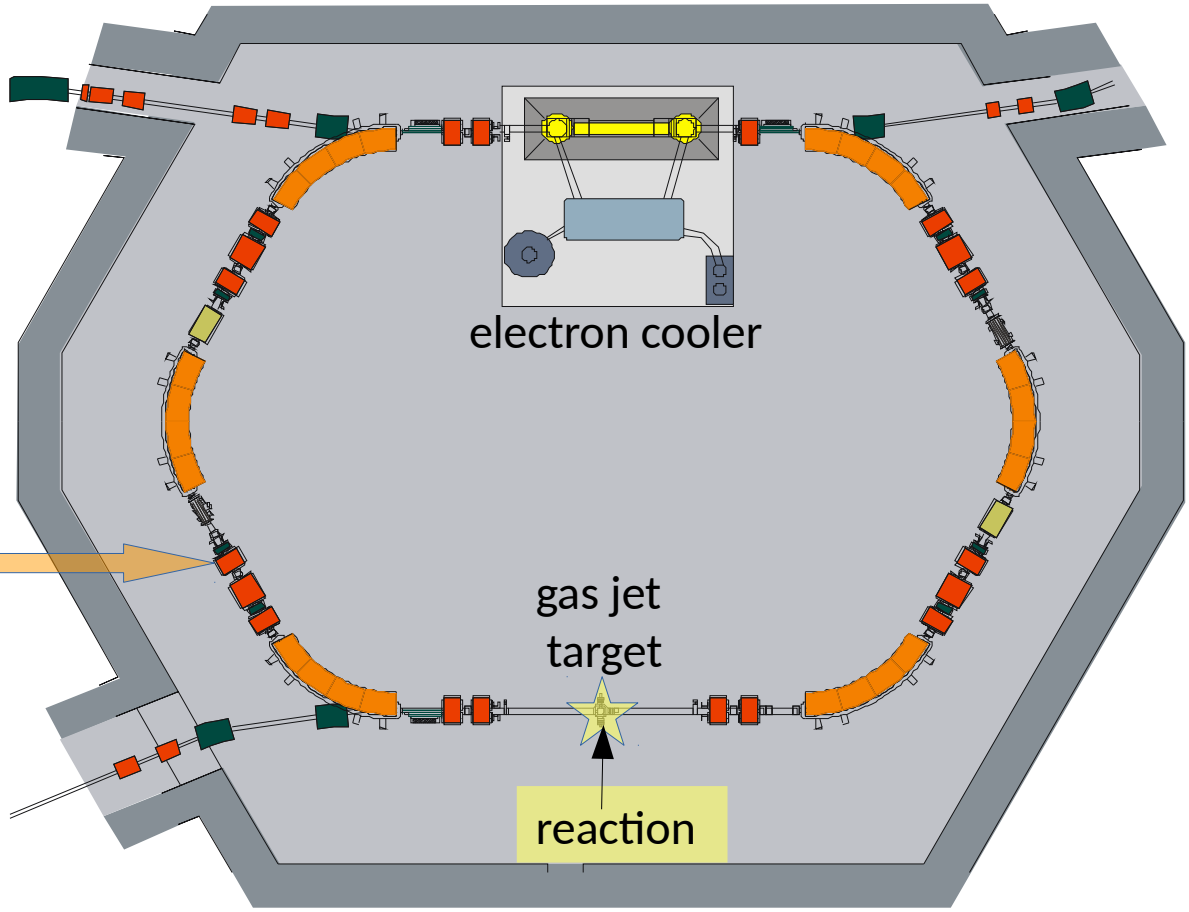
Pilot experiment: ^{96}Ru(p,γ)^{97}Rh

reaction products separated by **m/q ratio by B**

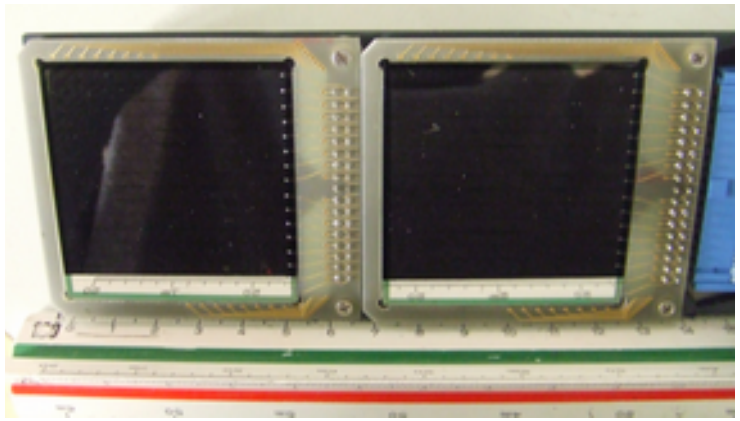
$$B\rho \propto \frac{m}{q}$$



detection by position-sensitive detectors



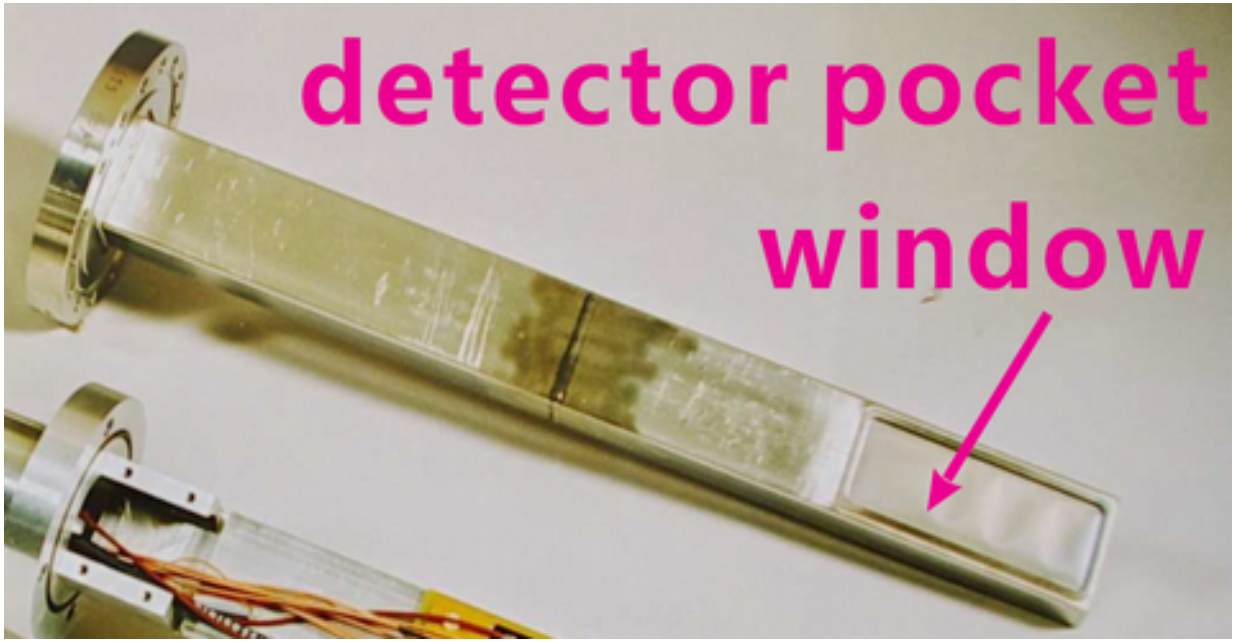
Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$



DSSSD (**D**ouble **S**ided **S**ilicon **S**trip **D**etectors)

16 x 16 strips
5 x 5 cm^2
not UHV compatible

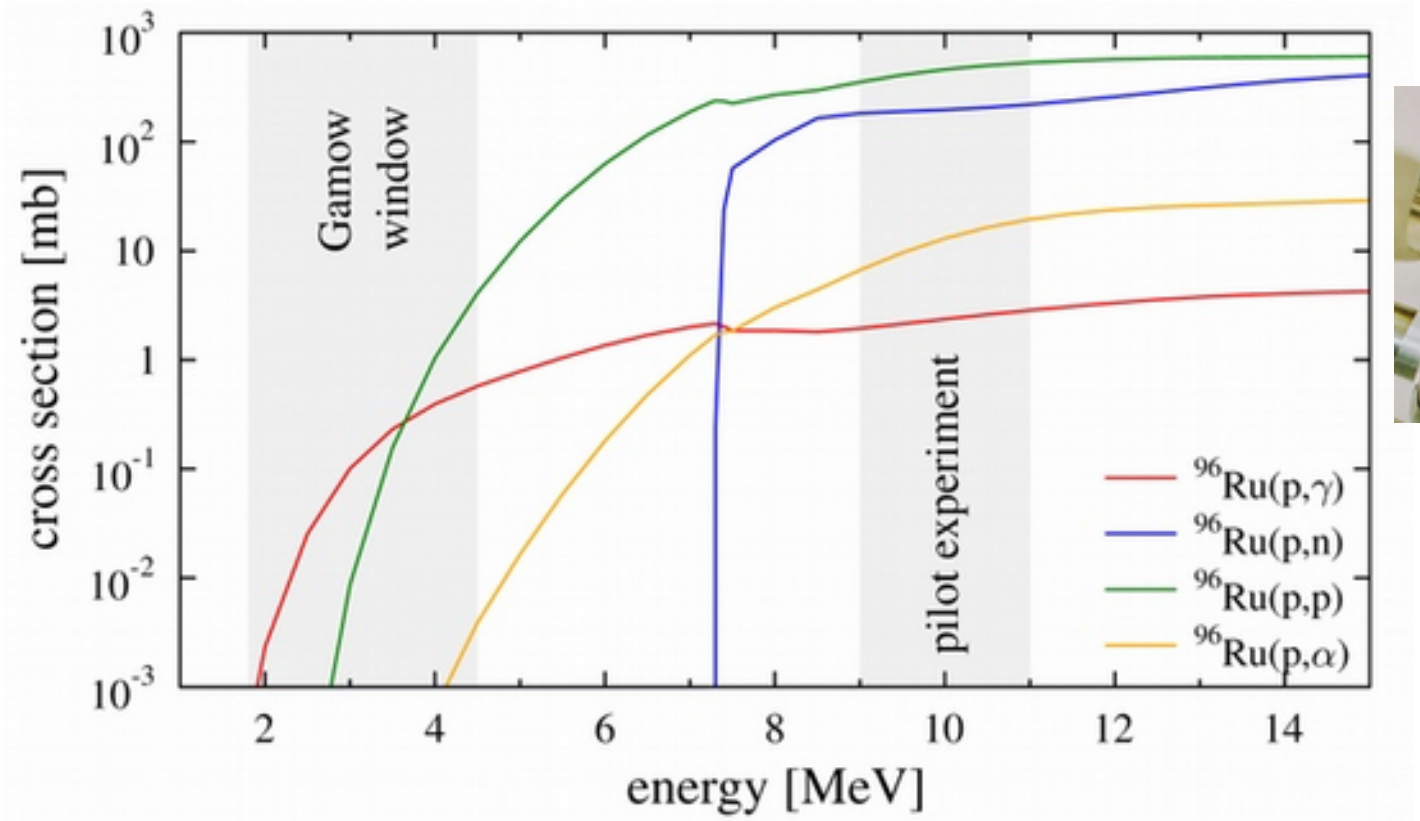
position sensitive

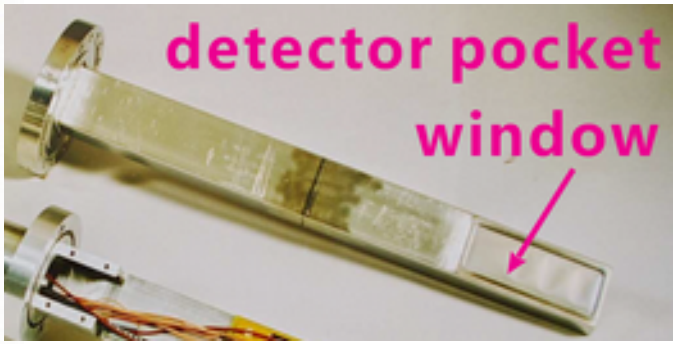


Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$

Our energies: **9, 10 and 11 AMeV**

→ (p,γ) the weakest channel according to TALYS

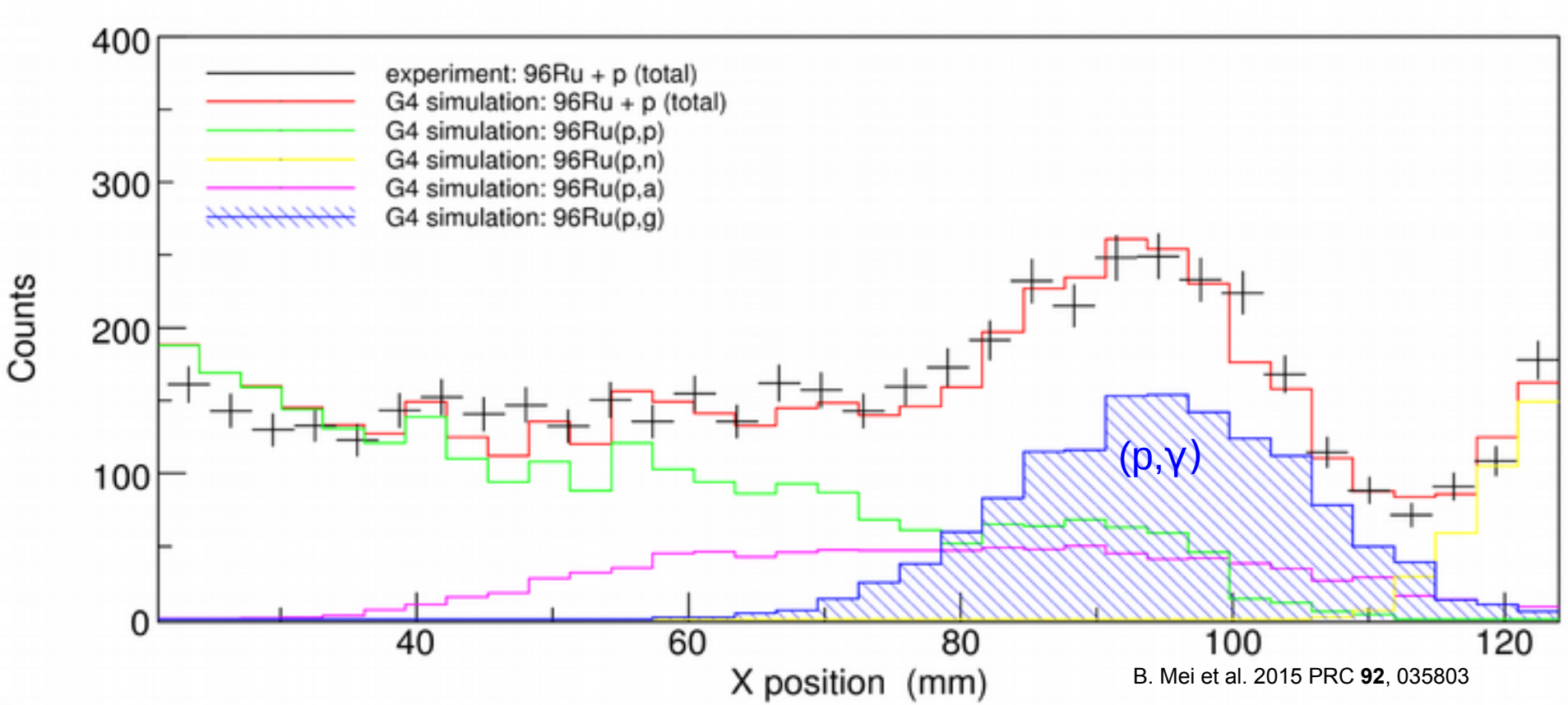




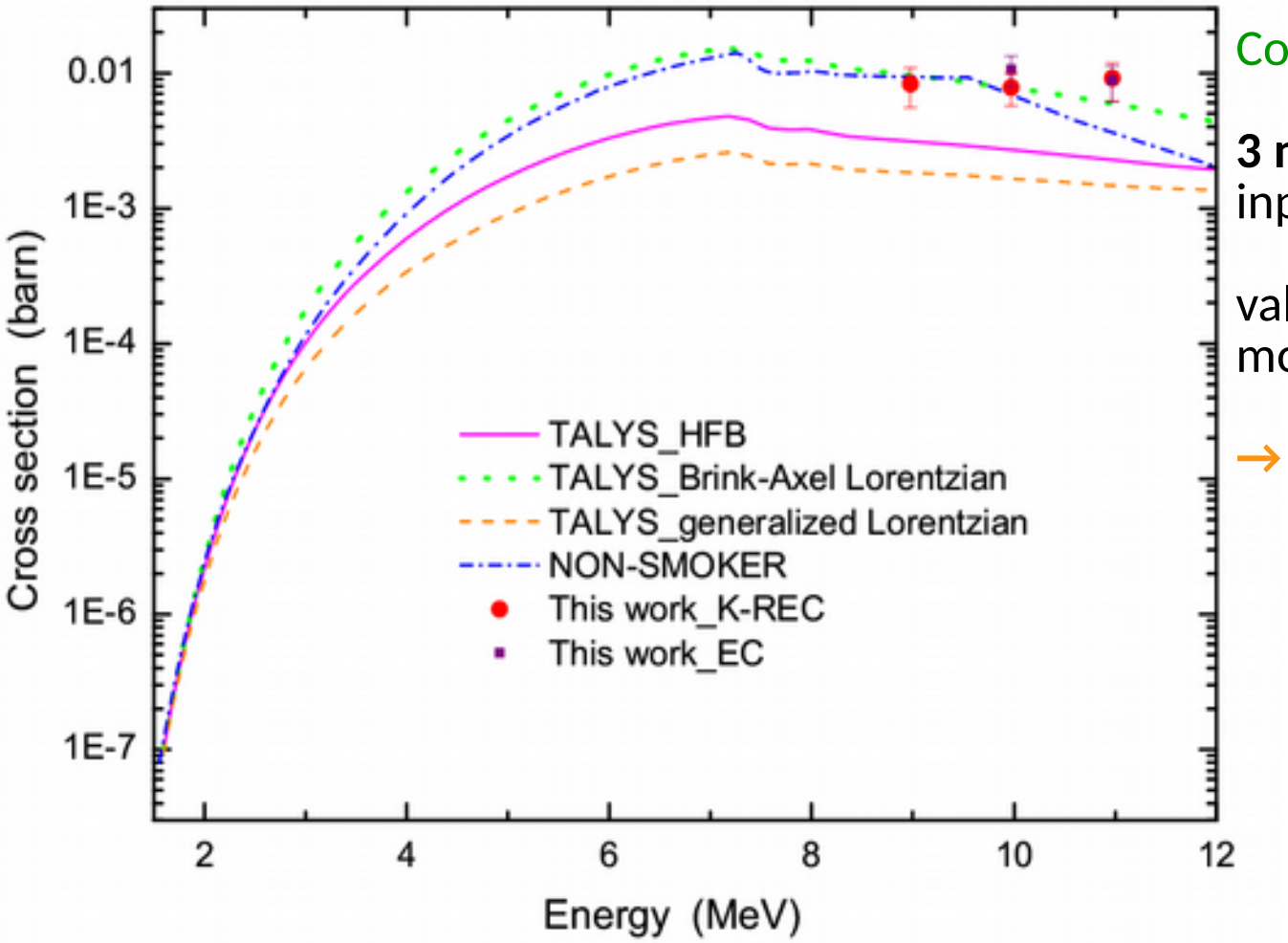
energy loss

Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$

GEANT4: peaks from different channels can be disentangled
clear **signature of (p,γ)** reaction after subtraction of background



Pilot experiment: $^{96}Ru(p,\gamma)^{97}Rh$



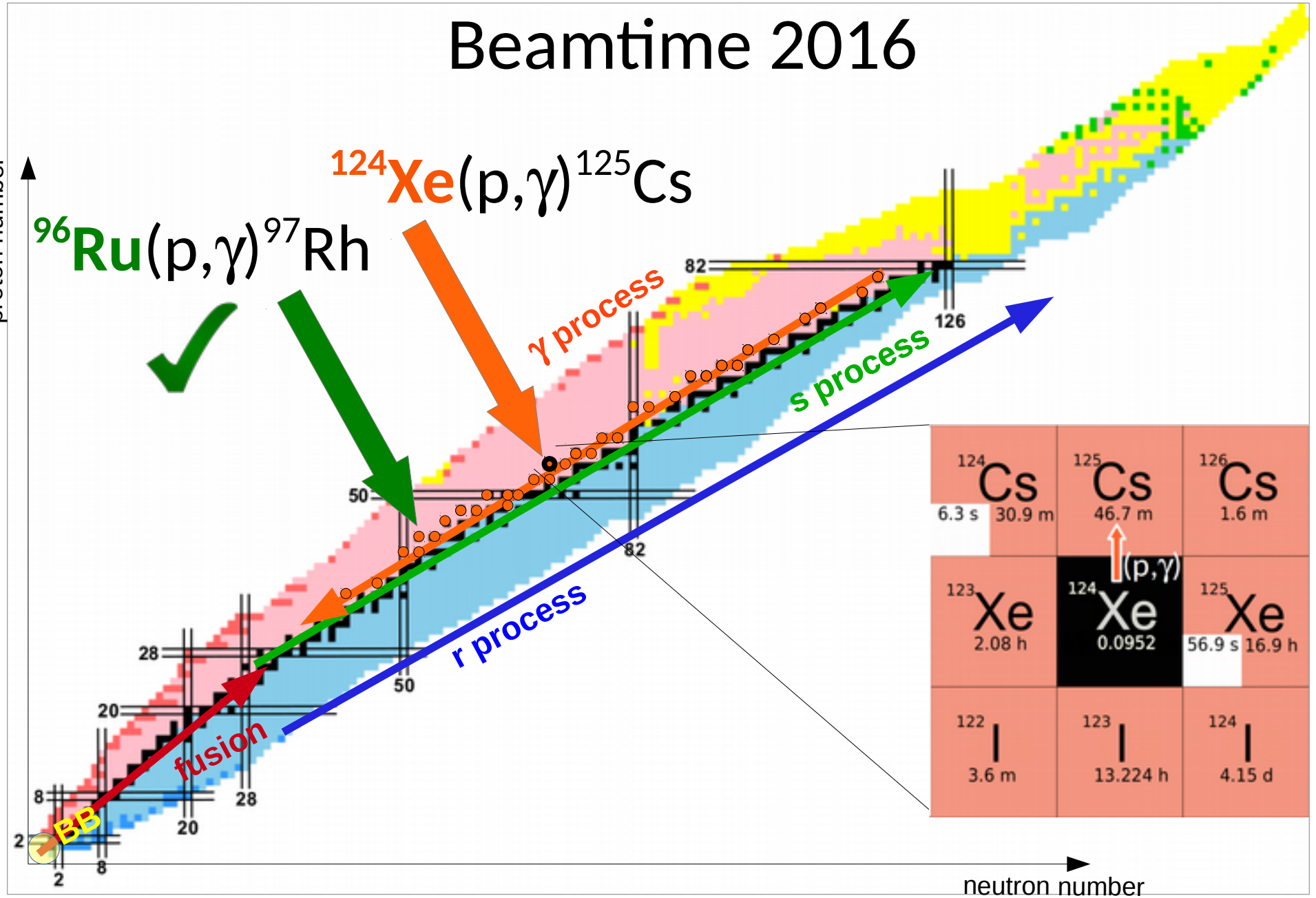
Conclusion:

3 new data points for theory input

validation of theoretical models

→ **principle succesfully tested**

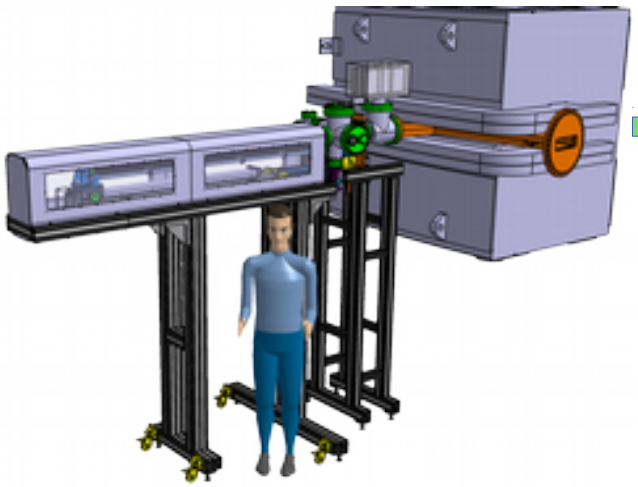
Mei et al., PRC 92 (2015) 035803

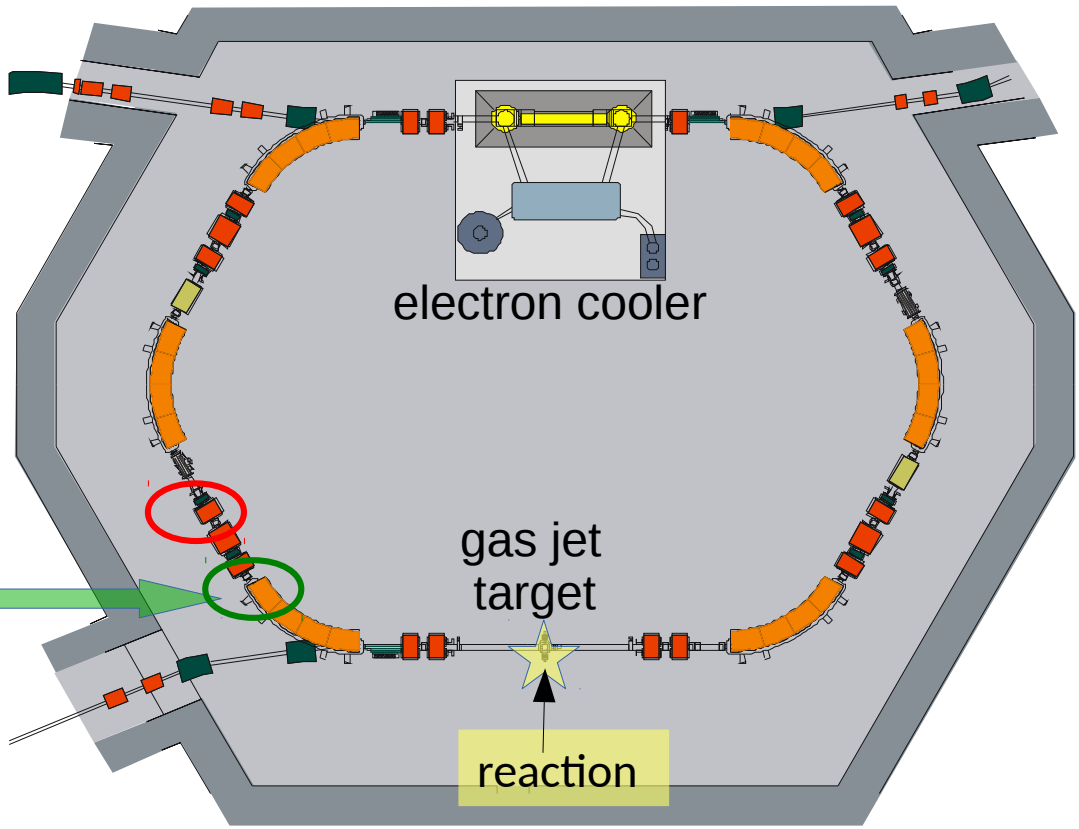

Beamtime 2016
^{124}Xe(p,γ)^{125}Cs
^{96}Ru(p,γ)^{97}Rh
γ process
s process
r process
fusion
BB
proton number
neutron number
2
8
20
28
50
82
126
^{124}Cs
6.3 s
30.9 m
^{125}Cs
46.7 m
^{126}Cs
1.6 m
(p,γ)
^{123}Xe
2.08 h
^{124}Xe
0.0952
^{125}Xe
56.9 s
16.9 h
^{122}
3.6 m
^{123}
13.224 h
^{124}
4.15 d

Beamtime 2016: $^{124}Xe(p,\gamma)^{125}Cs$

Improvements:

1. **position at the end of 1st dipole**
   (larger angular acceptance)





Beamtime 2016: $^{124}Xe(p,\gamma)^{125}Cs$

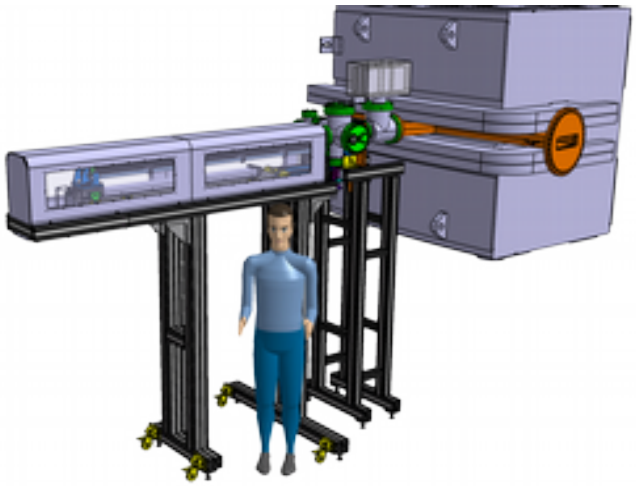
Improvements:

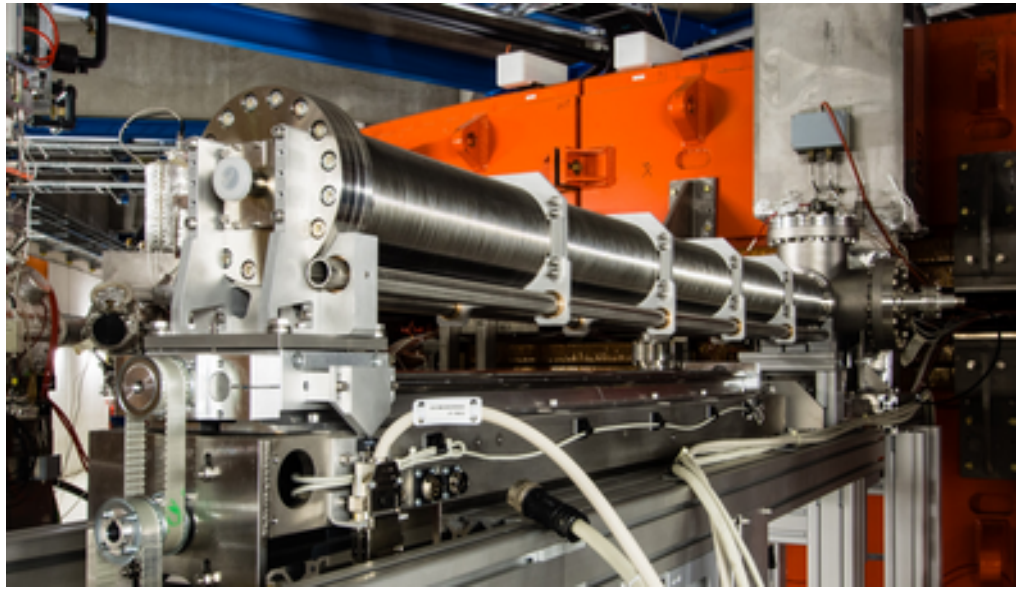
1. **position at the end of 1st dipole**

movable detector **arm**

exact positioning of detector (step motor)

fast and fine-tunable system



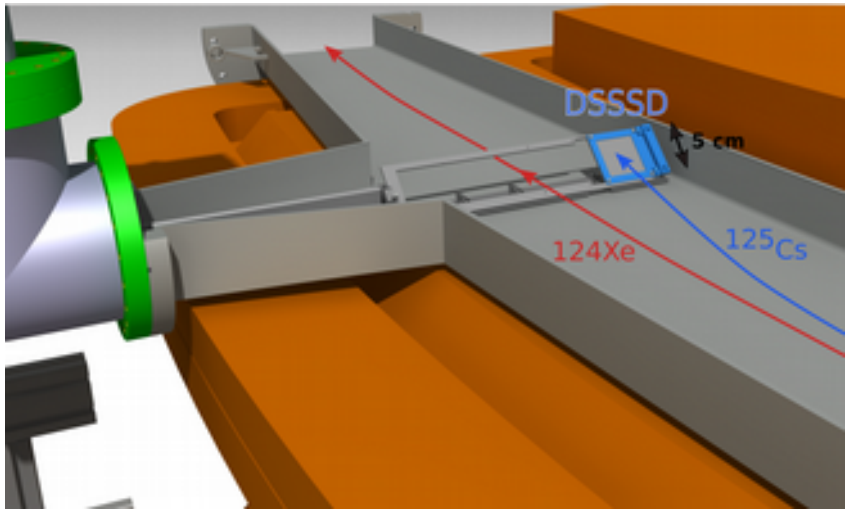


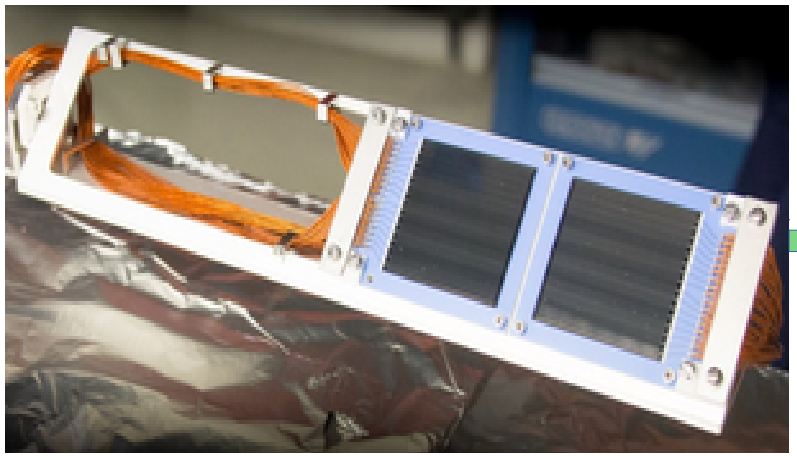
Beamtime 2016: $^{124}Xe(p,\gamma)^{125}Cs$

Improvements:

1. **position at the end of 1st dipole**

2. **one** DSSSD (closer to primary beam)





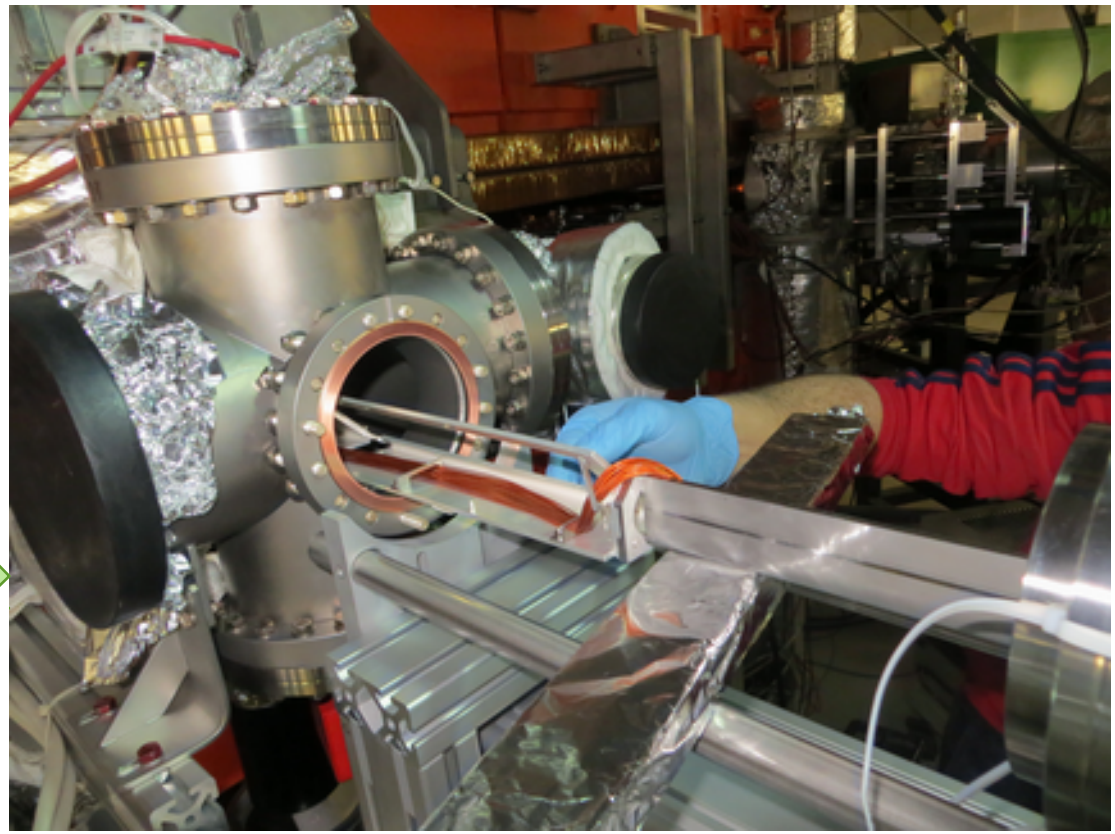
Beamtime 2016: $^{124}Xe(p,\gamma)^{125}Cs$

Improvements:

1. **position at the end of 1st dipole**

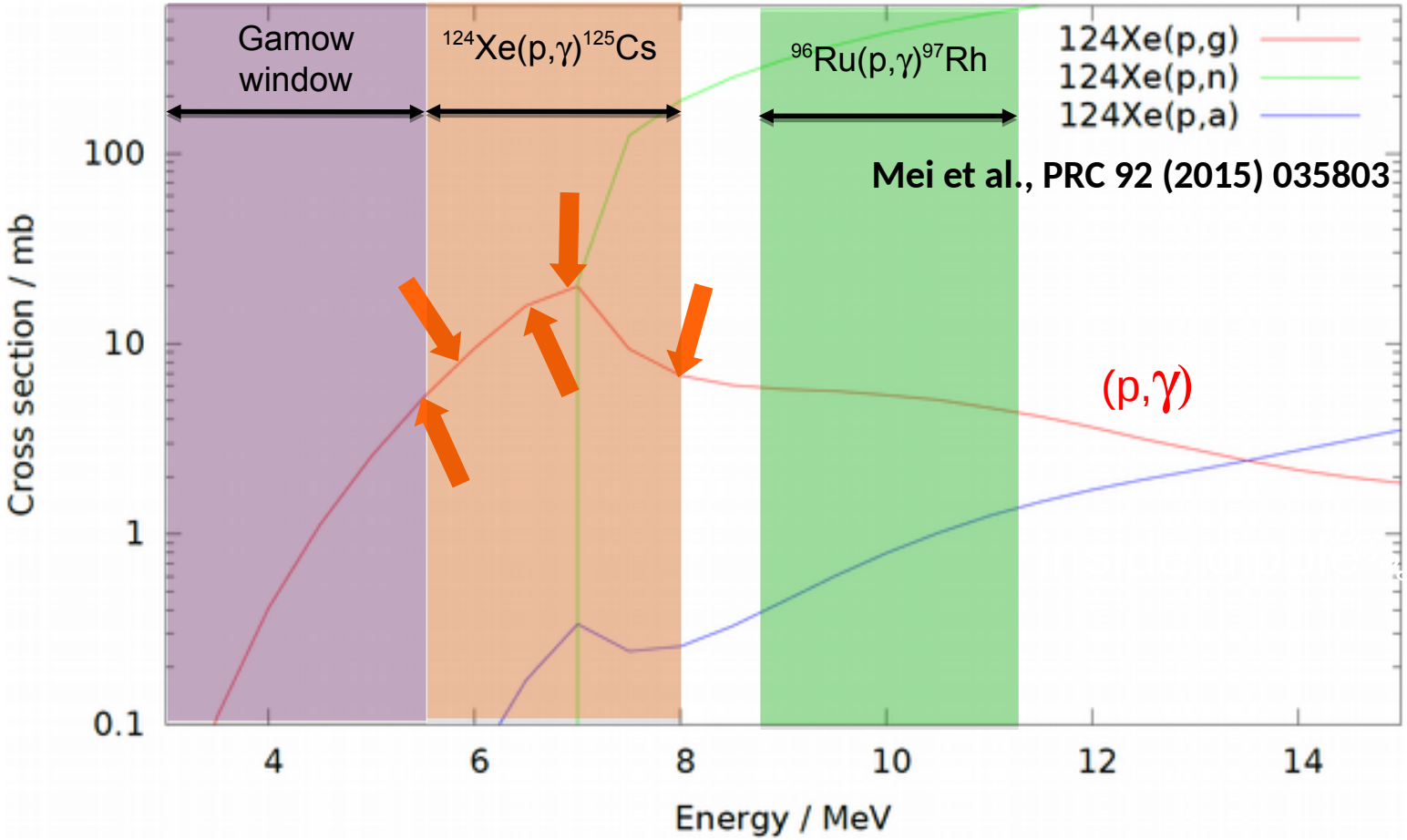
2. **one** DSSSD

3. **UHV compatible** detectors
   → **lower energies**



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

beamtime ESR: **June 13th – 28th, 2016:** measurement: **(p,γ) at 5 different energies**



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

beamtime ESR: **June 13th – 28th, 2016**

Conditions:

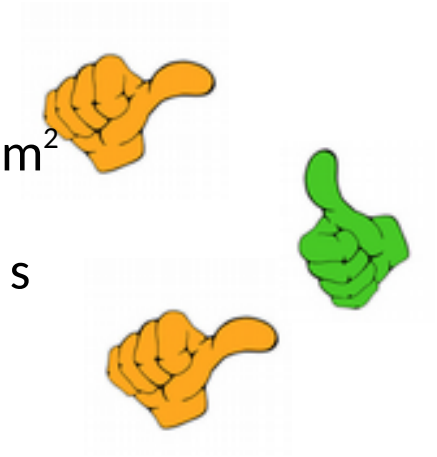
fill cycle: ~1 min: stored ^{124}Xe ions per pulse: $5*10^{6}$

frequency: 500 kHz

ring vacuum: $5*10^{-11}$ mbar

gas target density: up to 10^{14} /cm^2

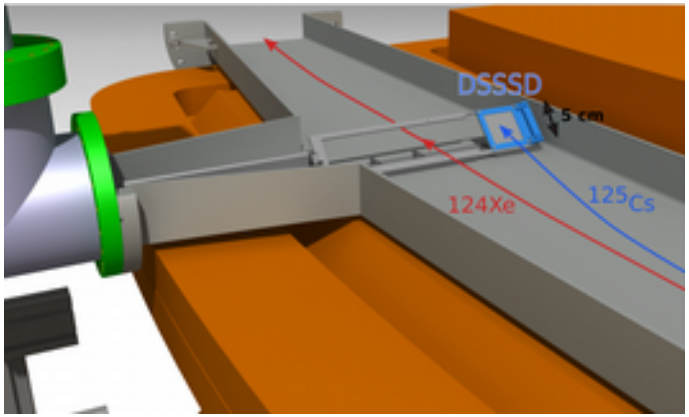
→ beam lifetime (7 AMeV): 2.5 s

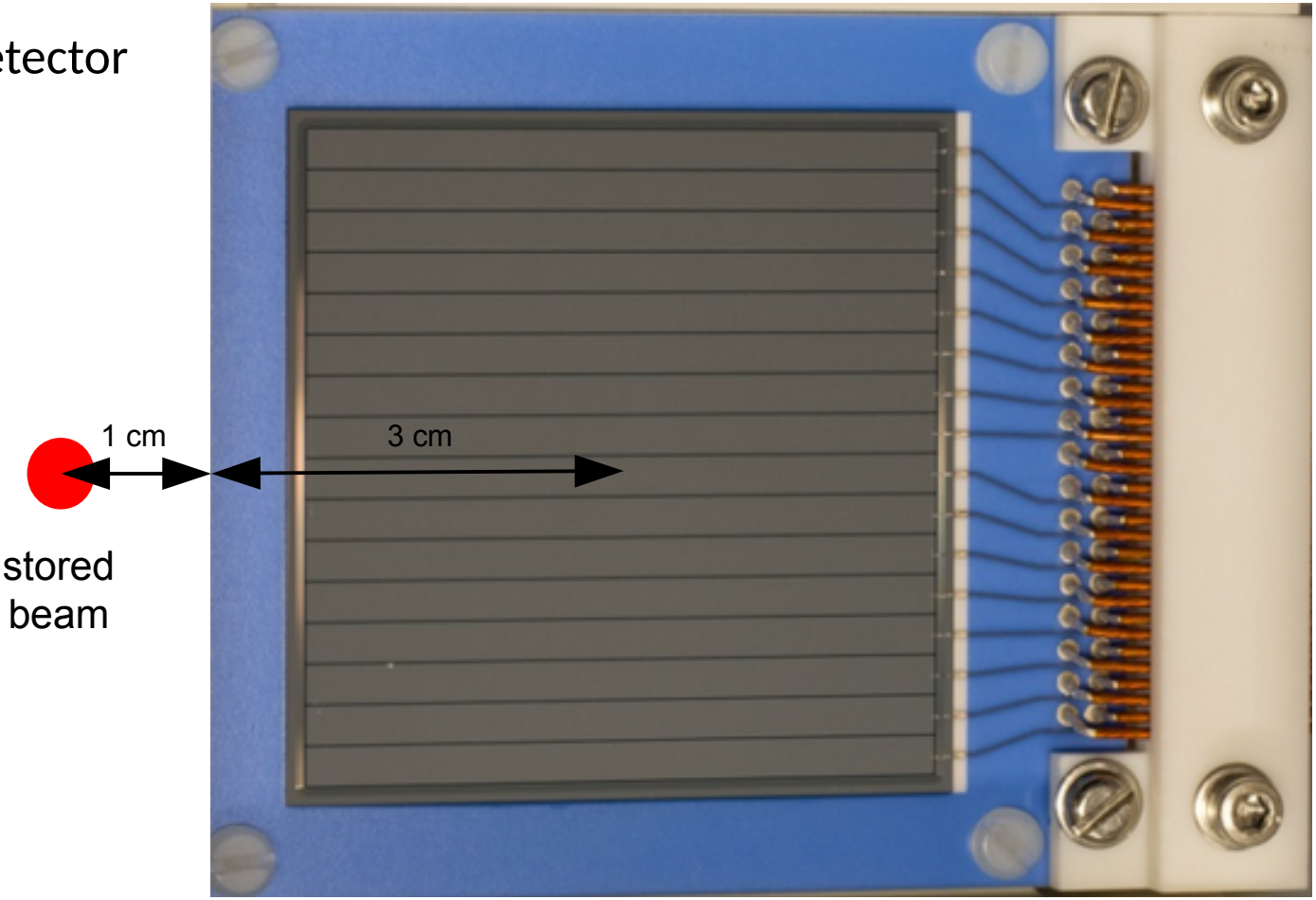


Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

(p,γ) expected **~4 cm from primary beam** (MOCADI ion optical calculations)

-> **finding beam** using the detector





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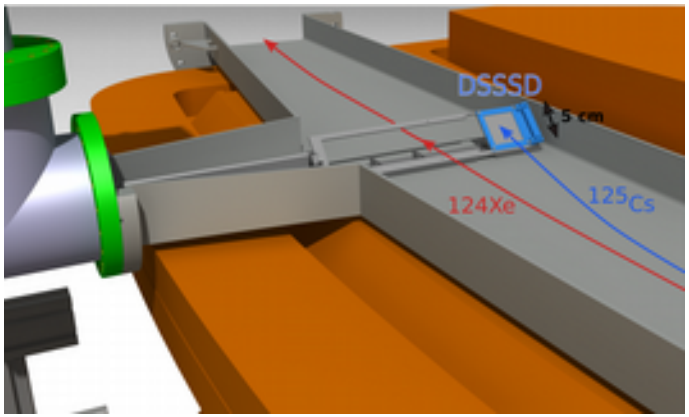
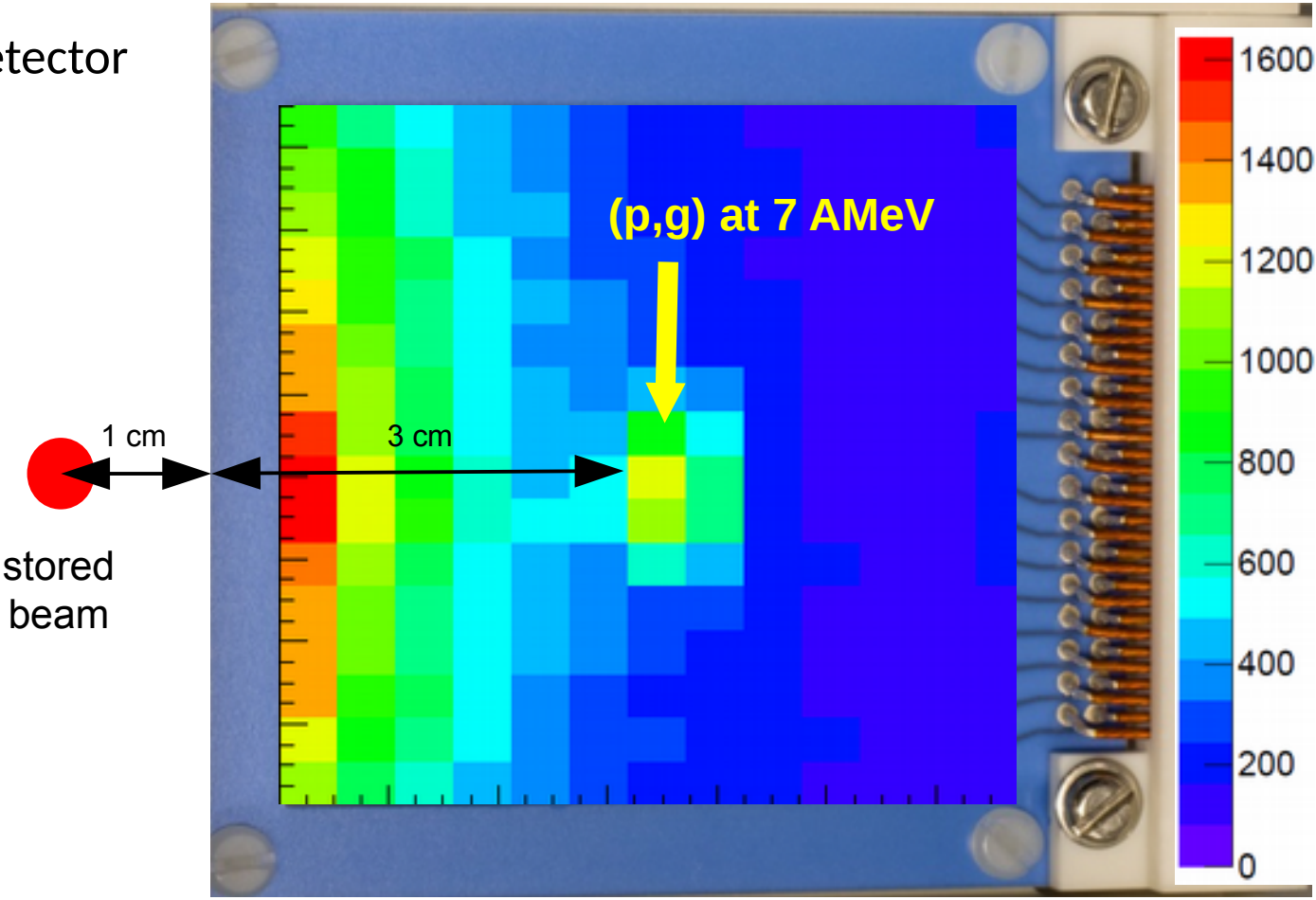
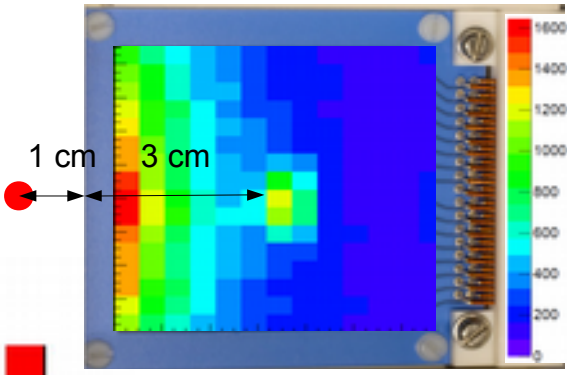
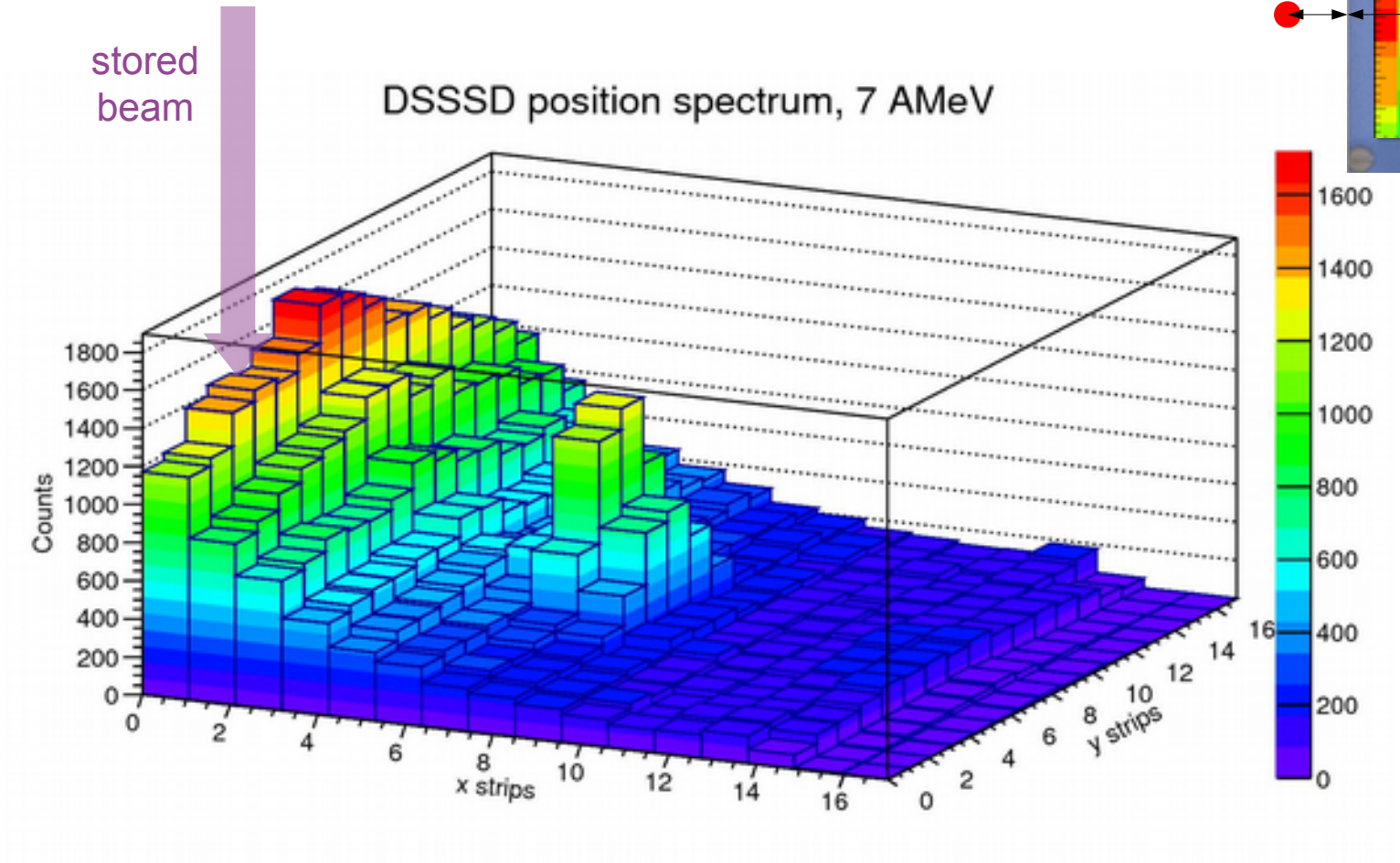




Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

1st (p,γ) measurement at **7 AMeV,** 32.5 h with jet ON





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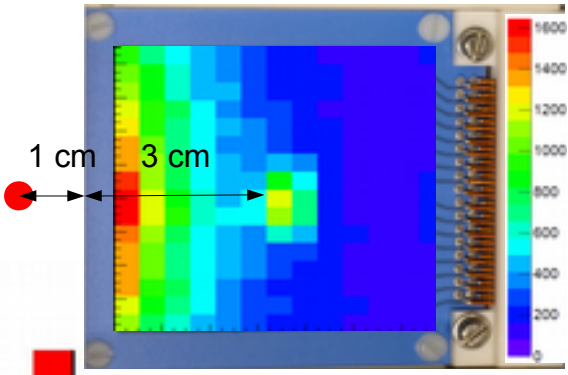

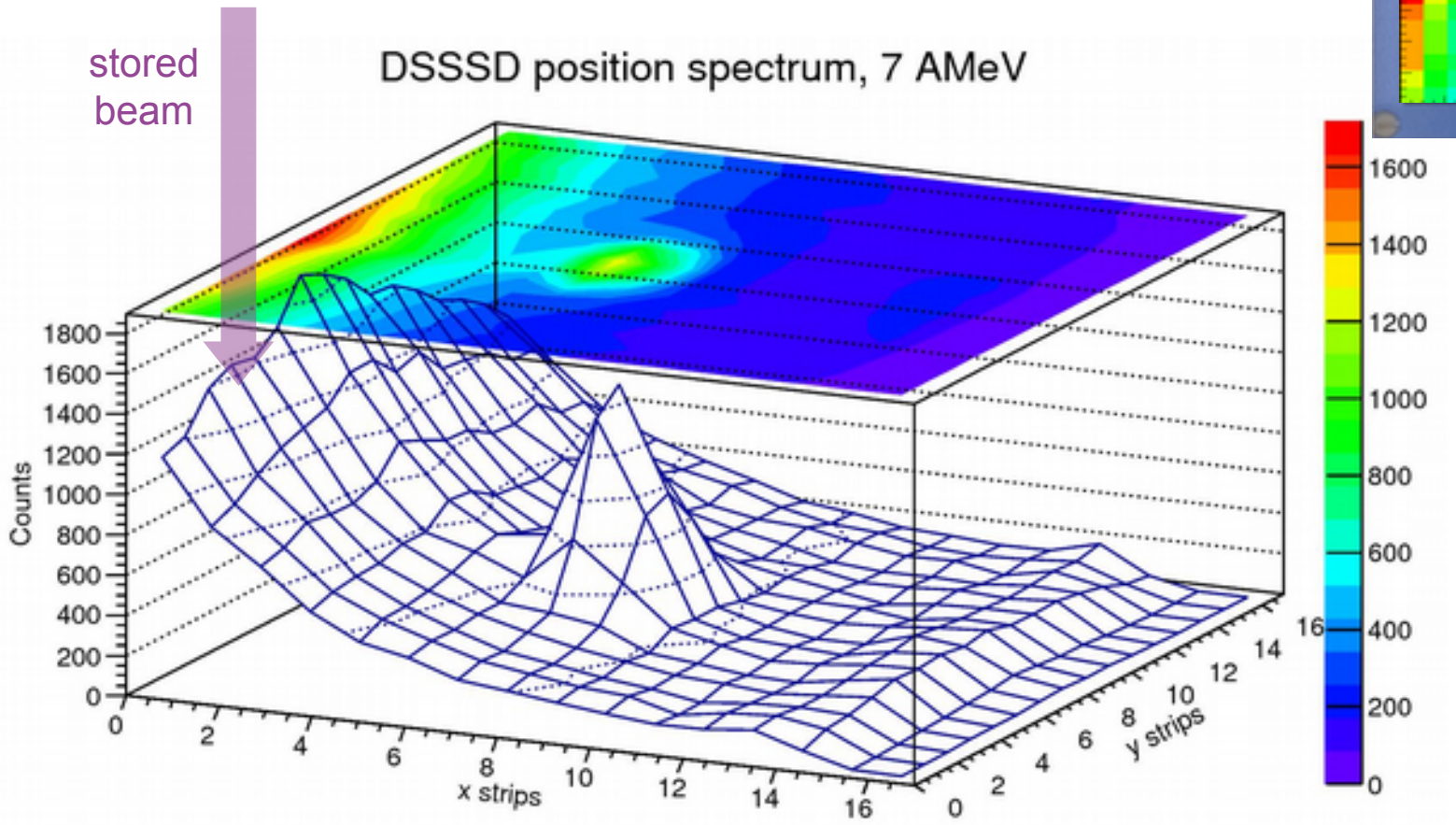

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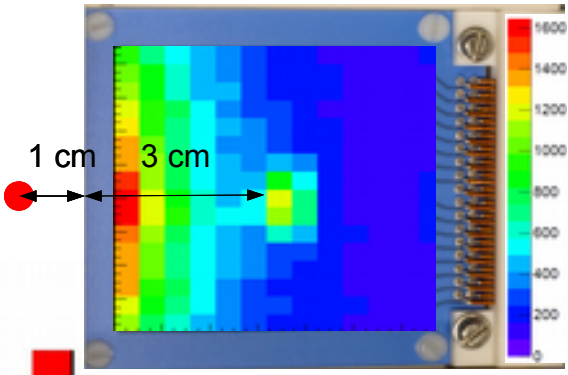
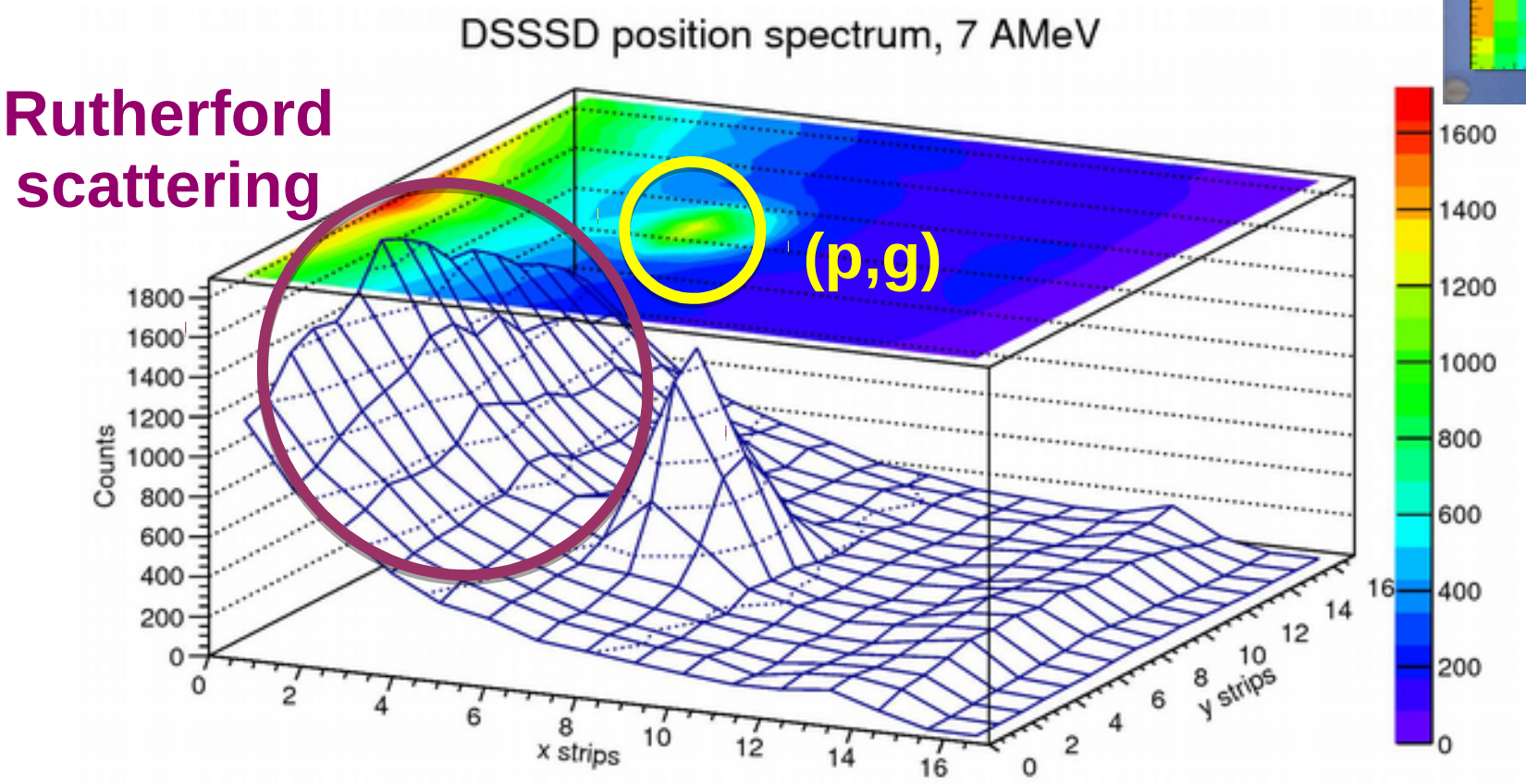
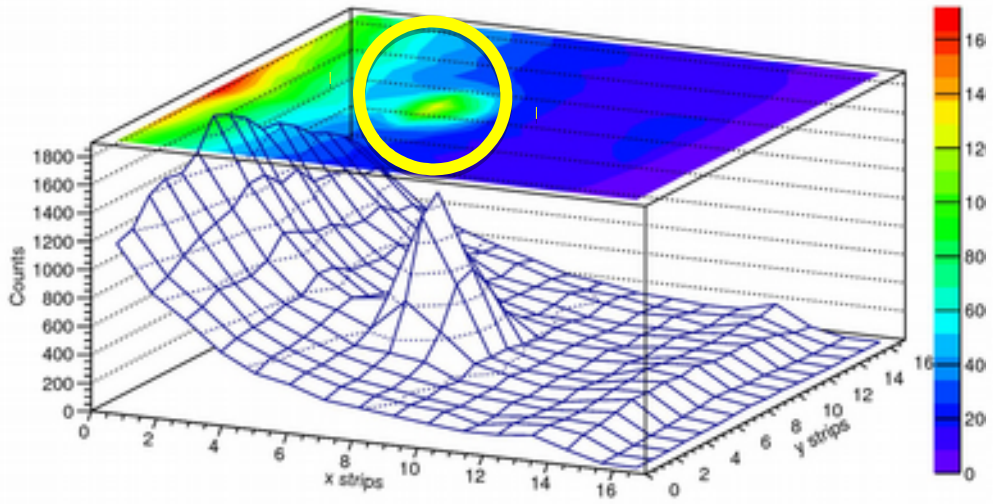




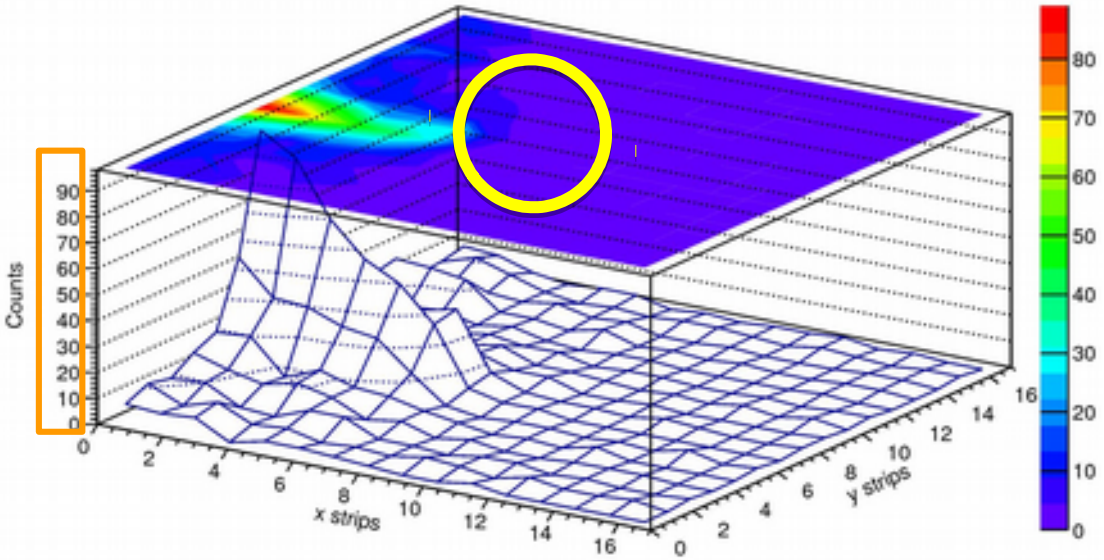
Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

Comparison to measurement at **7 AMeV without gas jet**

32h of beam

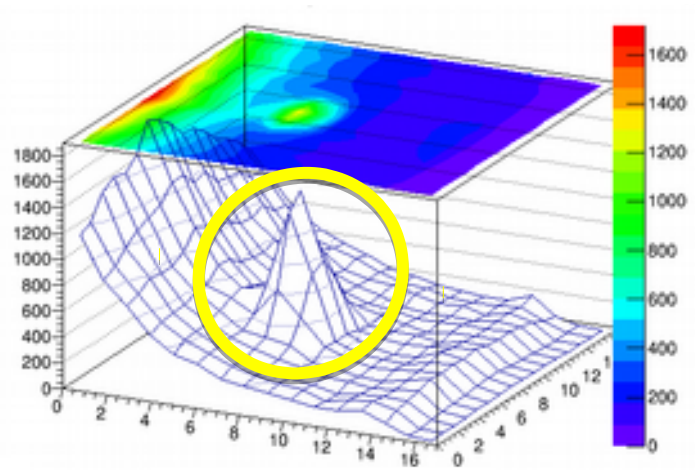


11h of beam

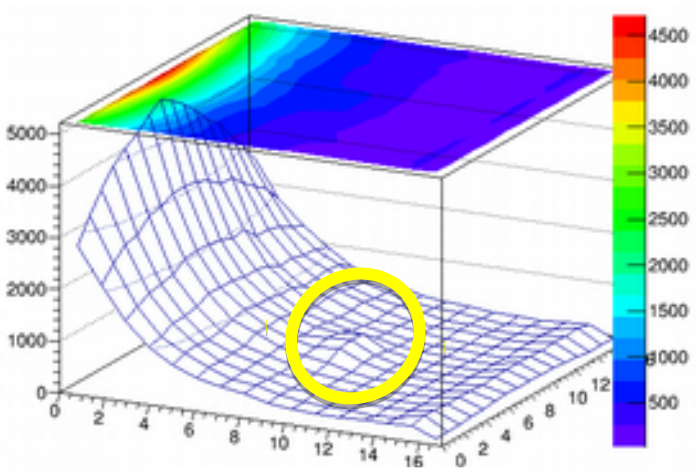


Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

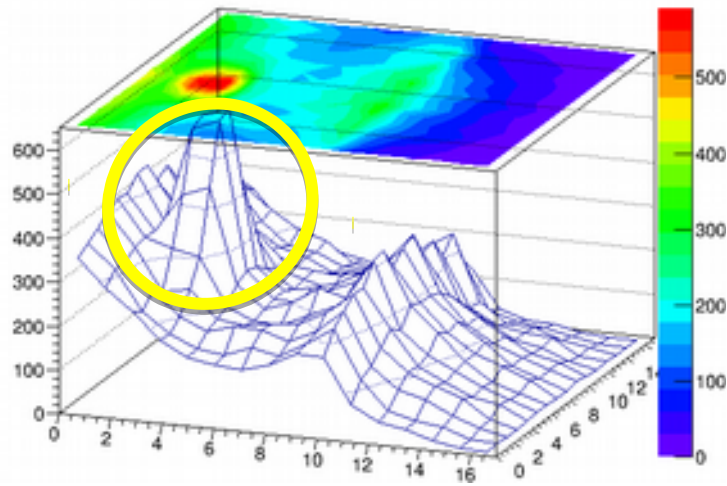
7 MeV/u



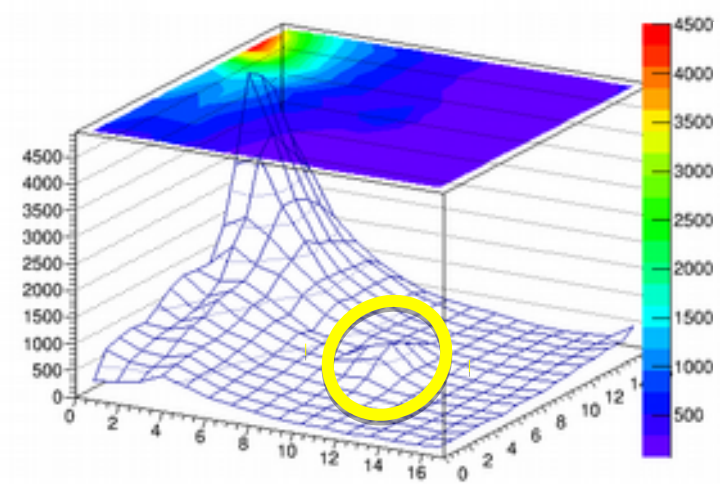
6 MeV/u



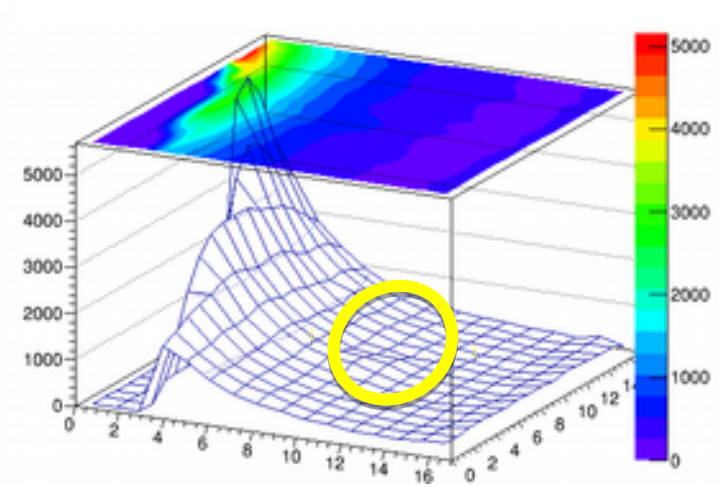
8 MeV/u



6.7 MeV/u

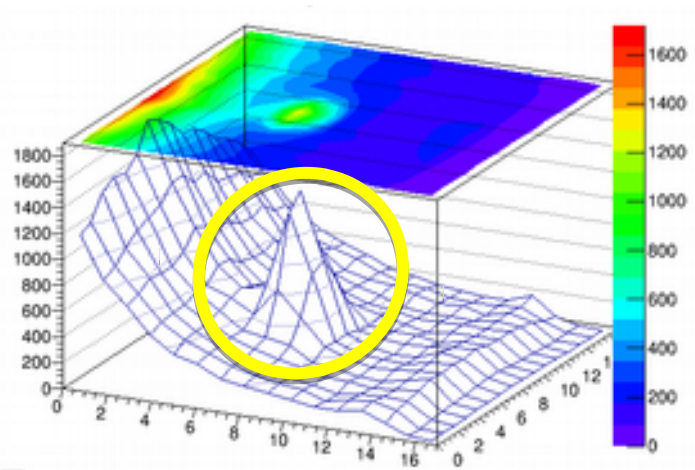


5.5 MeV/u

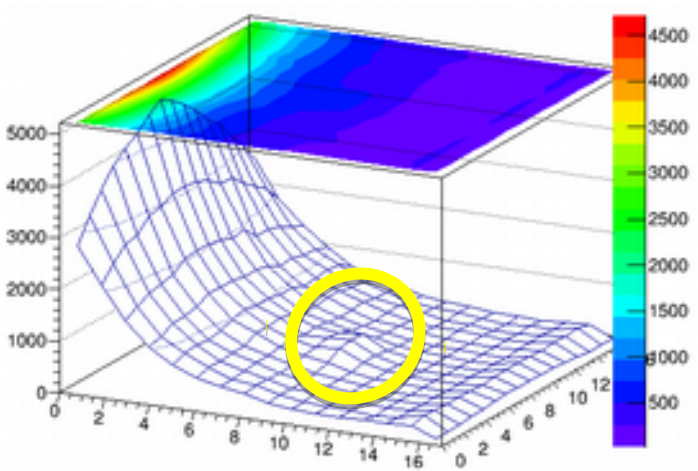


Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

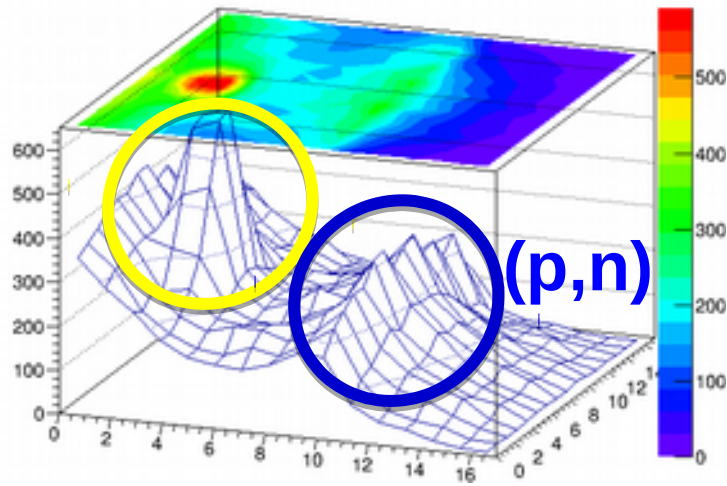
7 MeV/u



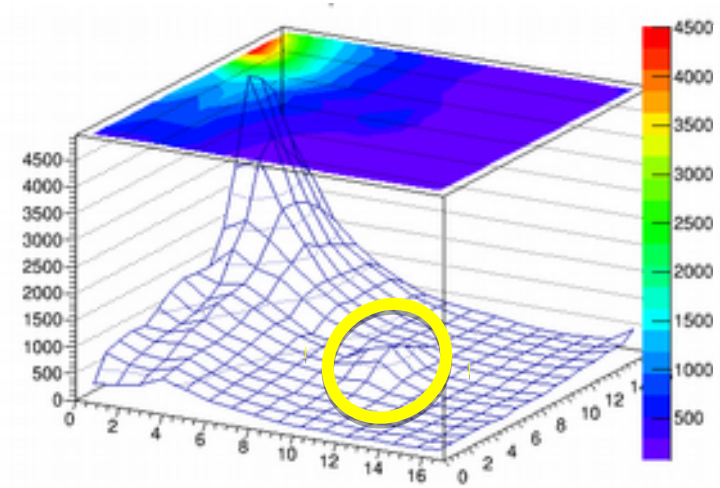
6 MeV/u



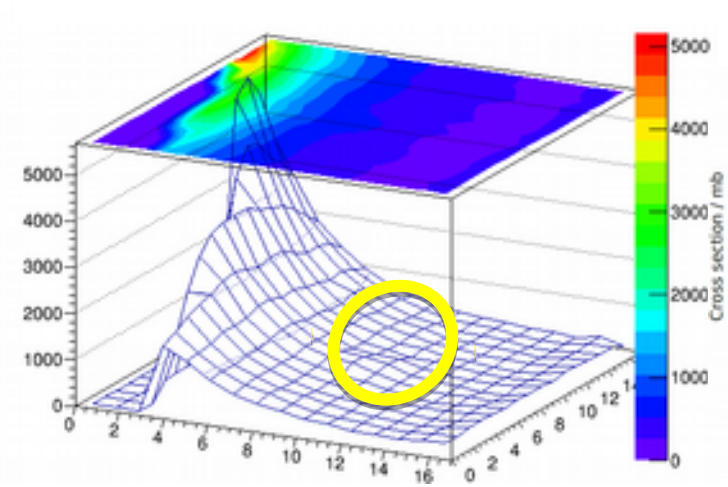
8 MeV/u

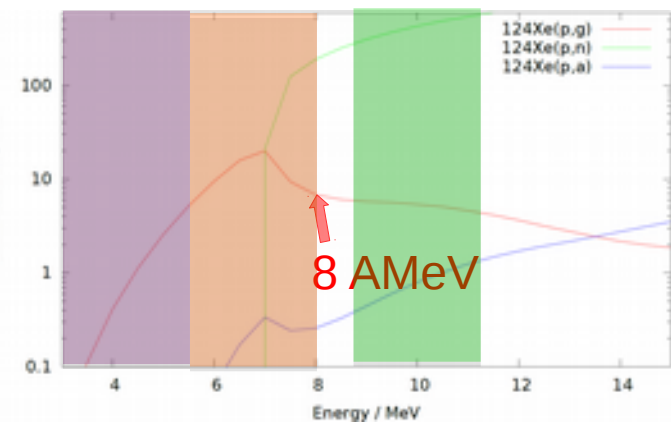


6.7 MeV/u



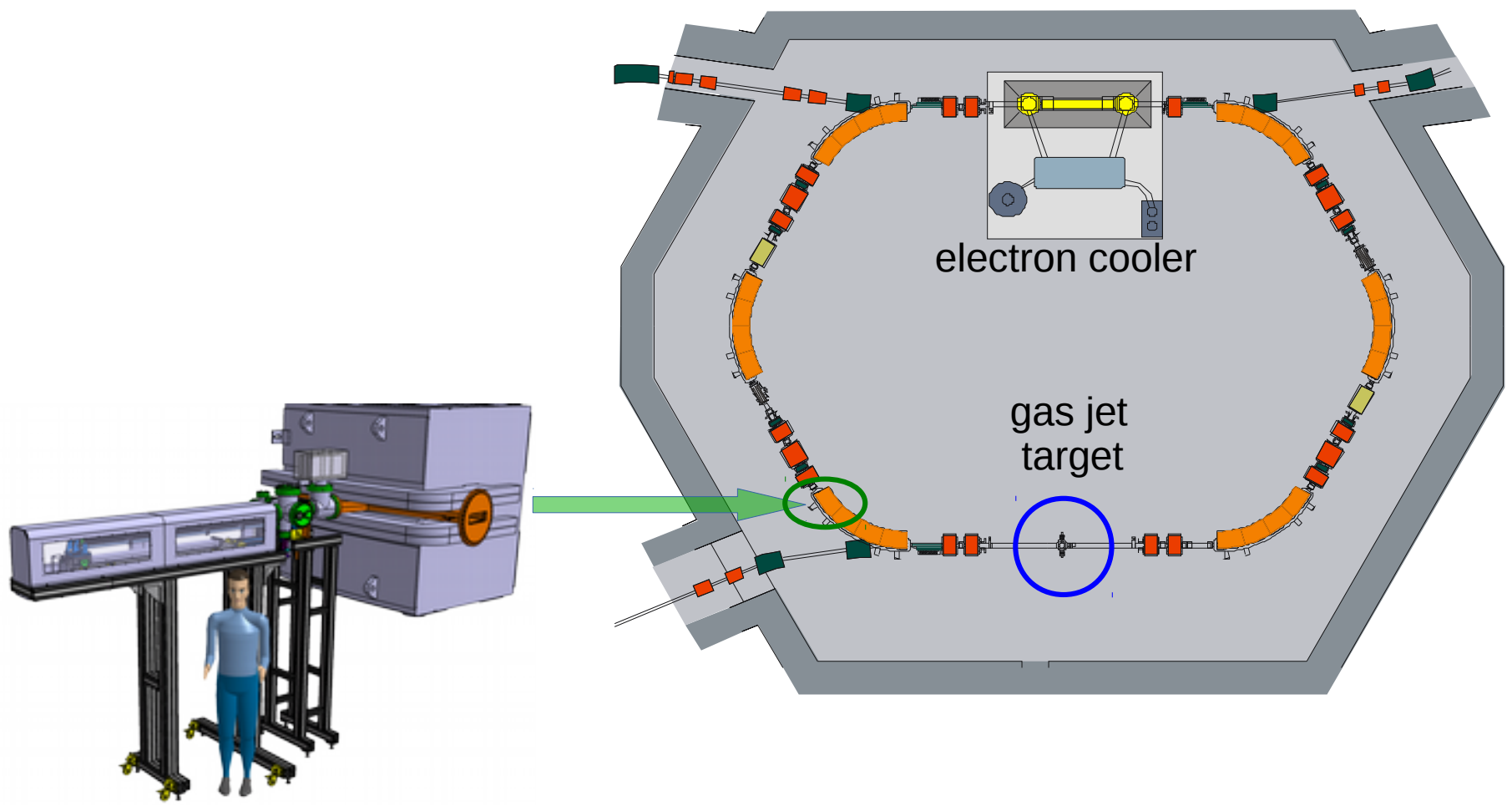
5.5 MeV/u





Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

Also important: **X-ray detectors**



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

Also important: **X-ray detectors**

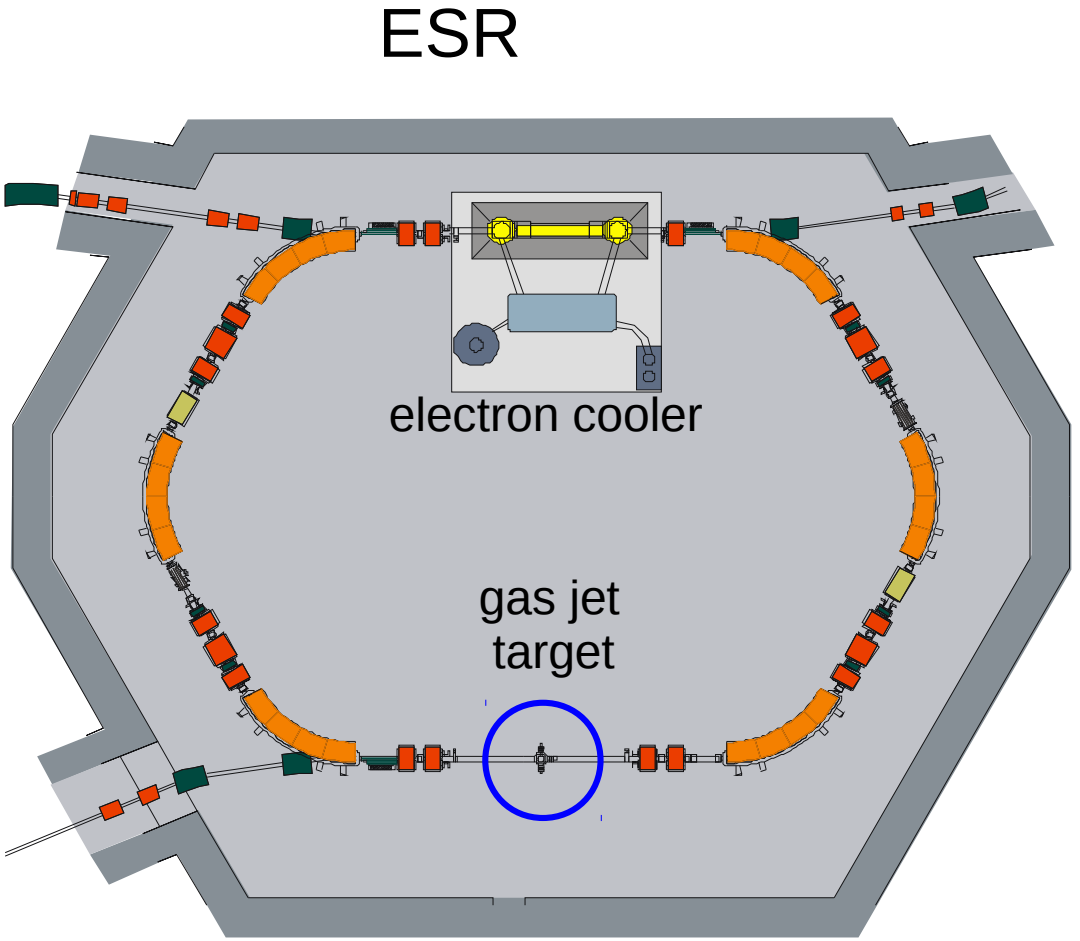
at target: large **xs for EC**

(reliably known quantity)

characteristic X-ray emission

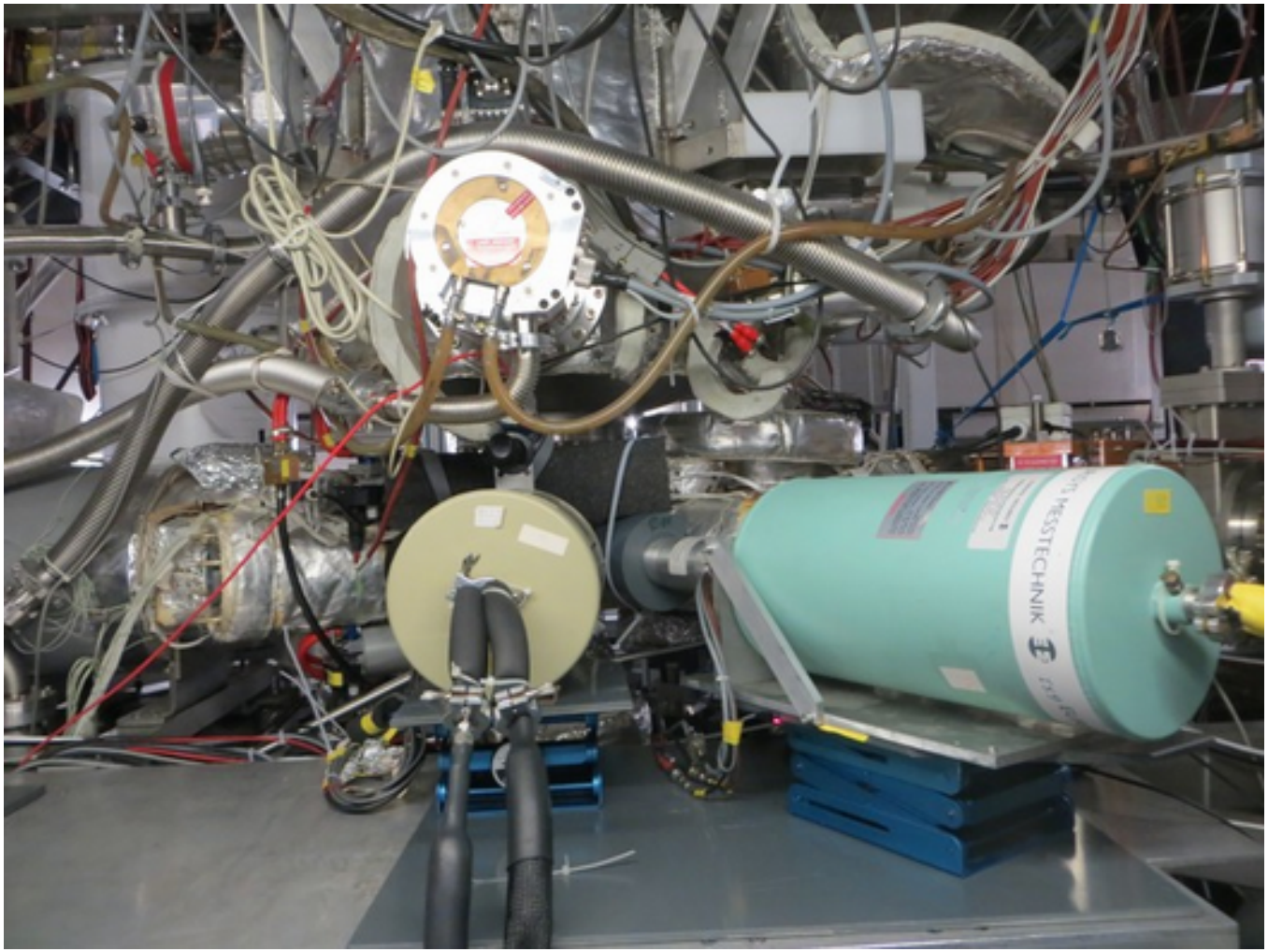
of radiative component at target

→ used for **normalization**



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

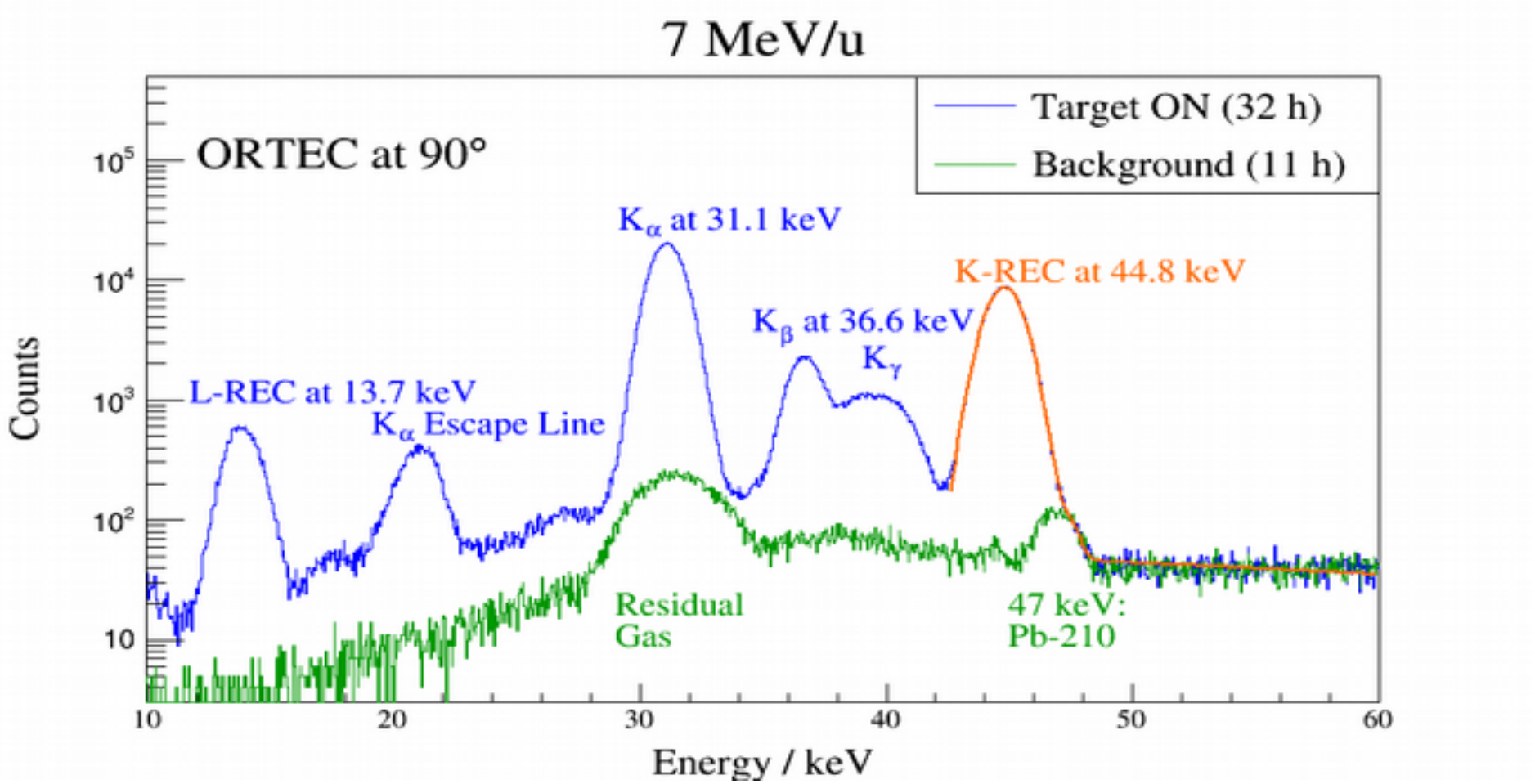
Also important: **X-ray detectors**



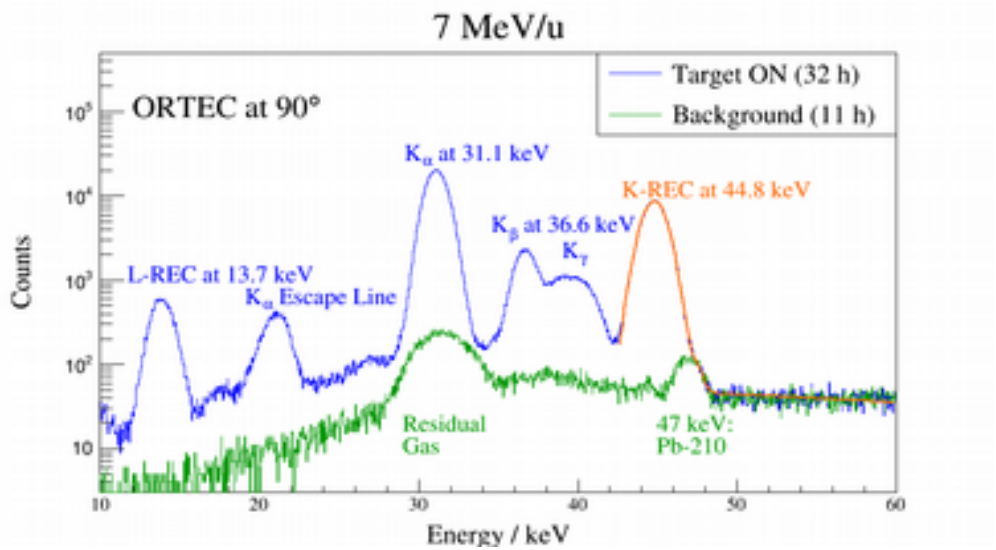
Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$

REC: fast projectile ion captures a bound e^- from target atom → x-ray emission

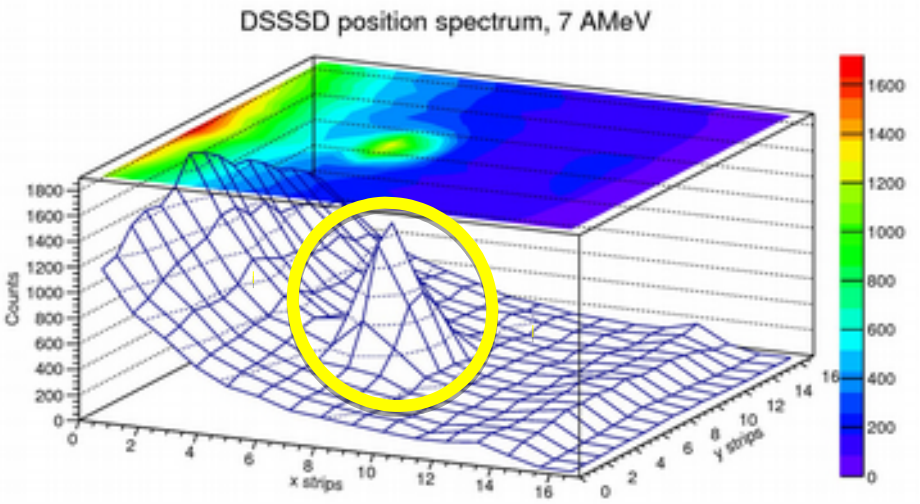
K-REC: REC into K shell of Xe



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$



Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$



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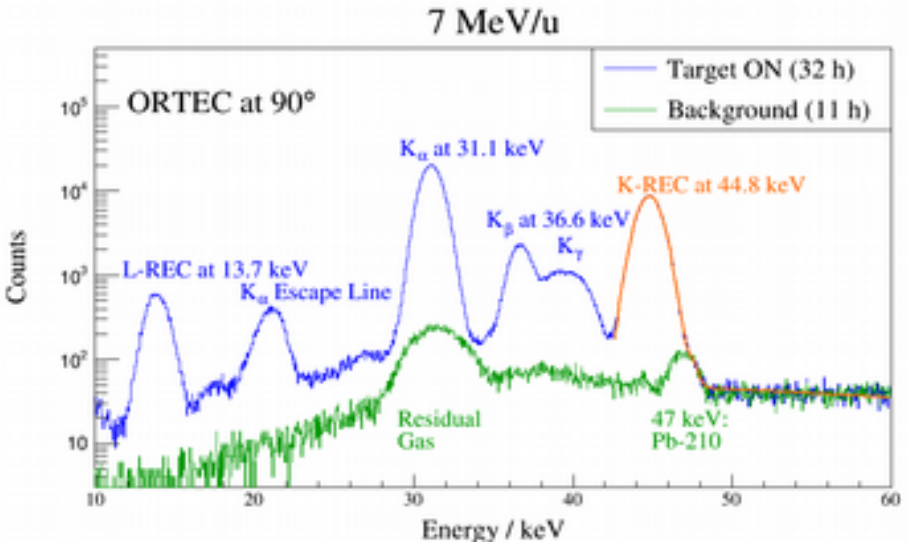
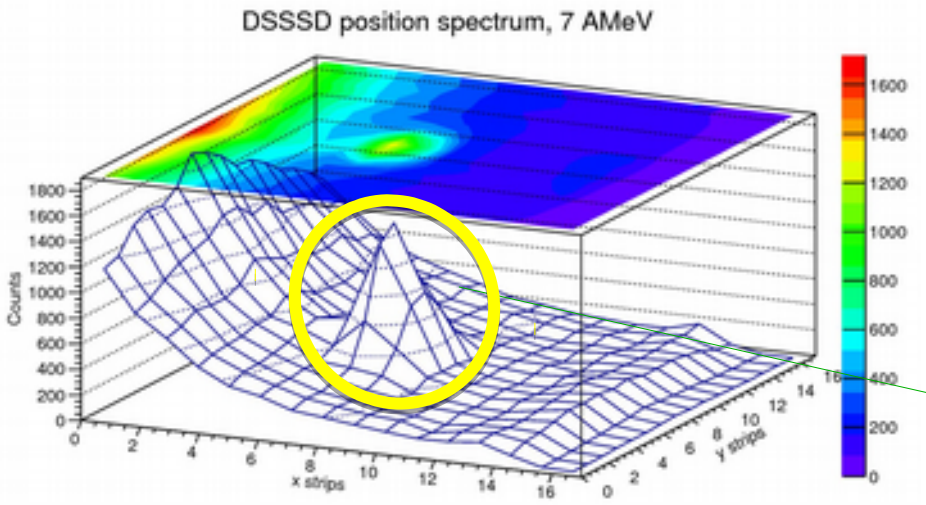


Beamtime and results: $^{124}Xe(p,\gamma)^{125}Cs$



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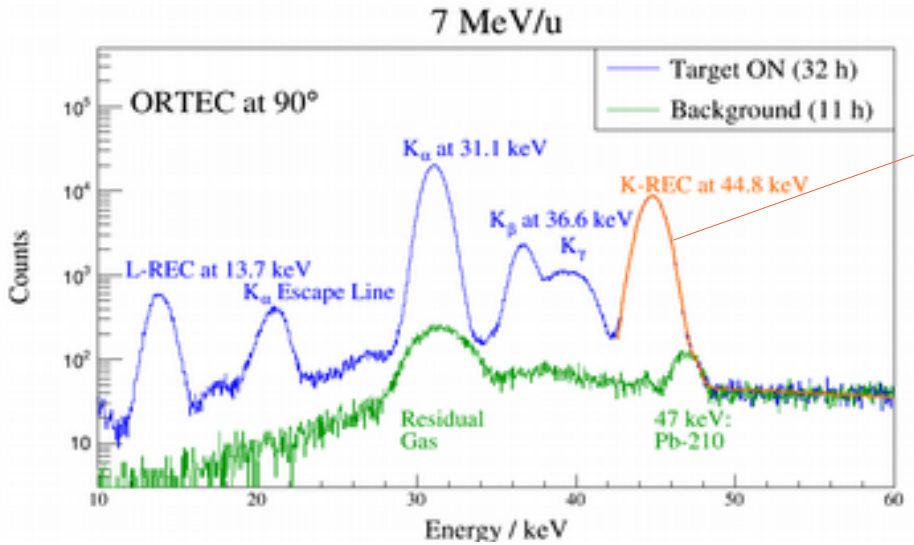


next step: cross section determination:

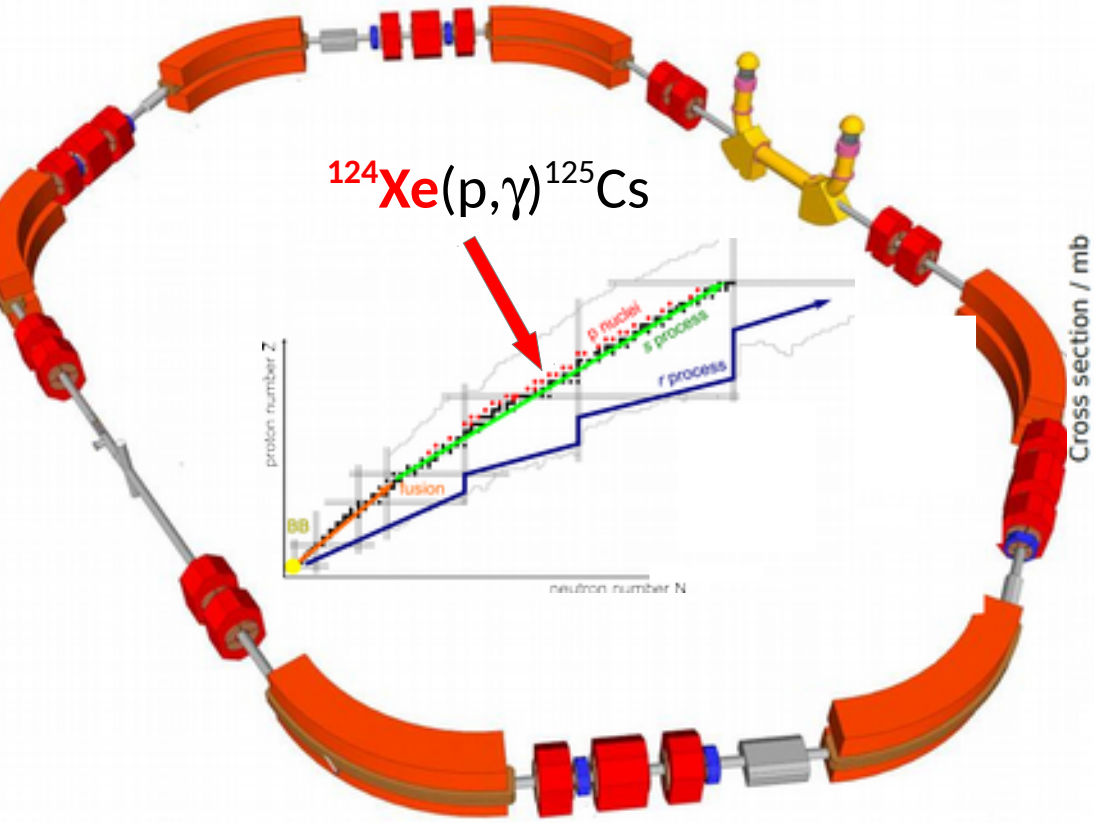
theory:

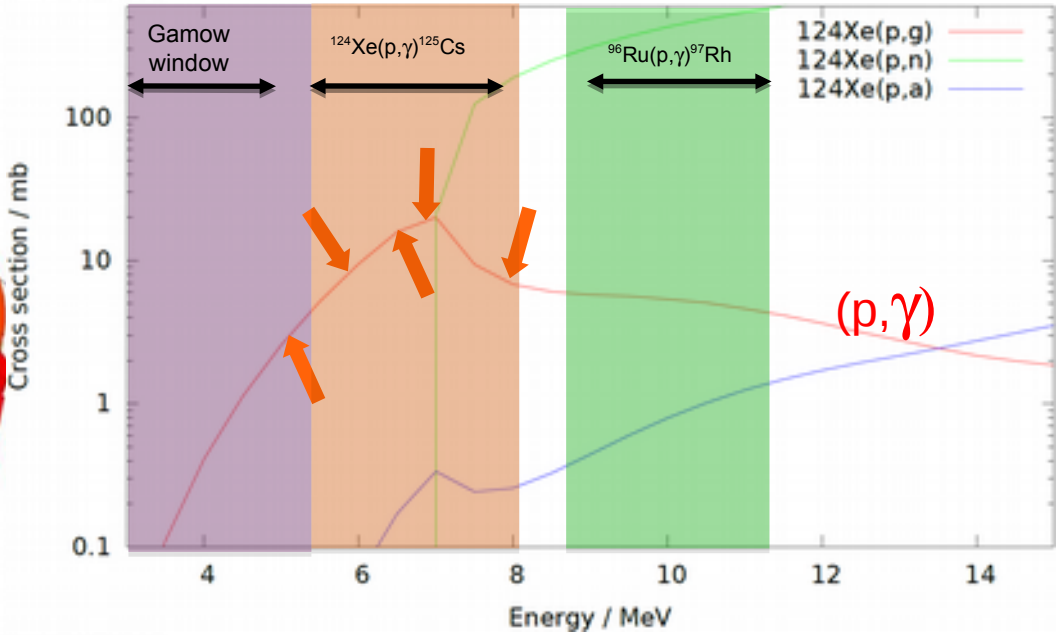
$$\sigma_{p,\gamma} = \frac{N_{p,\gamma}}{N_{K-REC}} \epsilon_{K-REC} \frac{d\sigma_{K-REC}}{d\Omega} \Delta\Omega$$

analysis in progress

Summary

7 MeV/u ✓ 6 MeV/u ✓ 8 MeV/u ✓
6.7 MeV/u ✓ 5.5 MeV/u ✓





Thank you!

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— 1 Goethe-University Frankfurt, Germany
— 2 GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
— 3 University of Edinburgh, UK
— 4 Helmholtz Insitute Jena, Germany
— 5 Centre Etudes Nucléaires de Bordeaux Gradignan, France
— 6 Saint Petersburg State University, Russia
— 7 Institute for Nuclear Research (MTA ATOMKI) Debrecen, Hungary
— 8 Australian National University, Australia
— 9 Institute of Modern Physics, Lanzhou, China
— 10 Technische Universität Darmstadt, Germany
— 11 Helmholtz Insitute Jena, Germany
— 12 Justus Liebig University Giessen, Germany