NUCLEAR REACTION STUDIES USING THE CRYRING REACTION CHAMBER SYSTEM

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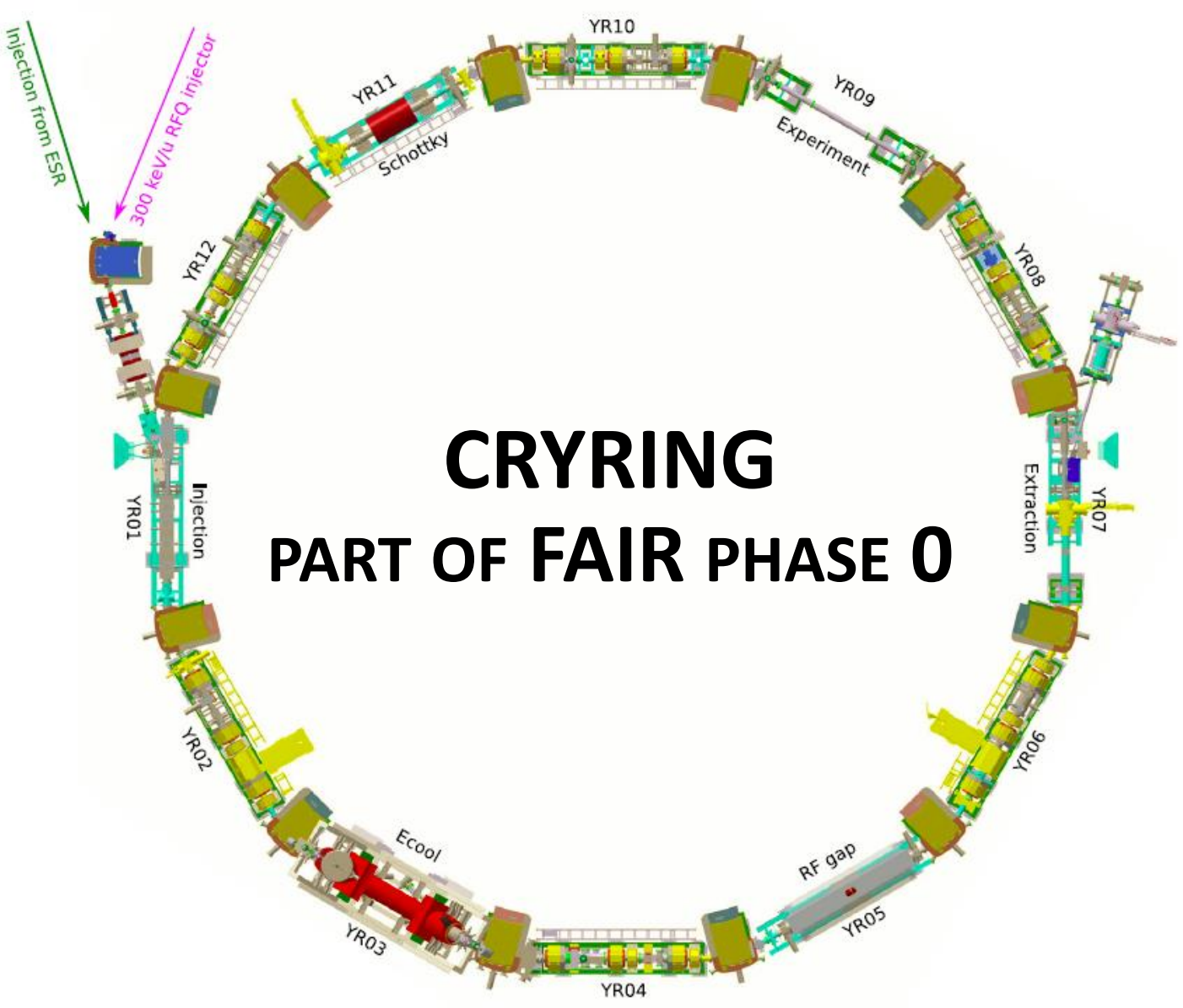
on behalf of the NucAR collaboration

NARRS workshop, 14 March 2018
GSI, Darmstadt



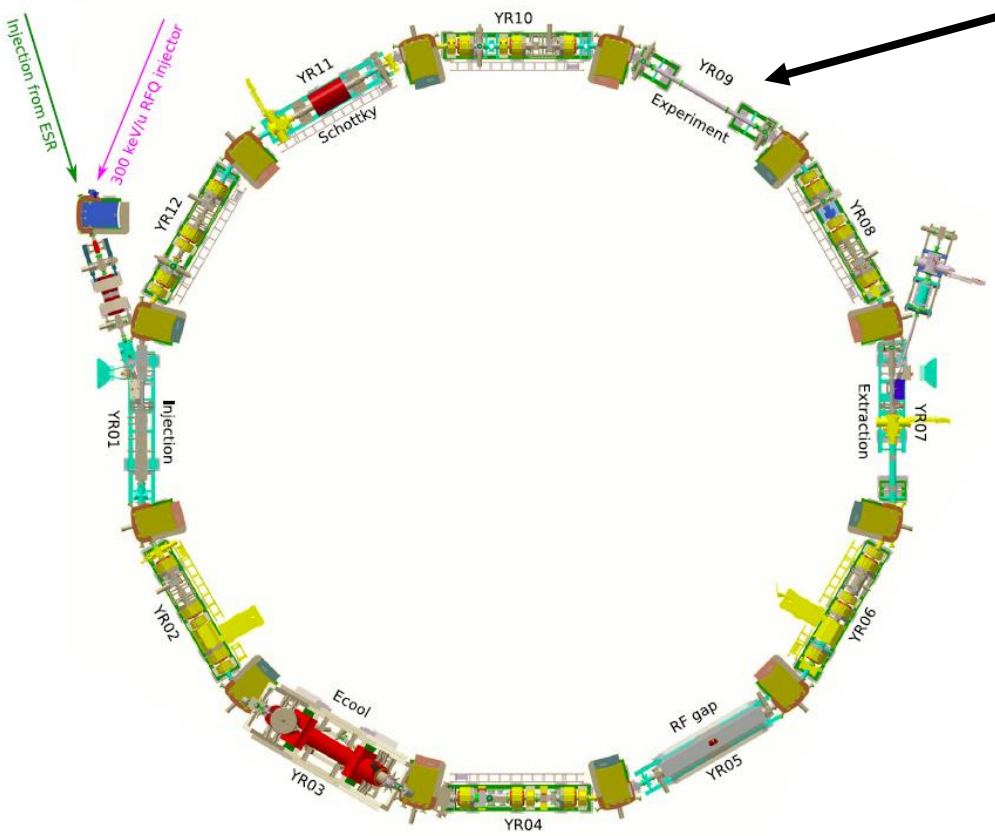
CRYRING

PART OF FAIR PHASE 0

CRYRING
PART OF FAIR PHASE 0

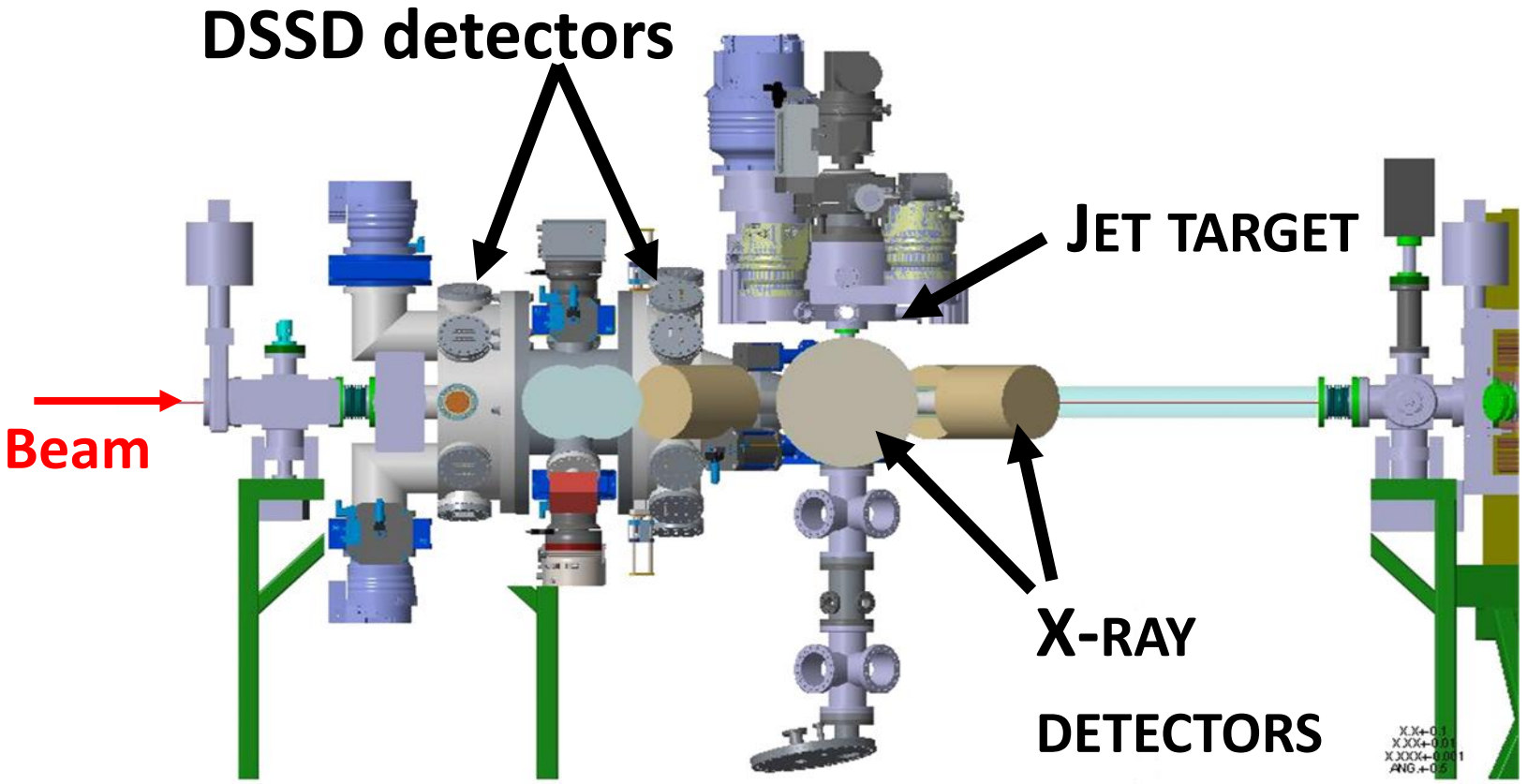
- Energy range: ~hundreds of keV/u to ~10 MeV/u
- Circumference: 54 m (half of ESR)
- Vacuum: 10^{-11} – 10^{-12} mbar

Section YR09

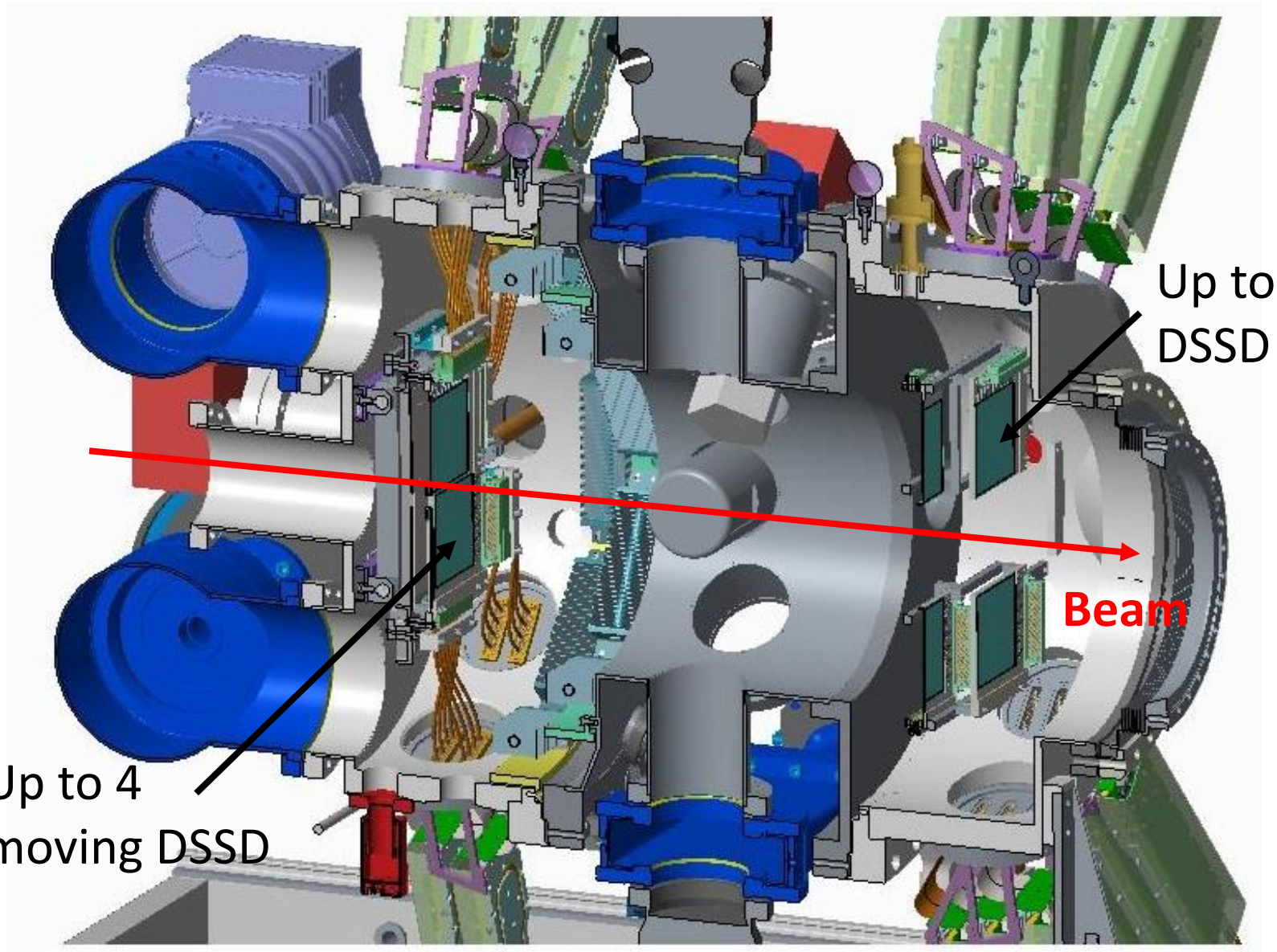


THE CRYRING REACTION CHAMBER SYSTEM

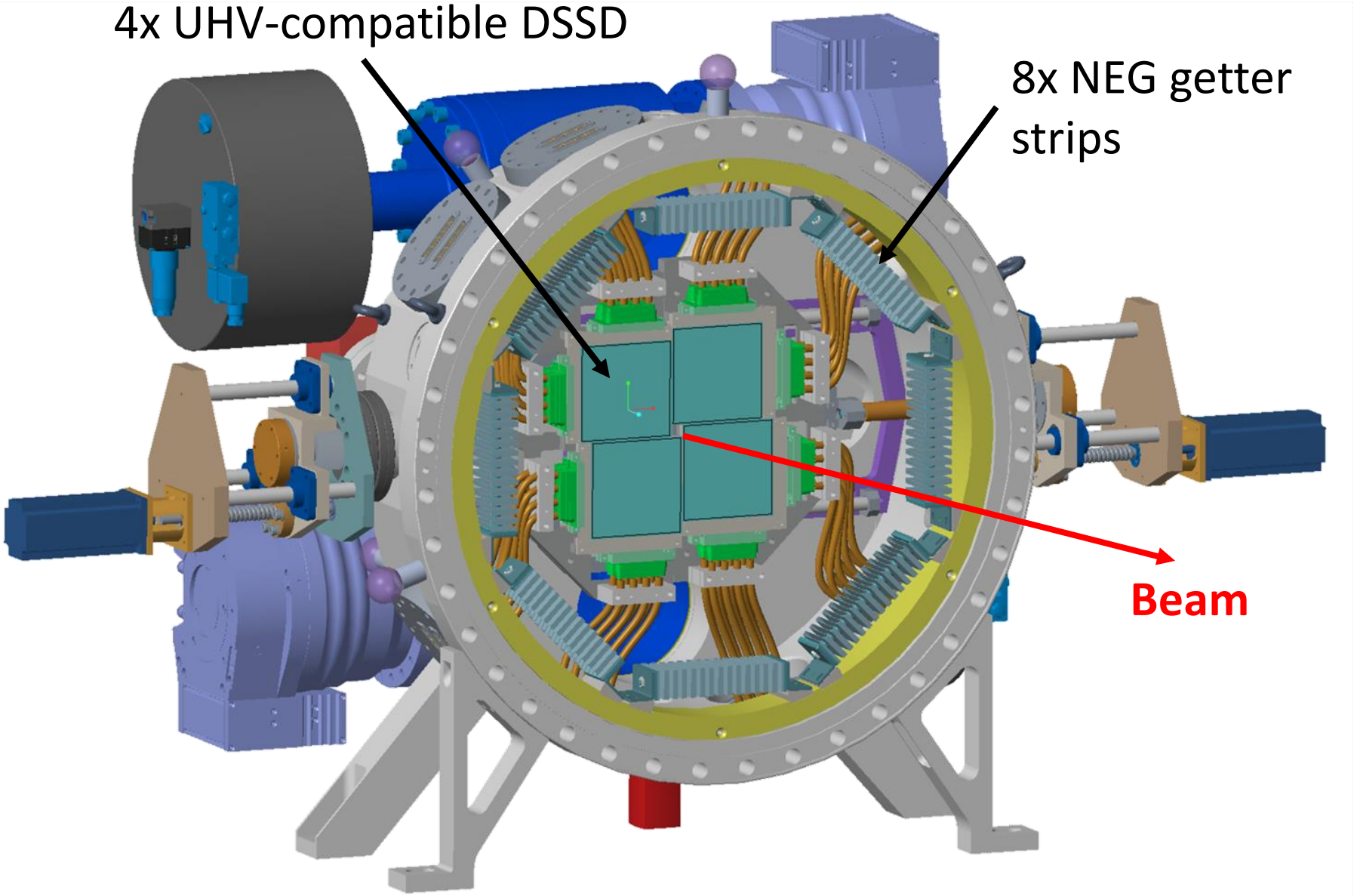
- **Two** chambers mounted downstream, upstream, or both
- Allows combined nuclear and atomic physics measurements
- Fully funded by UK STFC. **TDR submitted to GSI**.
- To be mounted on the CRYRING by Summer 2019



UPSTREAM CONFIGURATION



THE MOVING DSSDS



EXPERIMENTAL SETUP

In-ring target

• A cryogenic jet micro-droplet target is being developed by GSI (N. Petridis *et al.*)

• Design goal: at least **10^{14} atoms/cm^2**

• No gas recirculation system (at present)

Detectors & DAQ

• Highly segmented Double-sided Silicon Strip Detectors

• 128x128 = 256 channels per det. x 8 dets. = **2048 channels**!

• We will use **AIDA** FEE64 ASIC cards to read data out

• AIDA is in use at BRIKEN@RIKEN, and will be at DESPEC@GSI

• FEE64 cards have already been produced and tested

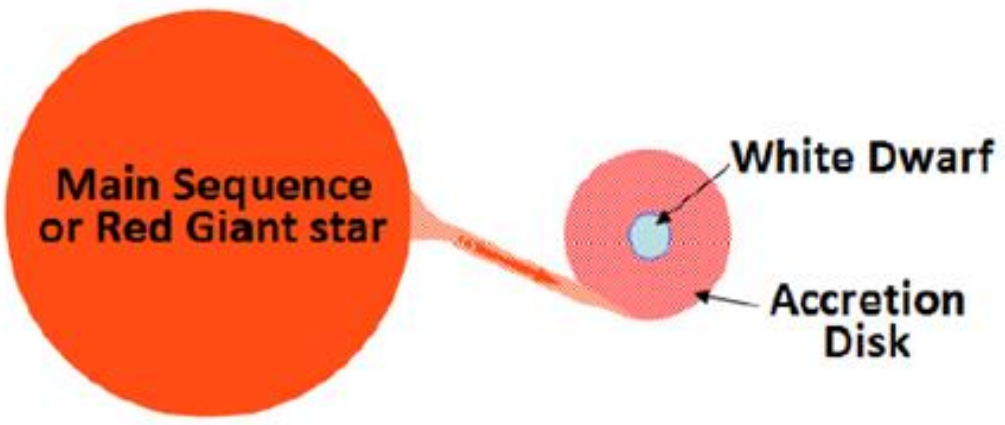
SCIENTIFIC AIMS

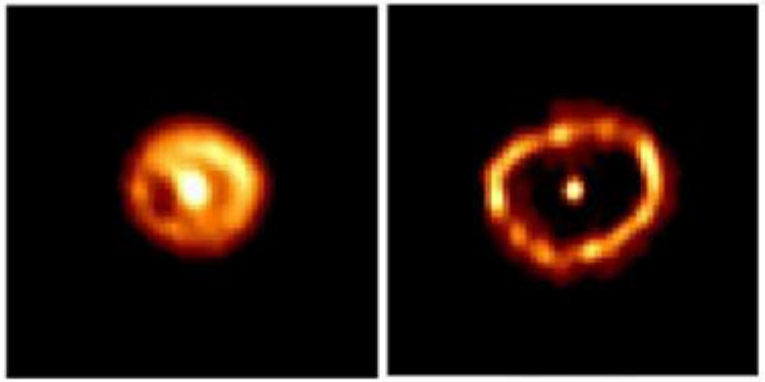
This system will be used for **high resolution** charge particle reaction studies for nuclear astrophysics including:

1. Direct astrophysical reaction measurements e.g. (p,α)
2. Indirect reactions probing key resonance properties e.g. (d,p)

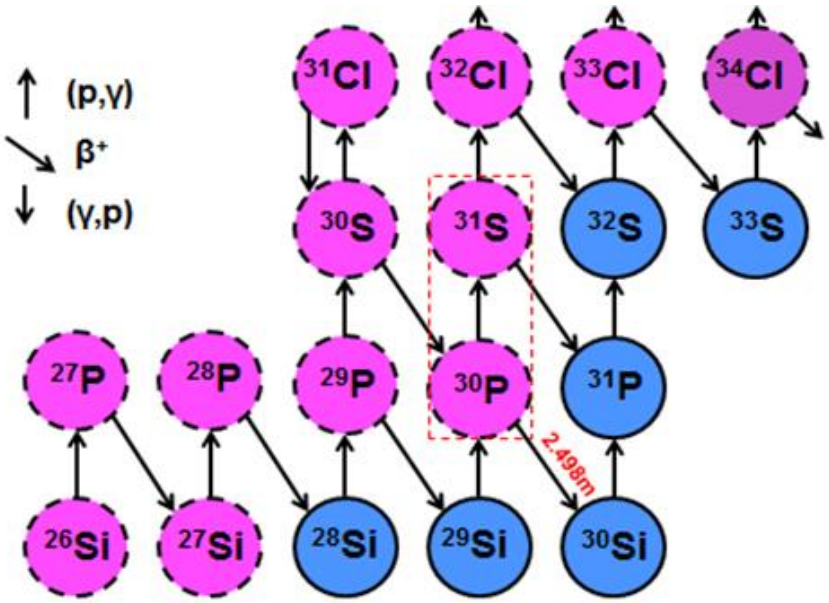
First measurement approved: **^{30}P(d,p)** (S461_Bruno)

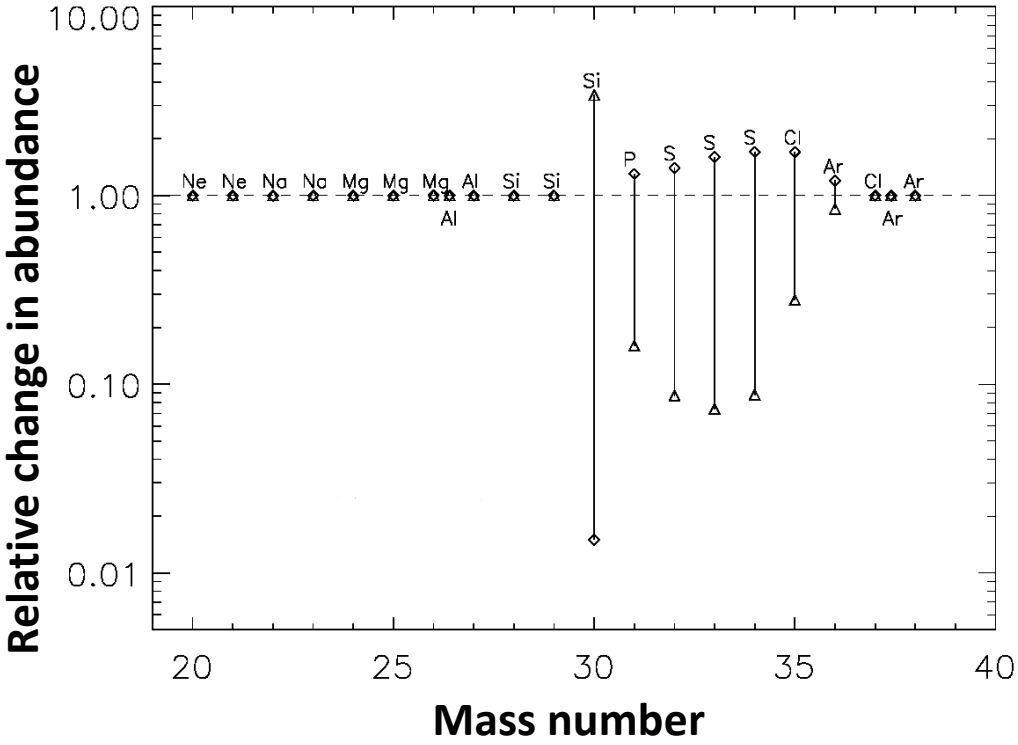
→ Relevant for modelling nucleosynthesis in novae explosions





NOVAE NUCLEOSYNTHESIS

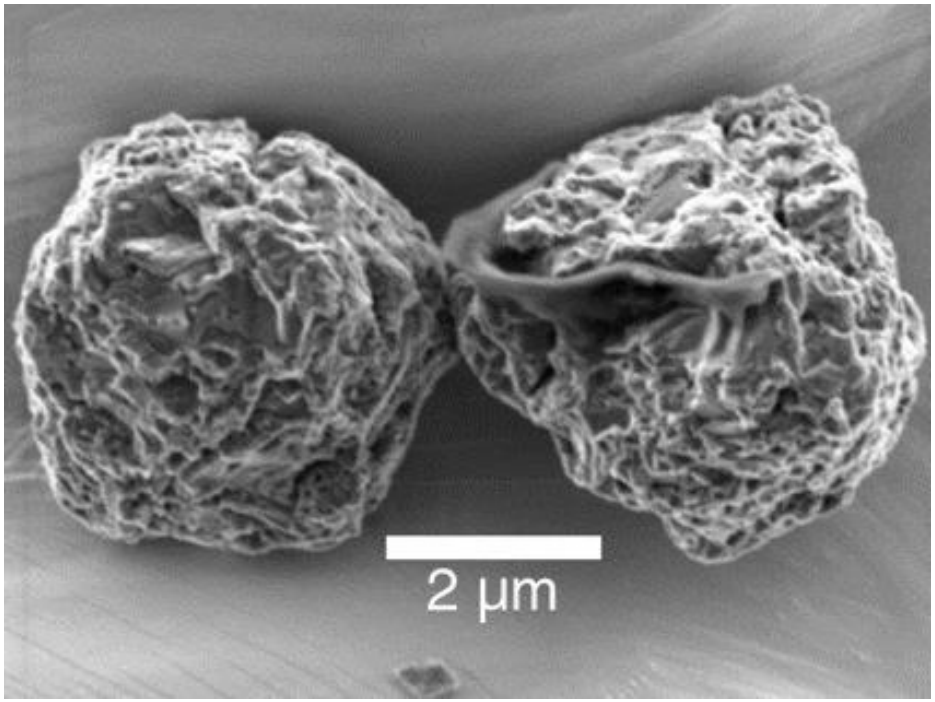




$^{30}P(p,\gamma)^{31}S$ is a bottleneck which controls abundance of elements from Si → Ca isotopes emitted in novae ejecta.

PRE-SOLAR GRAINS

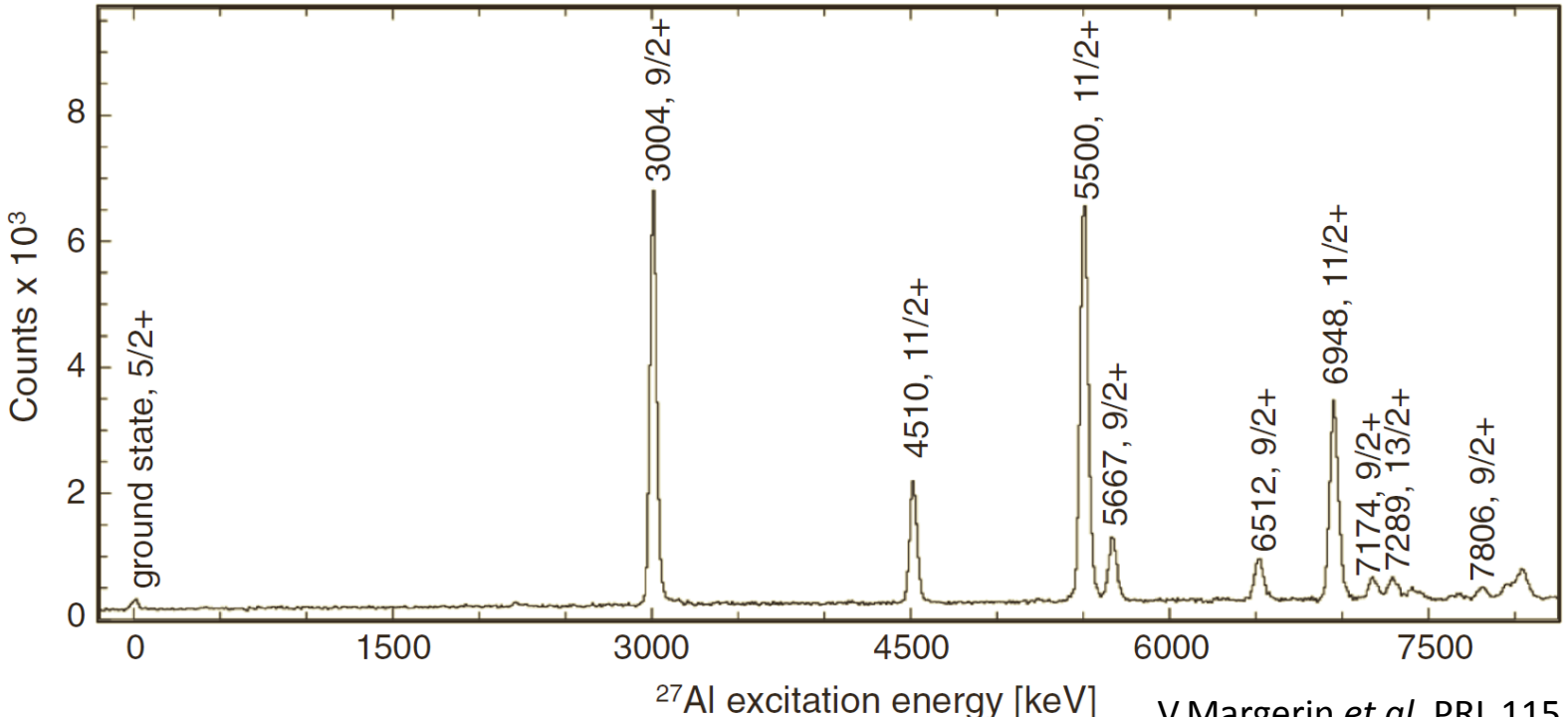
- Meteoritic grains predating the birth of Solar System
- Models predict large $^{30}Si/^{28}Si$ ratio for grains originating from novae
- Abundance of ^{30}Si is determined by the competition between the ^{30}P β^+ decay and the **$^{30}P(p,\gamma)^{31}S$** reaction rate.



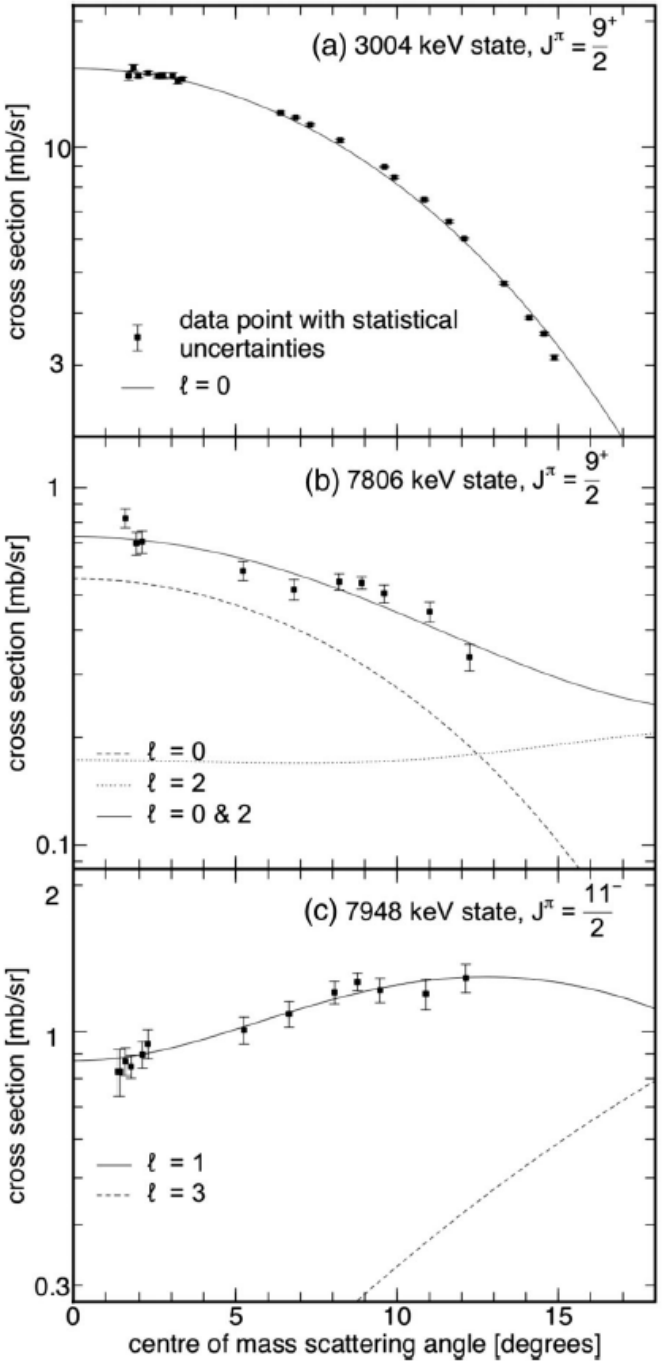
Andrew M Davis.
University of Chicago

SCIENTIFIC AIMS

- ^{30}P(p,γ) plays a key role in novae nucleosynthesis (currently single most important uncertainty)
- Direct measurement of ^{30}P(p,γ) impossible - ^{30}P beams too weak
- Use **^{30}P(d,p)^{31}P** transfer reaction to probe unknown strength of **key *l*=0** and ***l*=1** capture resonances for ^{30}P(p,γ) reaction rate in novae.



V.Margerin *et al.* PRL 115 (2015)



SCIENTIFIC AIMS

From a **single** measurement at a single energy one obtains:

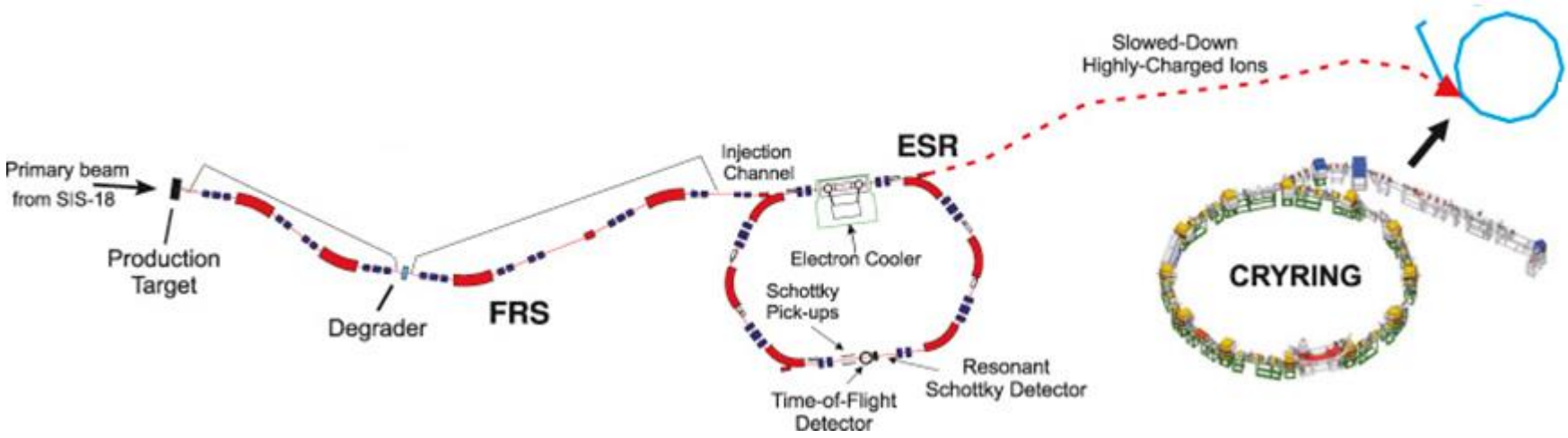
- The energy of all states
- The angular distribution of all states
- Fitting the angular distributions, the J^π of the states
- Comparing with models (e.g. DWBA), the spectroscopic factor C^2S of all states

V.Margerin *et al.* PRL 115 (2015)

EXPERIMENTAL PROCEDURE

- Primary beam: ^{40}Ar (480 MeV/u) -> to FRS
- Secondary beam from FRS: ^{30}P -> to ESR
- Cool down & stack beam in ESR -> to CRYRING
- Measure in CRYRING & stack beam in ESR
- Expected luminosity: ~100 (barn*s)$^{-1}$

- Shifts approved: **21** (A- priority)



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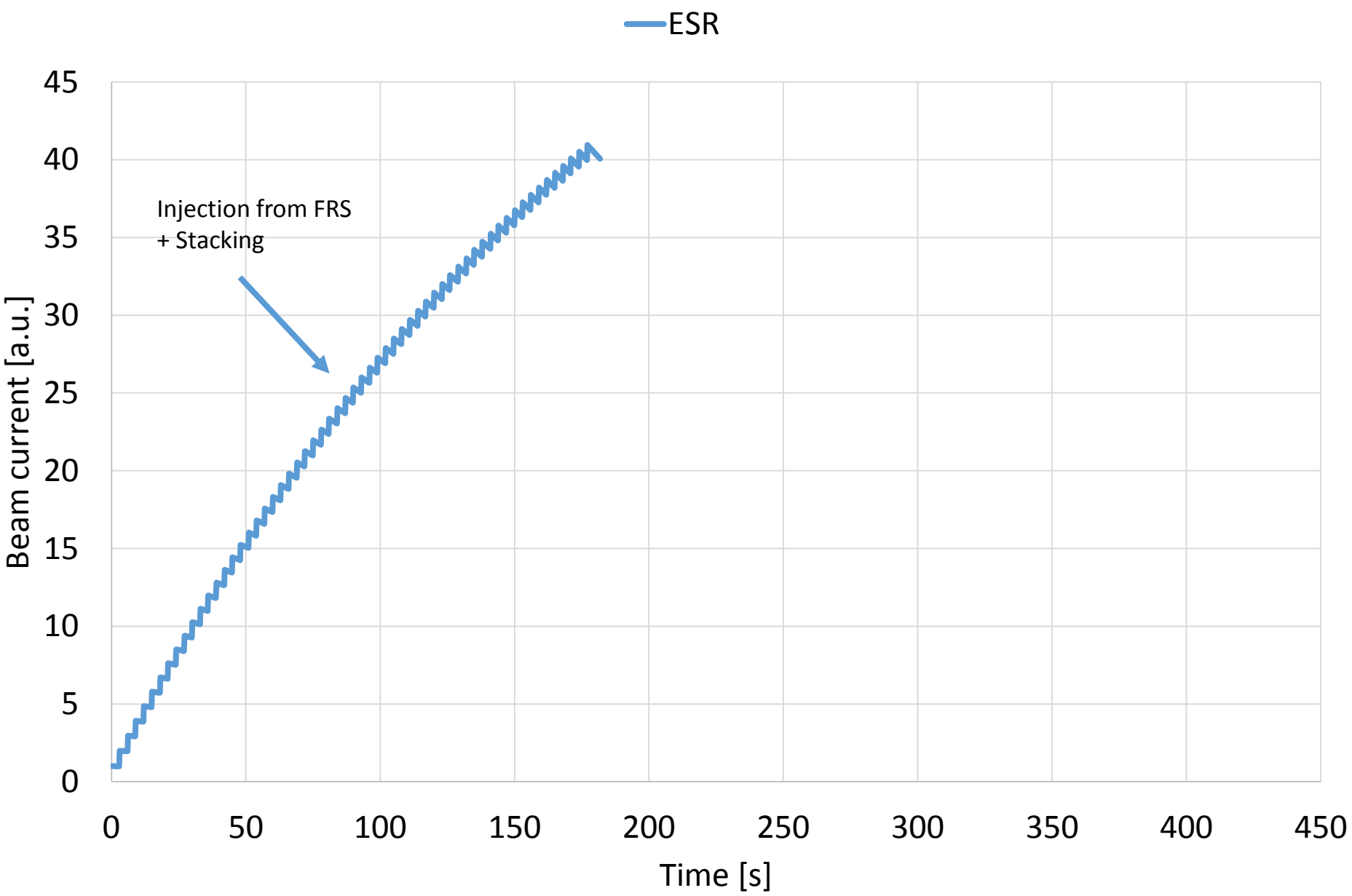

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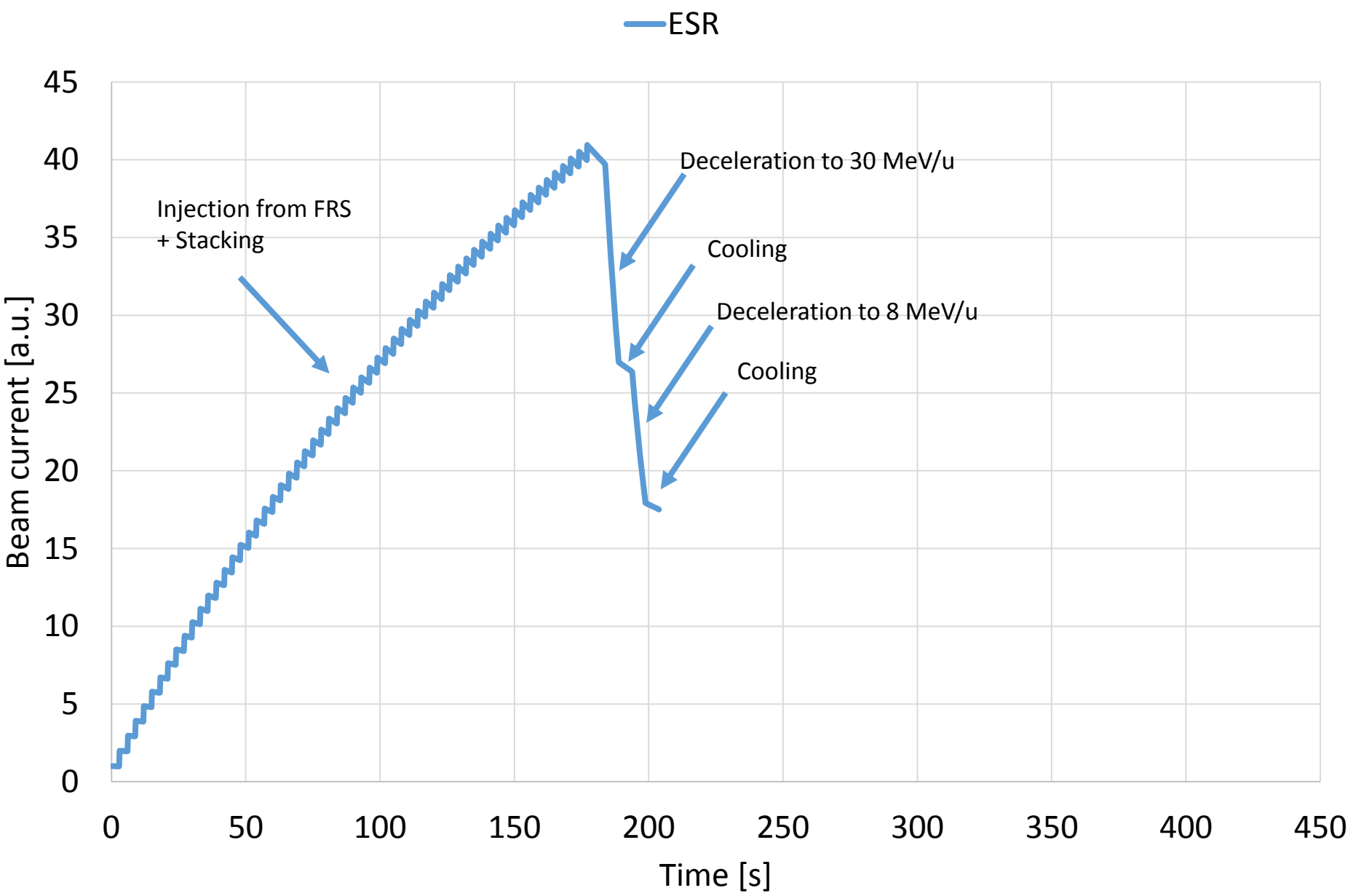

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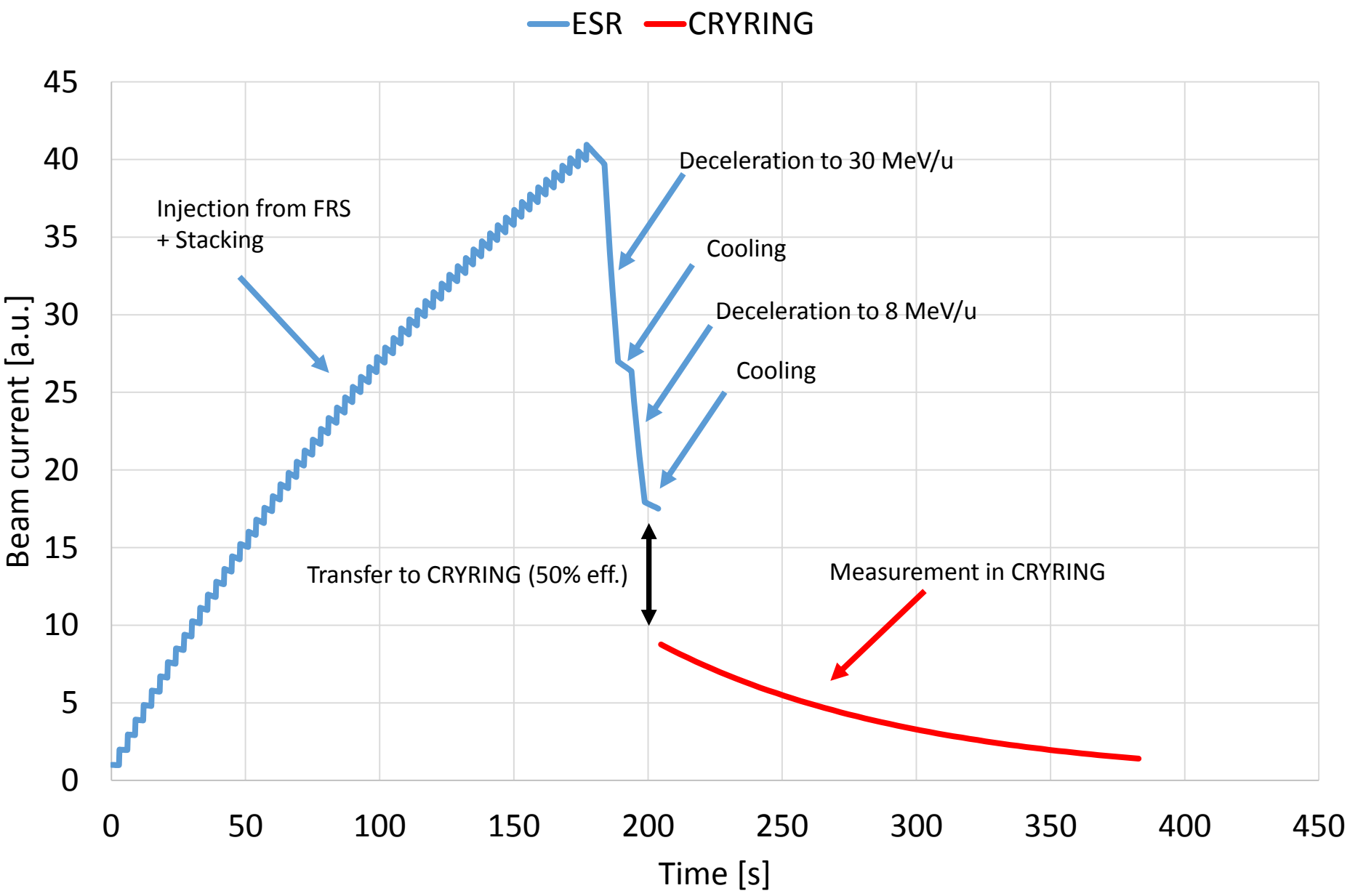

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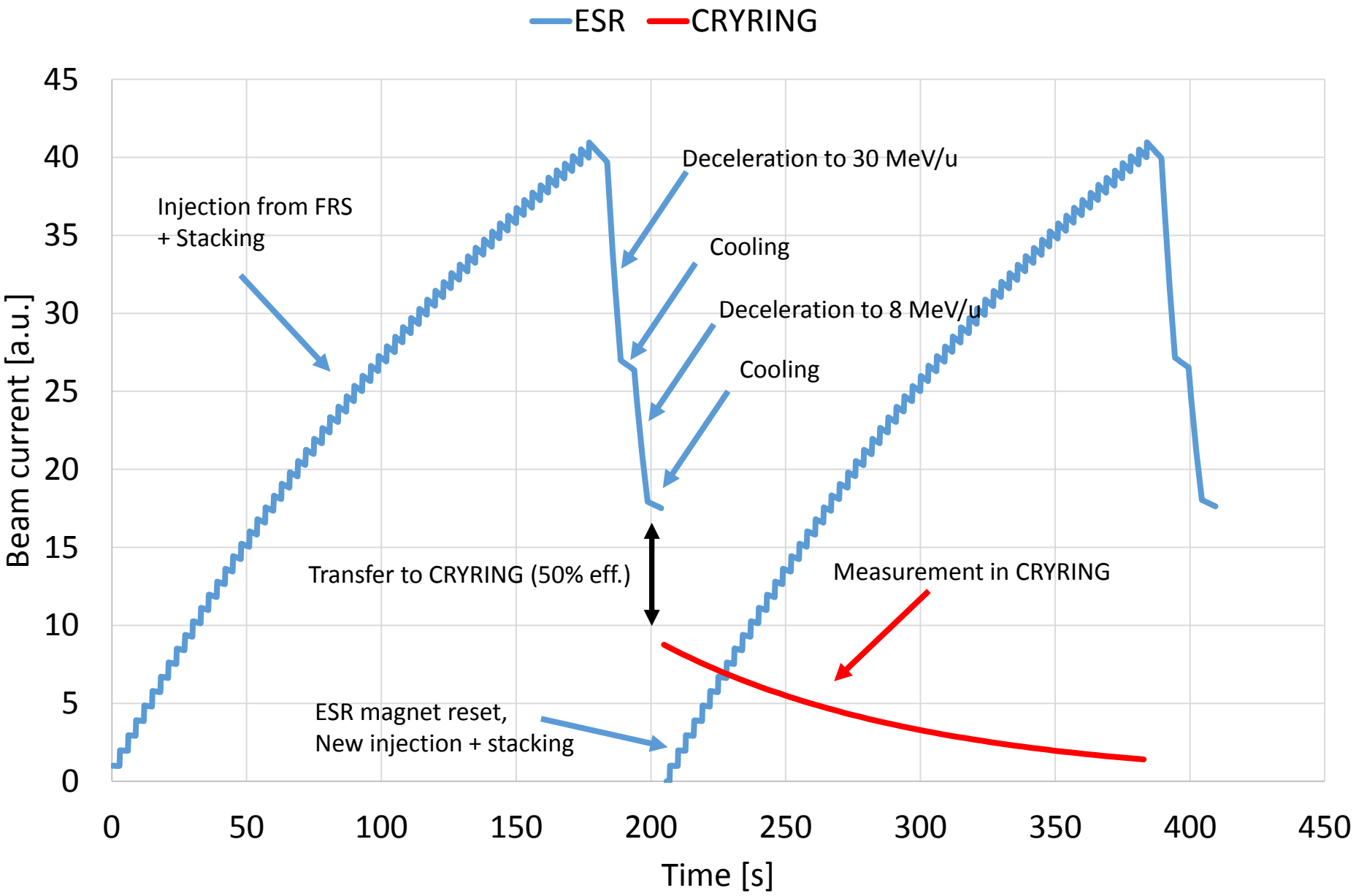

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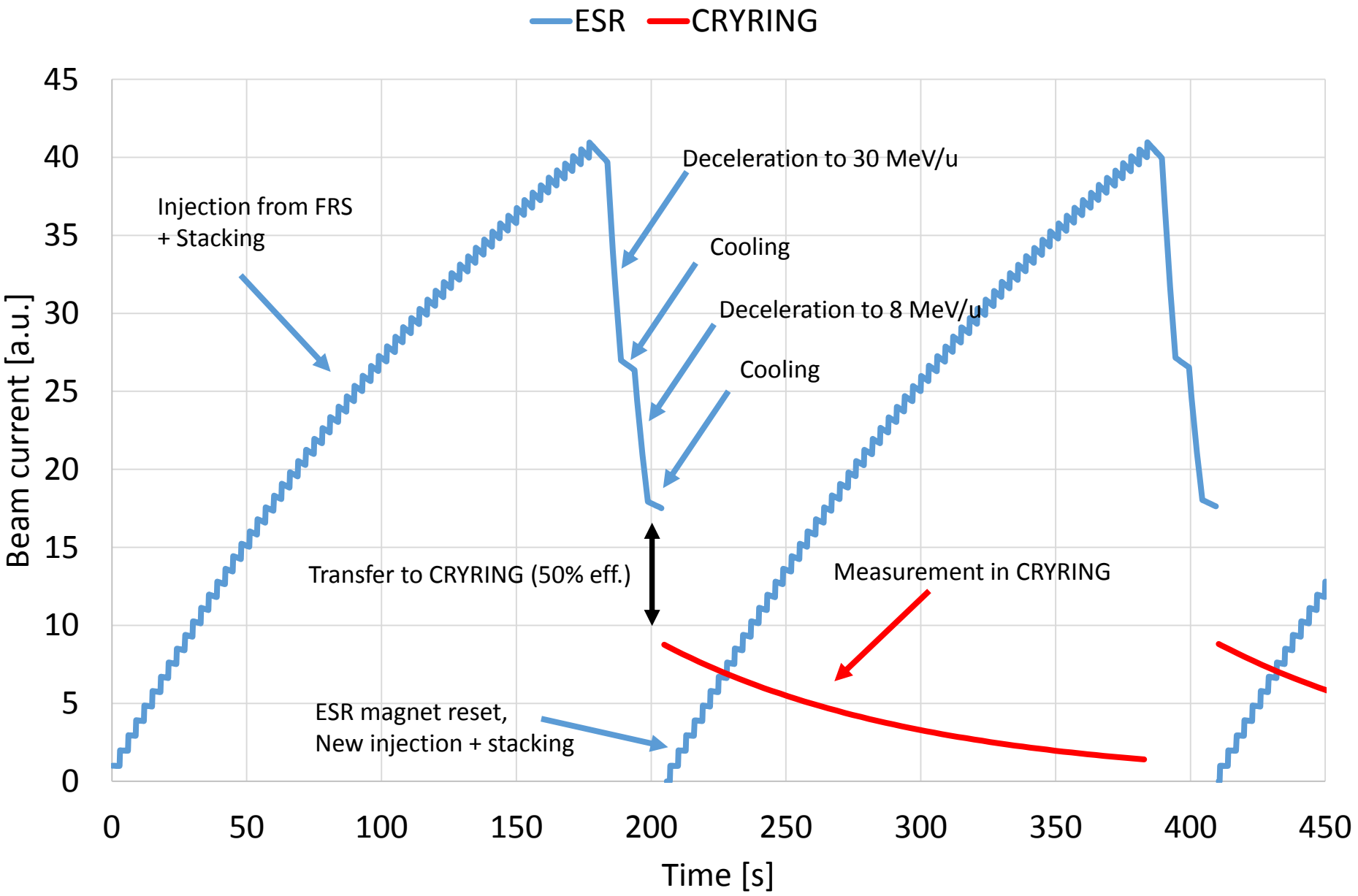

COMMISSIONING & PARASITIC STUDIES

Parasitic runs for commissioning are desirable

- Any beam heavier than deuterium - OK
- Primary beams (bypassing FRS) – OK

Call for proposals at the CRYRING local RFQ injector

- We submitted a **Letter of Intent** to have light ions (e.g. ^{12}C)
- We could use e.g. $^{12}C(d,p)$ to commission the setup (target, vacuum, DAQ, resolution, efficiency, etc.)

In principle high-resolution (d,p) **parasitic studies** can be performed with any beam heavier than deuterium transported to the CRYRING

CONCLUSIONS

- New setup for nuclear & atomic physics experiments
- To be mounted on CRYRING by Summer 2019
- Commission with local injector and/or parasitic runs
- First approved experiment ^{30}P(d,p)

- Other possible uses: Surrogate fission reactions measurements (see Beatriz Jurado's talk)