TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Workshop on Gas-filled Detectors and Systems (GDS): Rare-gas target handling and recycling systems

Institut de Physique Nucléaire (IPN), Orsay (FRANCE), January 23-25, 2019

The JENSA windowless gas-jet target

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Institute of Nuclear and Particle Physics, TU Dresden, Germany

JINA-CEE

MICHIGAN STATE UNIVERSITY

FRIB

NSCL

JENSA

Thanks to the JENSA collaboration

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Core Institutes:

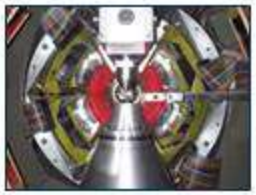
COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

MICHIGAN STATE UNIVERSITY

Outline

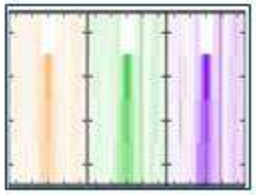
Part 1

Jet **E**xperiments in **N**uclear **S**tructure and **A**strophysics



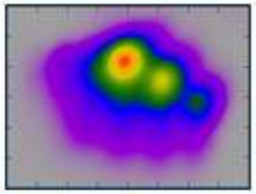
Part 2

Overlap between jet and ion beam



Part 3

Jet thickness measurements



Part 4

Rare isotope beam experiments with JENSA

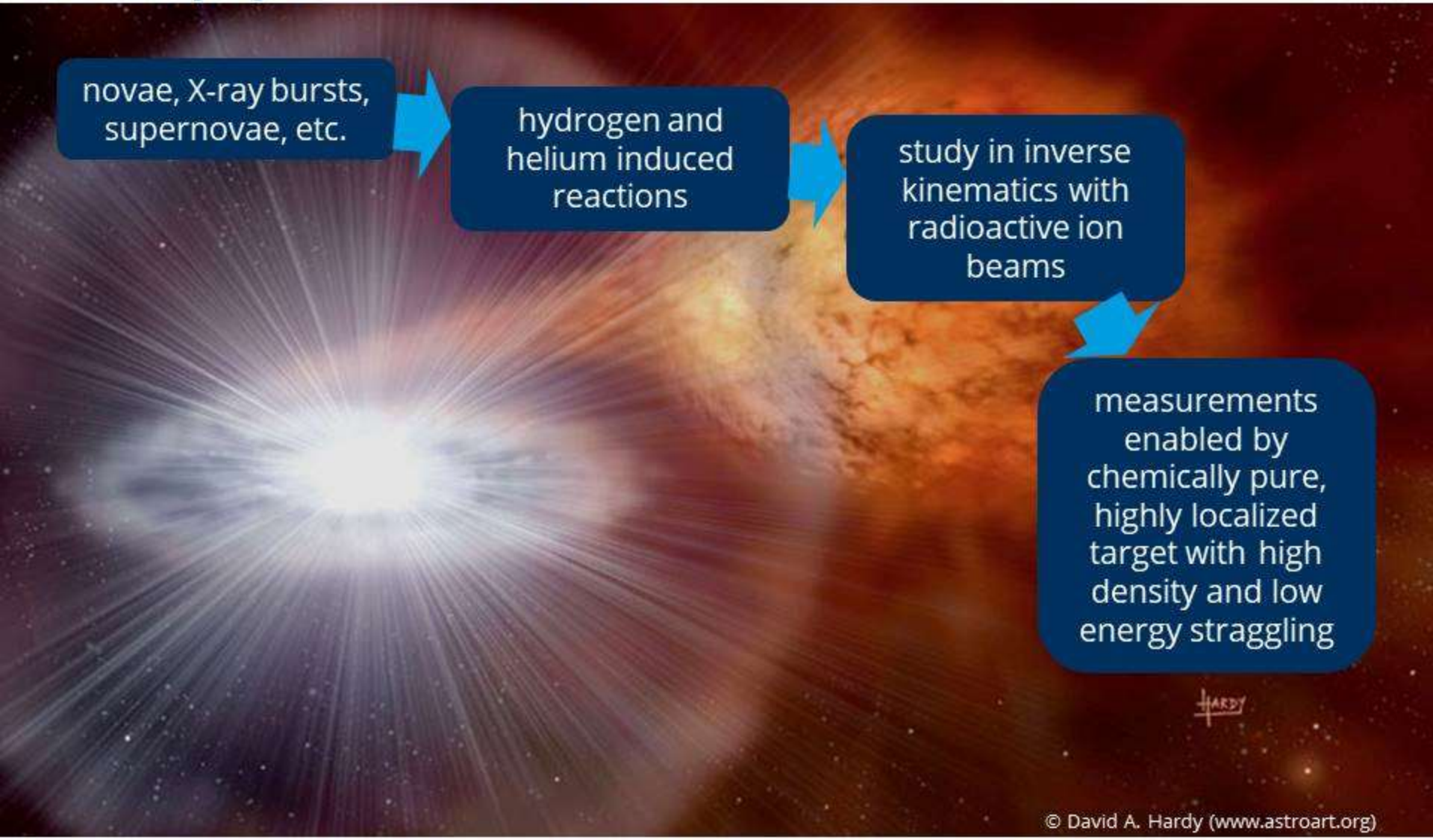
Part 5

The future of JENSA

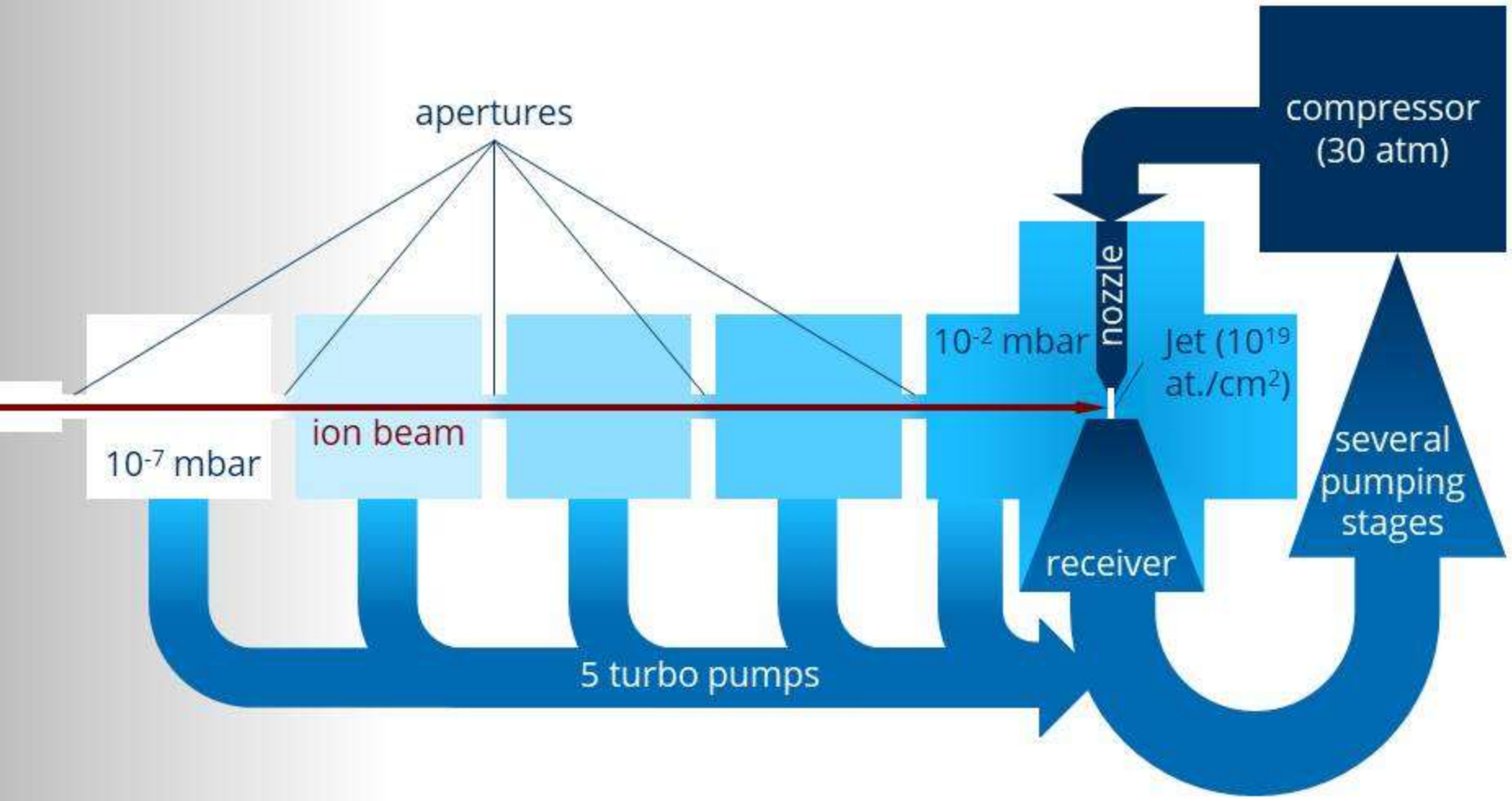
Part 1

Jet **E**xperiments in **N**uclear **S**tructure and **A**strophysics

Astrophysical motivation

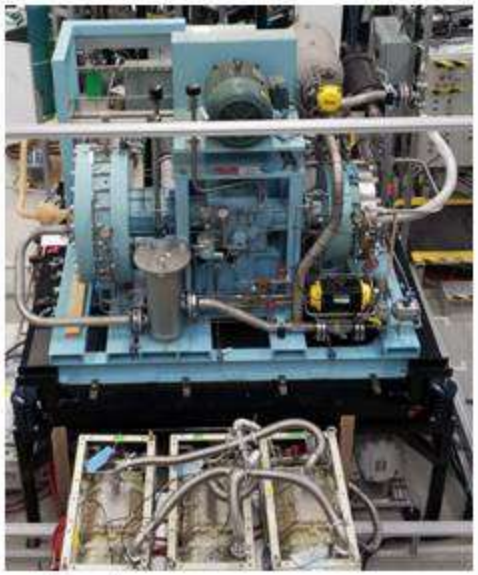


Recirculating gas system

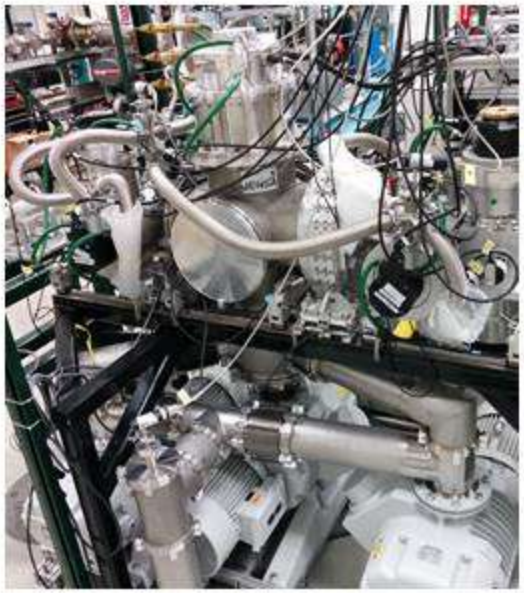


The JENSA gas jet target

Jet Experiments in Nuclear Structure and Astrophysics



diaphragm compressor



target chamber and pumps

nozzle, receiver and Si detectors

Attention should be paid to ...

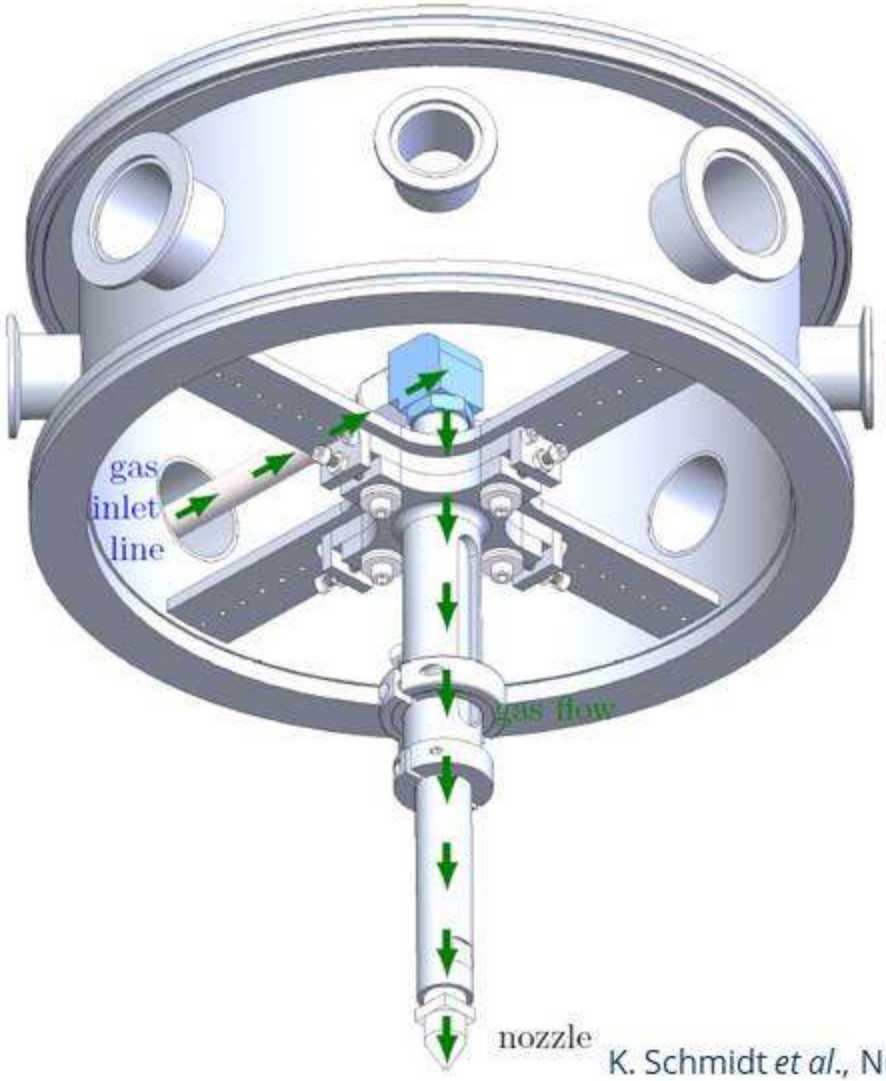
1. Overlap between gas-jet target and ion beam

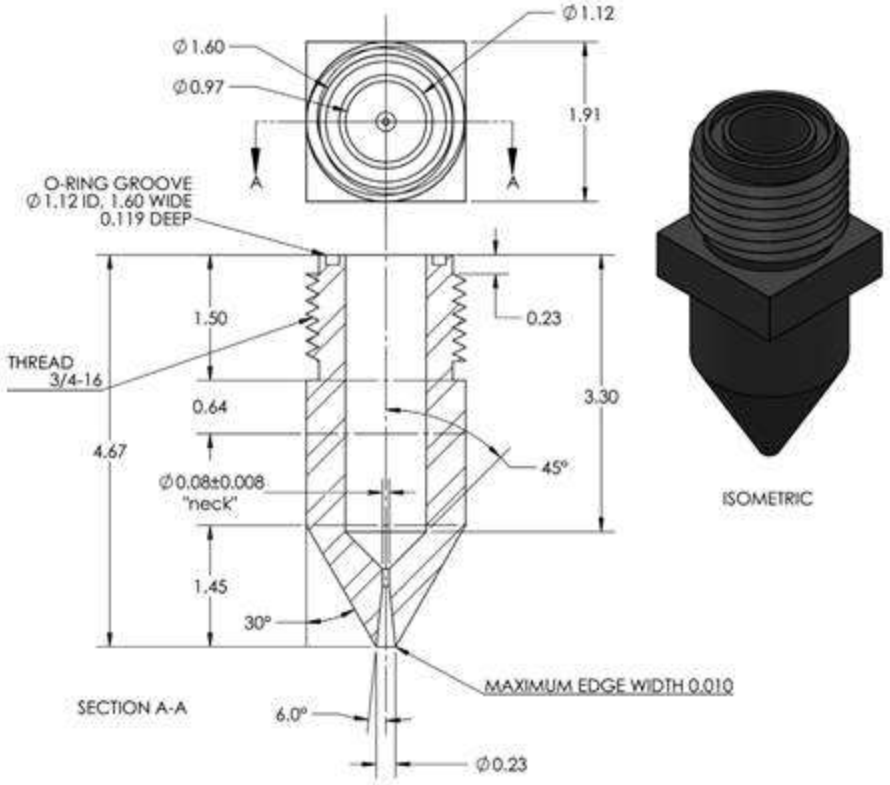
2. Distribution of the jet density

> of S_{34} (35–41) is displayed in Table 2. The value quoted for (35) is the published value. There are indications (C. Rolfs, private communication) that this value includes some measurements with a gas-jet target that used an incorrect value for the target thickness. This apparently increases the extracted value of S_{34} to 0.40 keV-barns.
>
> B.W. Filippone, Ann. Rev. Part. Sci. **36**, 717 (1986)

Part 2
Overlap between jet and ion beam

Precise alignment of the nozzle



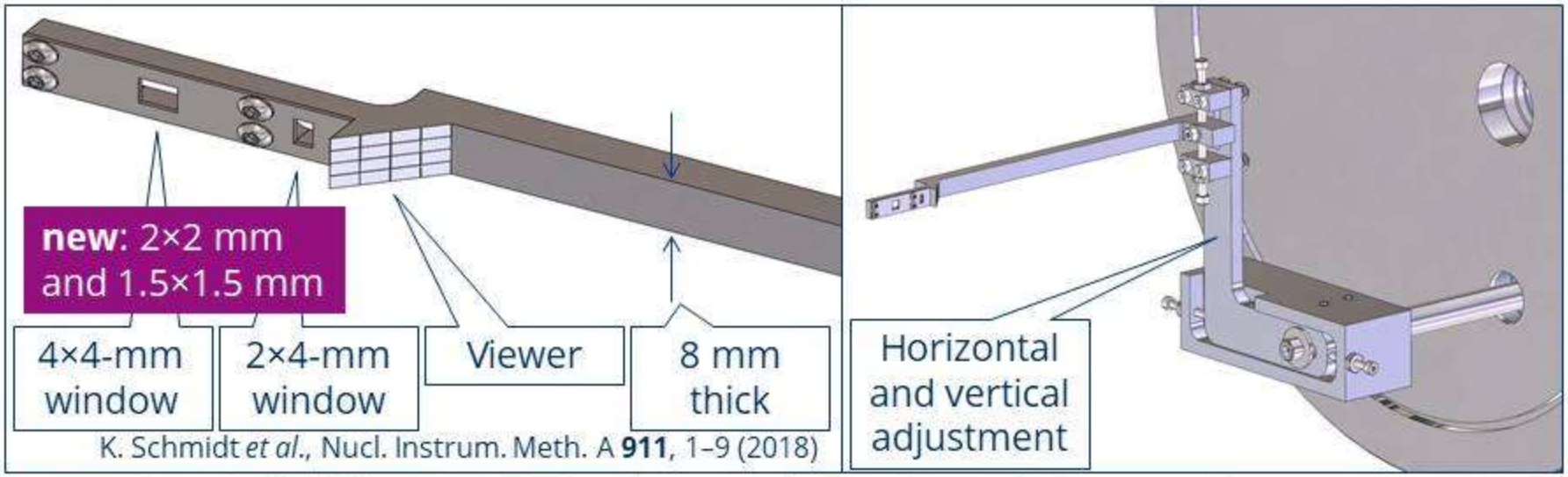


Nozzle for a supersonic jet

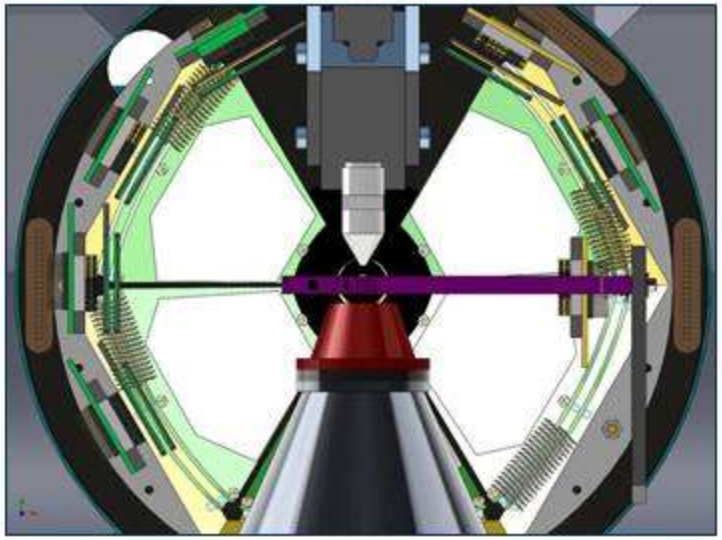
minimum inner diameter	0.8 mm

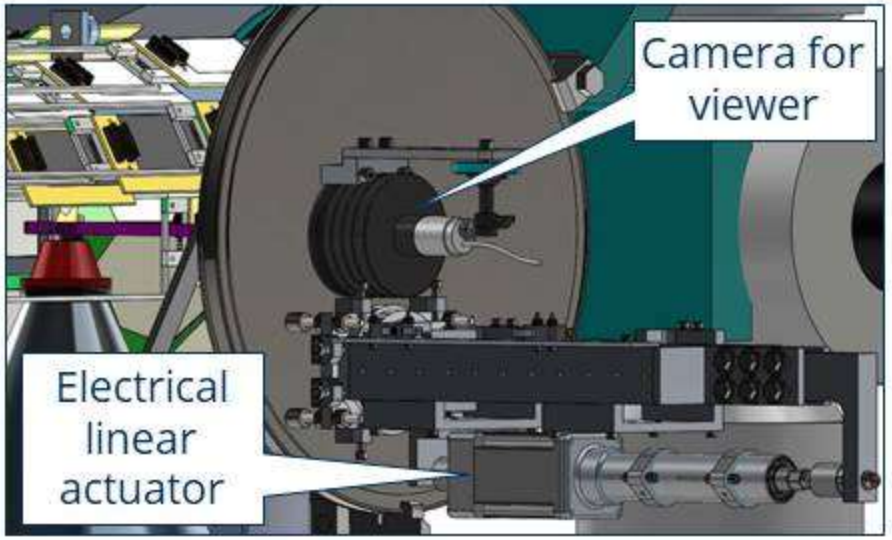
K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)

Beam viewer for transmission check



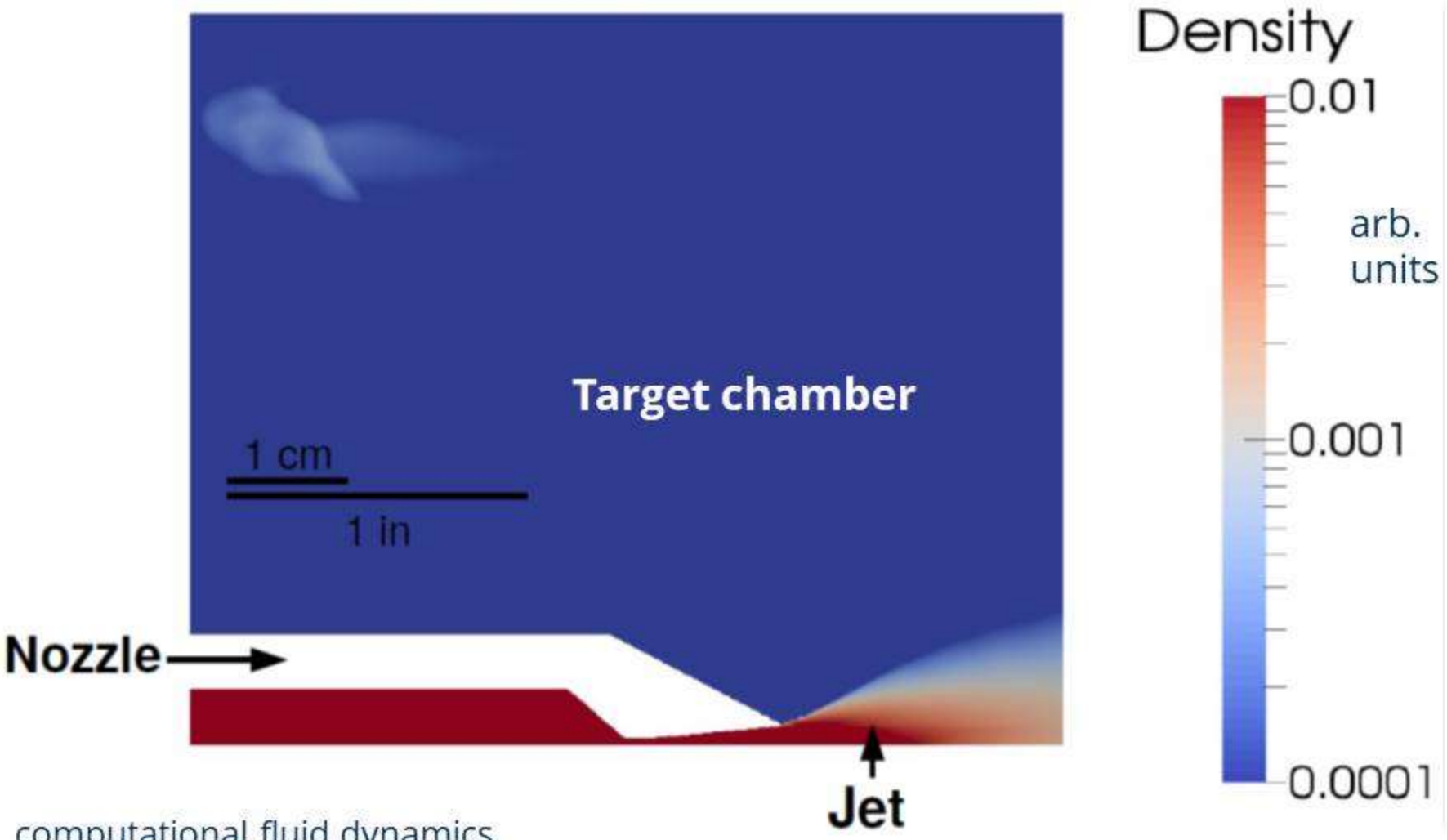
K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)





Part 3
Jet thickness measurements

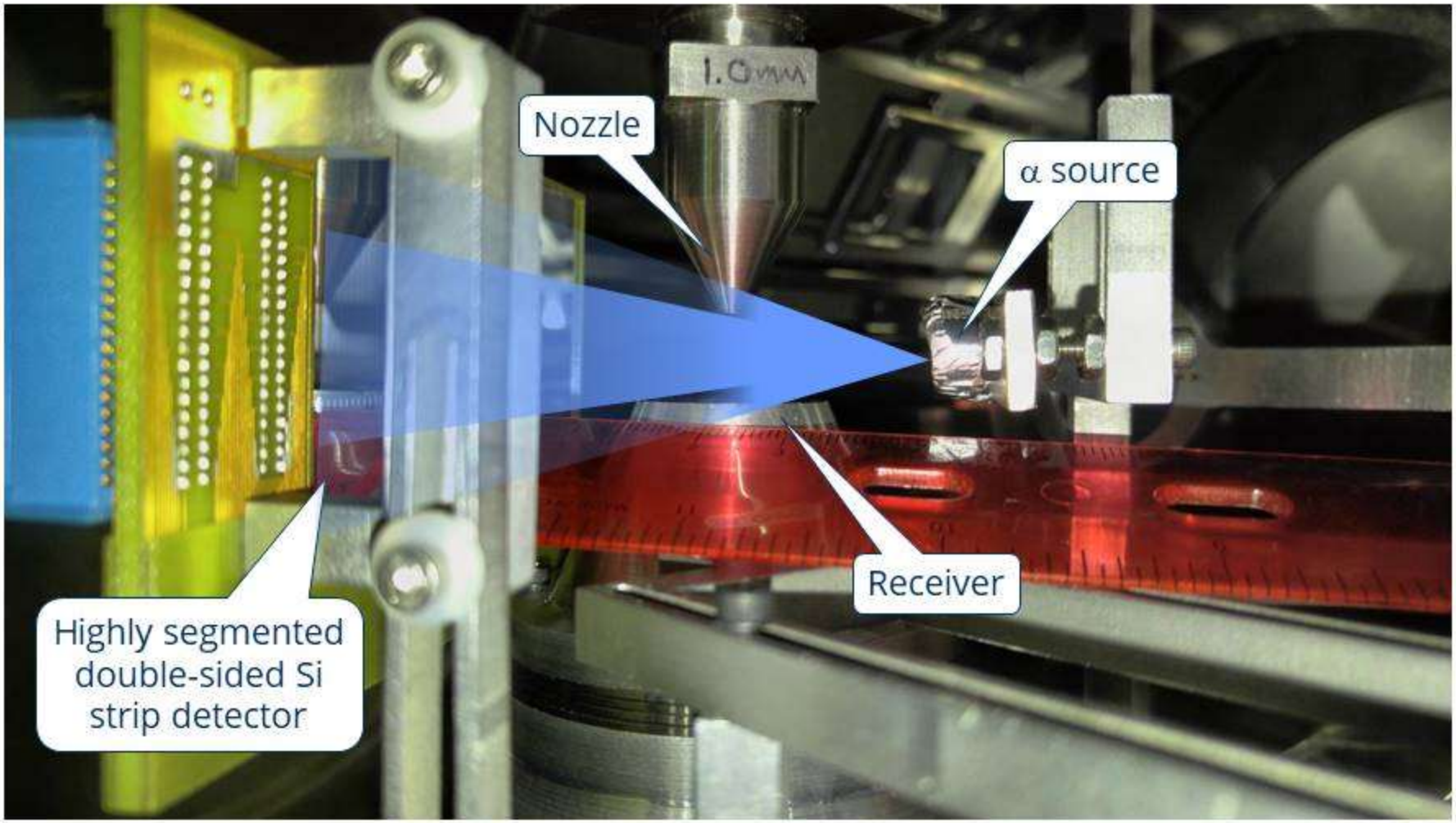
CFD simulation of the jet



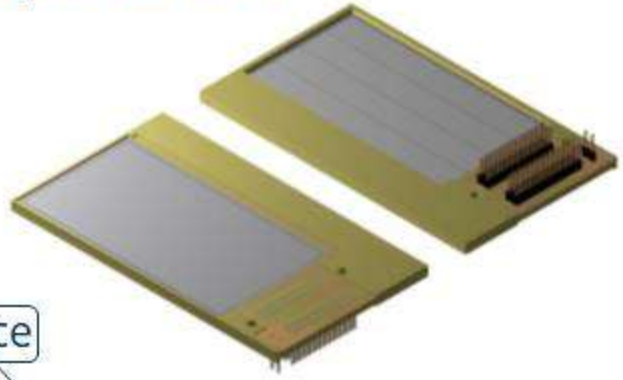
computational fluid dynamics
(CFD) software: WIND-US

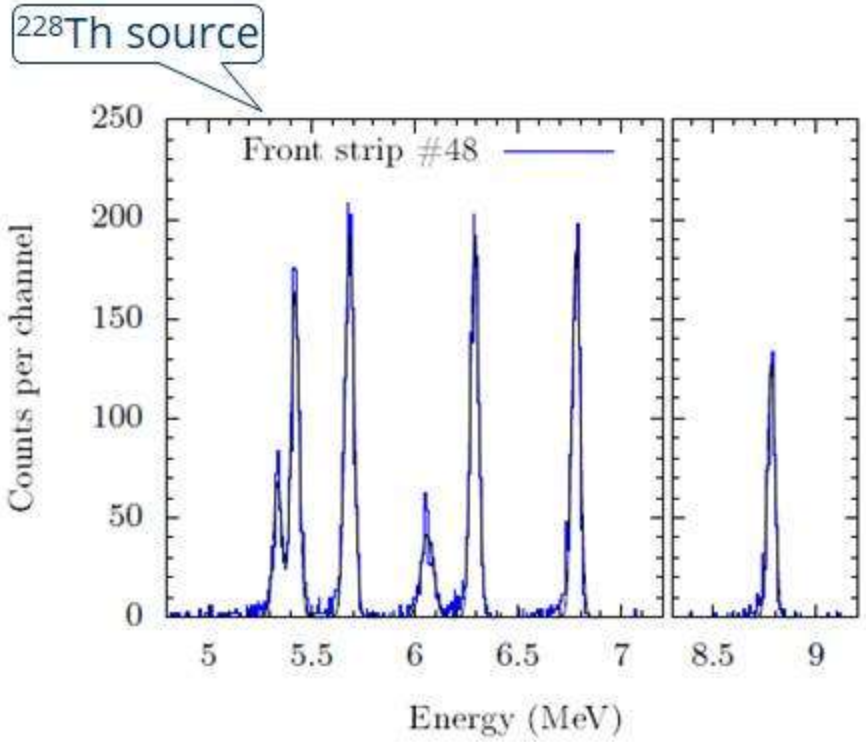
Contribution by graduate student Justin Browne

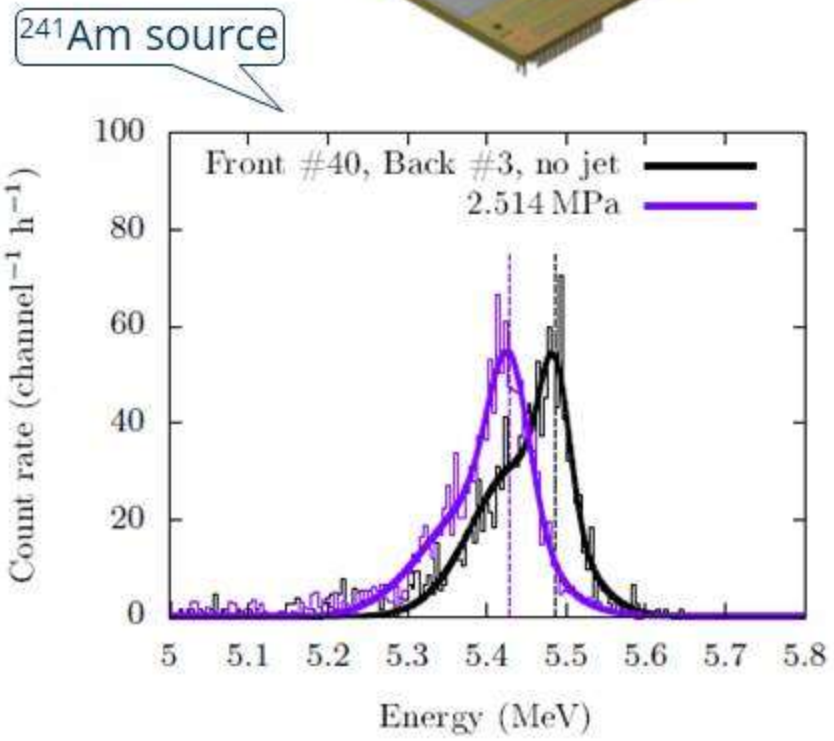
Setup for jet thickness study



Energy calibration and energy-loss spectrum

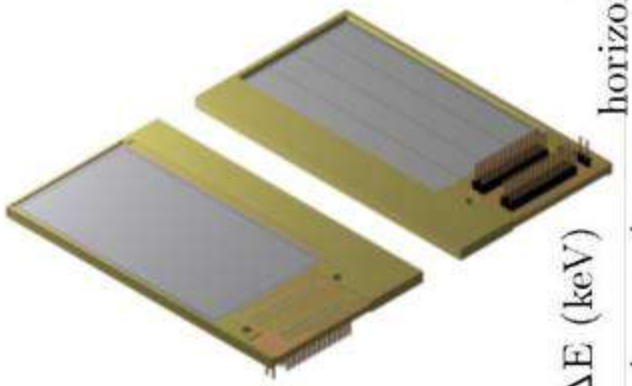


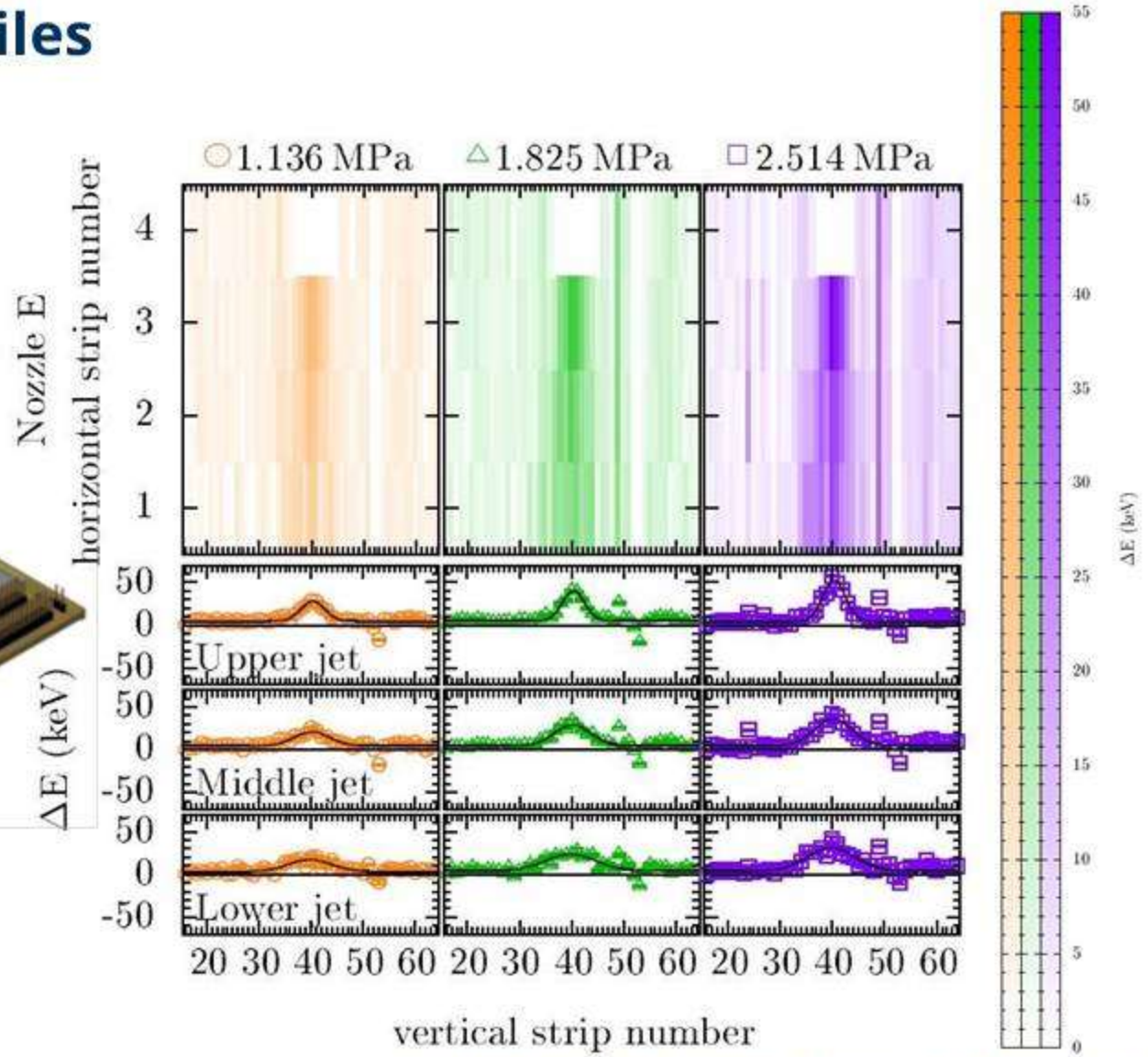




K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)

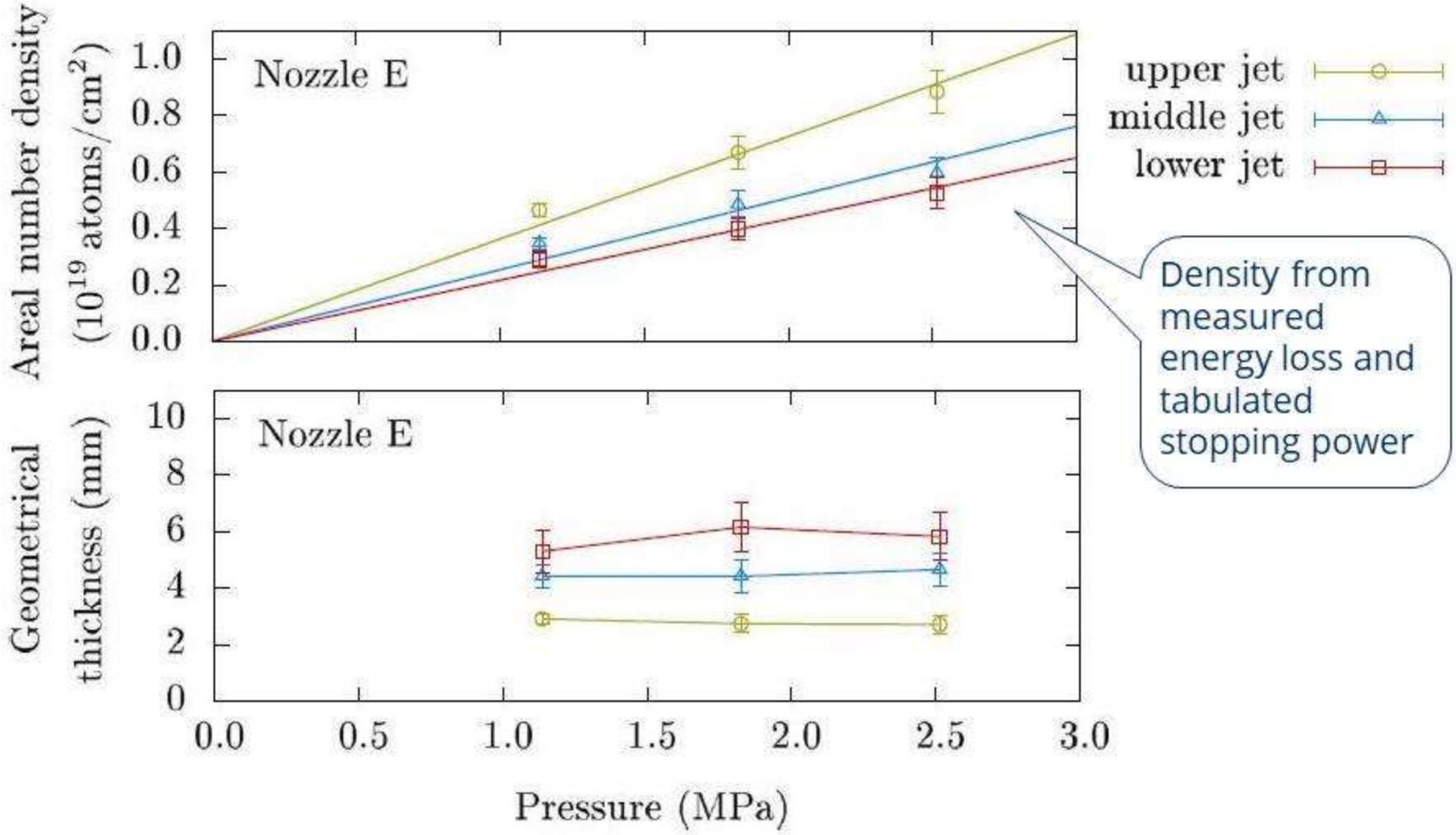
Energy loss profiles





K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)

10^{19} atoms/cm^2 in a 4-mm He jet

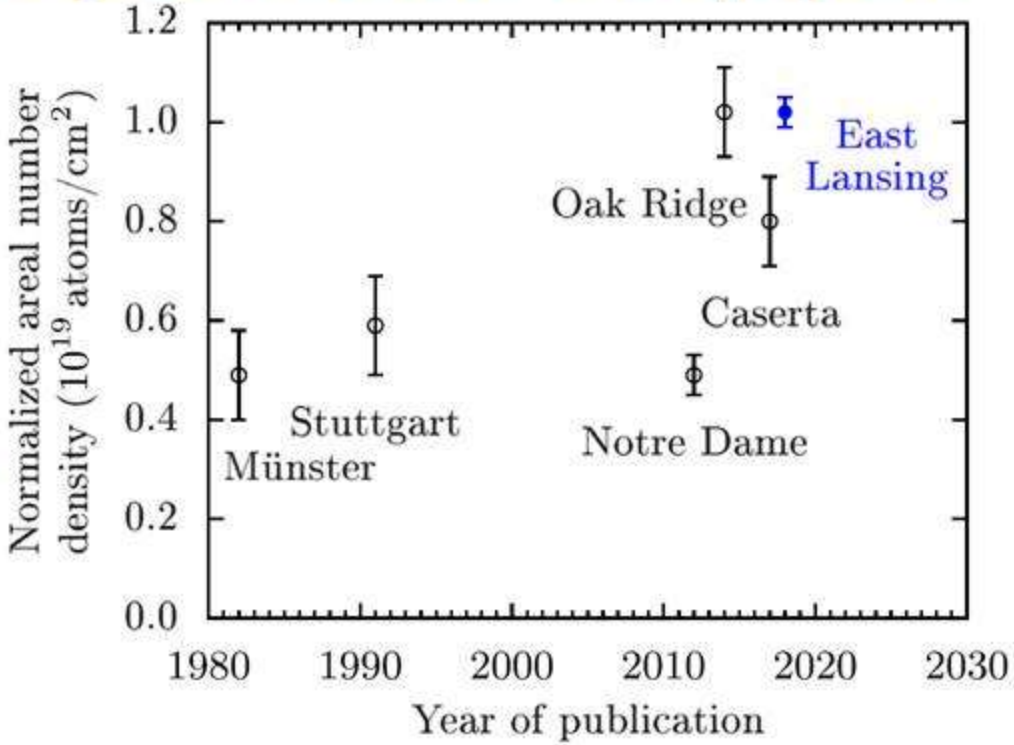


Density from measured energy loss and tabulated stopping power

K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)

Supersonic helium-jet targets in nuclear astrophysics

JENSA is the world's densest helium-jet target used in nuclear astrophysics studies



Normalized to 2.859 MPa input pressure

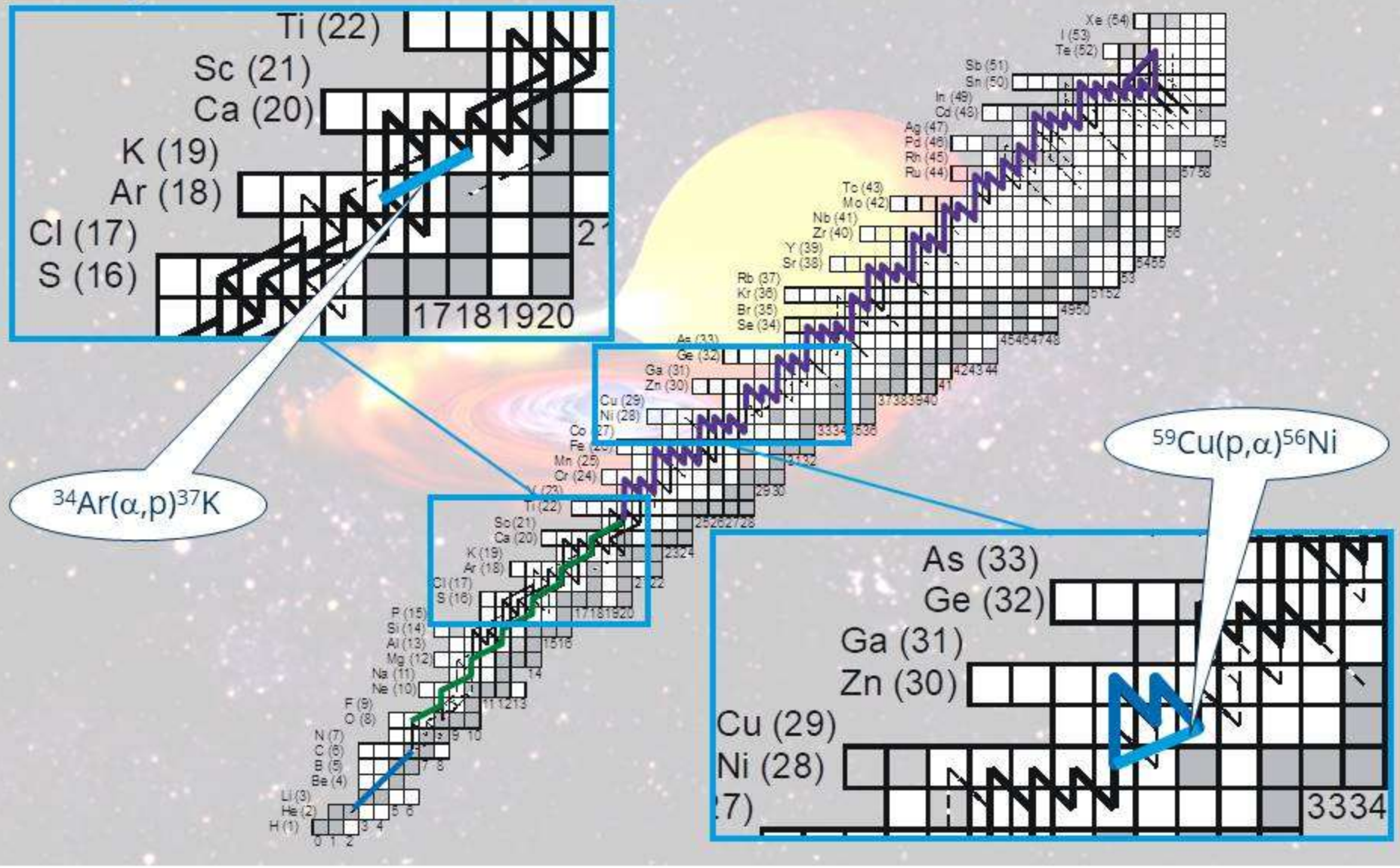
Location	Year	Input pressure (kPa)	^{4}He jet density (10^{18} at./cm^2)	^{4}He jet FWHM (mm)	Distance from nozzle (mm)
Münster	1982	200	0.34 ± 0.06	2.5 ± 0.2	1 to 5
Stuttgart	1991	38	0.078 ± 0.013	2.6 ± 0.2	~1.5
Notre Dame	2012	150	0.259 ± 0.021	2.2 ± 0.2	~4
Oak Ridge	2014	2859	10.2 ± 0.9	5.1 ± 0.3	~1
Caserta	2017	700	1.97 ± 0.21	Not reported	~5.5
East Lansing	2018	2515	9.0 ± 0.3	2.03 ± 0.09	$\lesssim$4

K. Schmidt *et al.*, Nucl. Instrum. Meth. A **911**, 1–9 (2018)

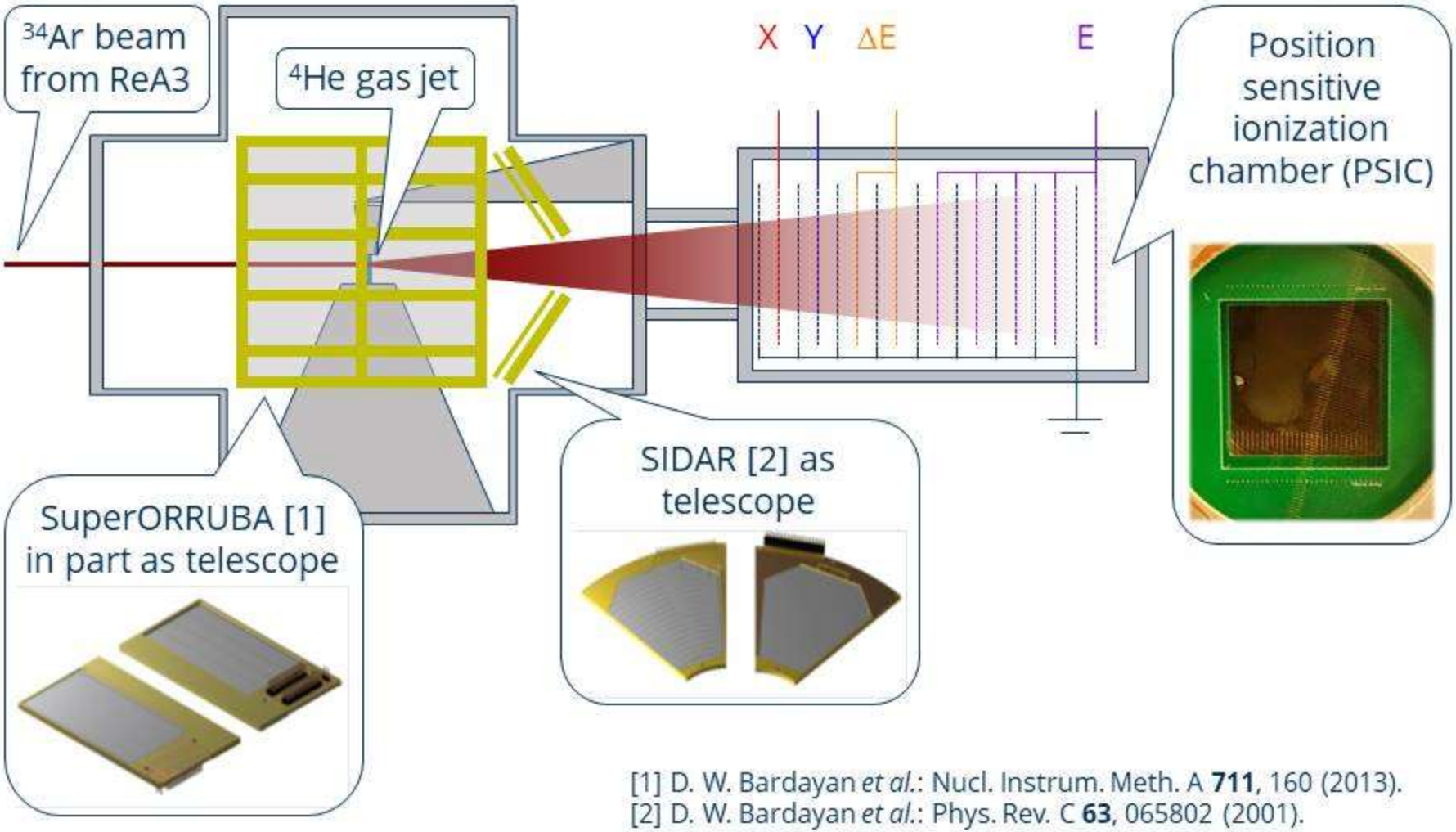
Part 4

Rare isotope beam experiments with JENSA

X-ray burst reaction studies



Setup to study $^{34}Ar(\alpha,p)^{37}K$

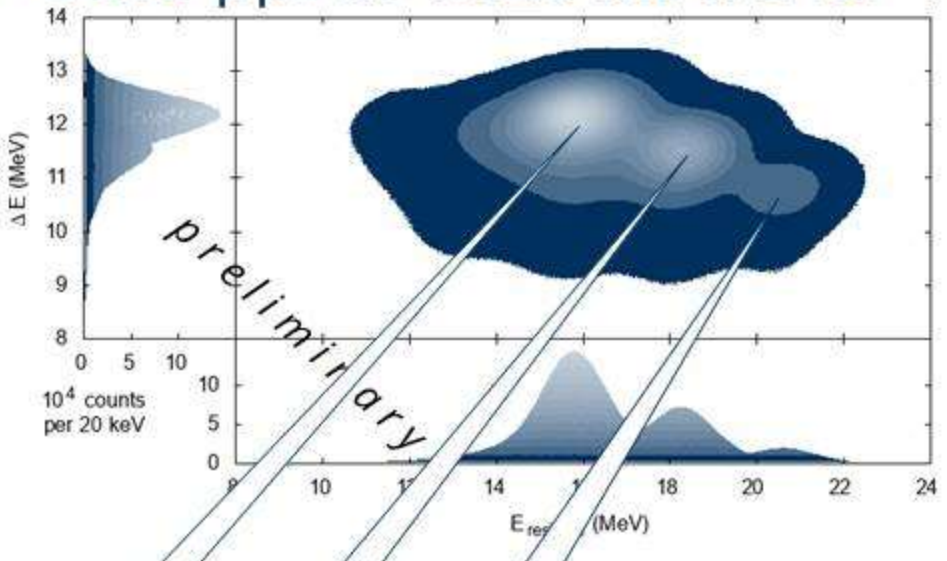


[1] D. W. Bardayan *et al.*: Nucl. Instrum. Meth. A **711**, 160 (2013).
[2] D. W. Bardayan *et al.*: Phys. Rev. C **63**, 065802 (2001).

Beam composition and proton signals

~3000 pps at 1.625 MeV/u for 108 h

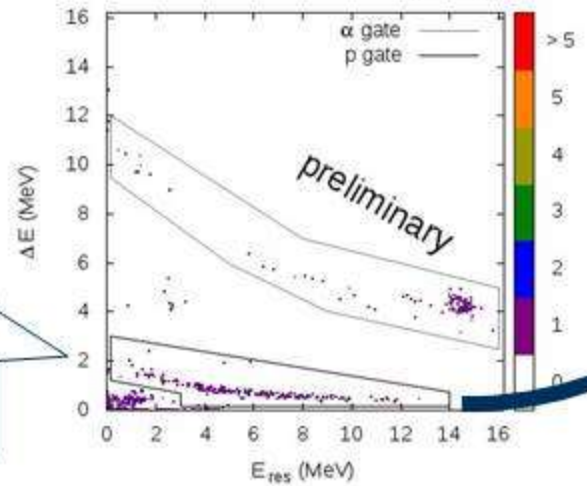
PSIC



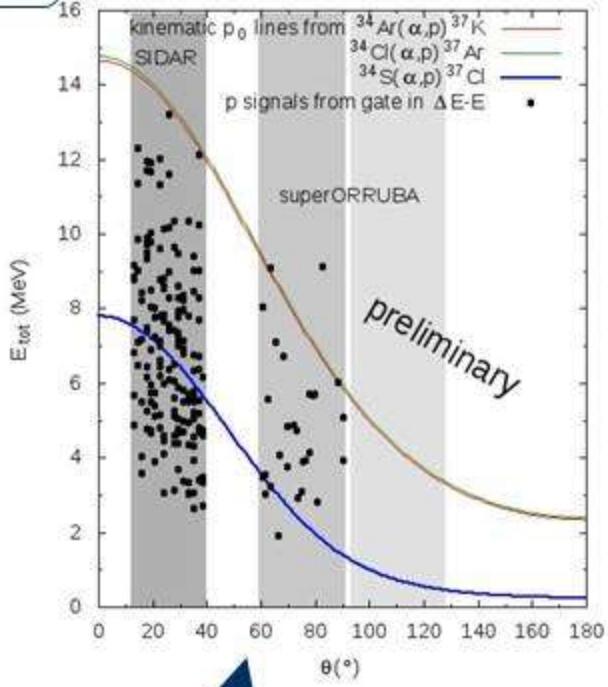
^{34}Ar (~ 60%)

^{34}Cl (~ 30%)

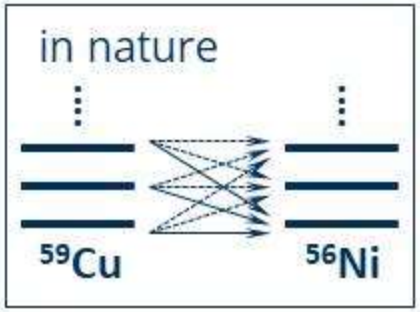
^{34}S (~ 10%)

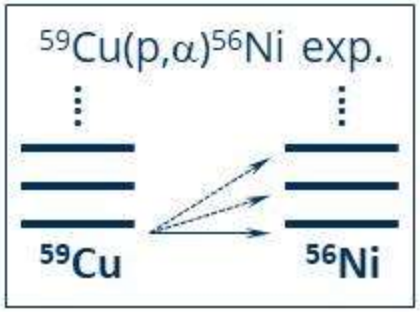


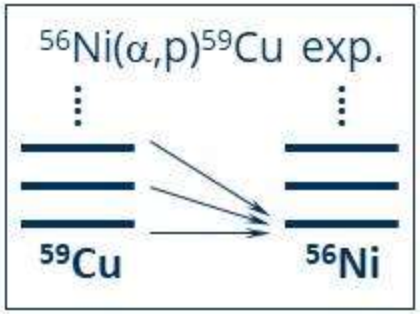
protons in telescope detectors

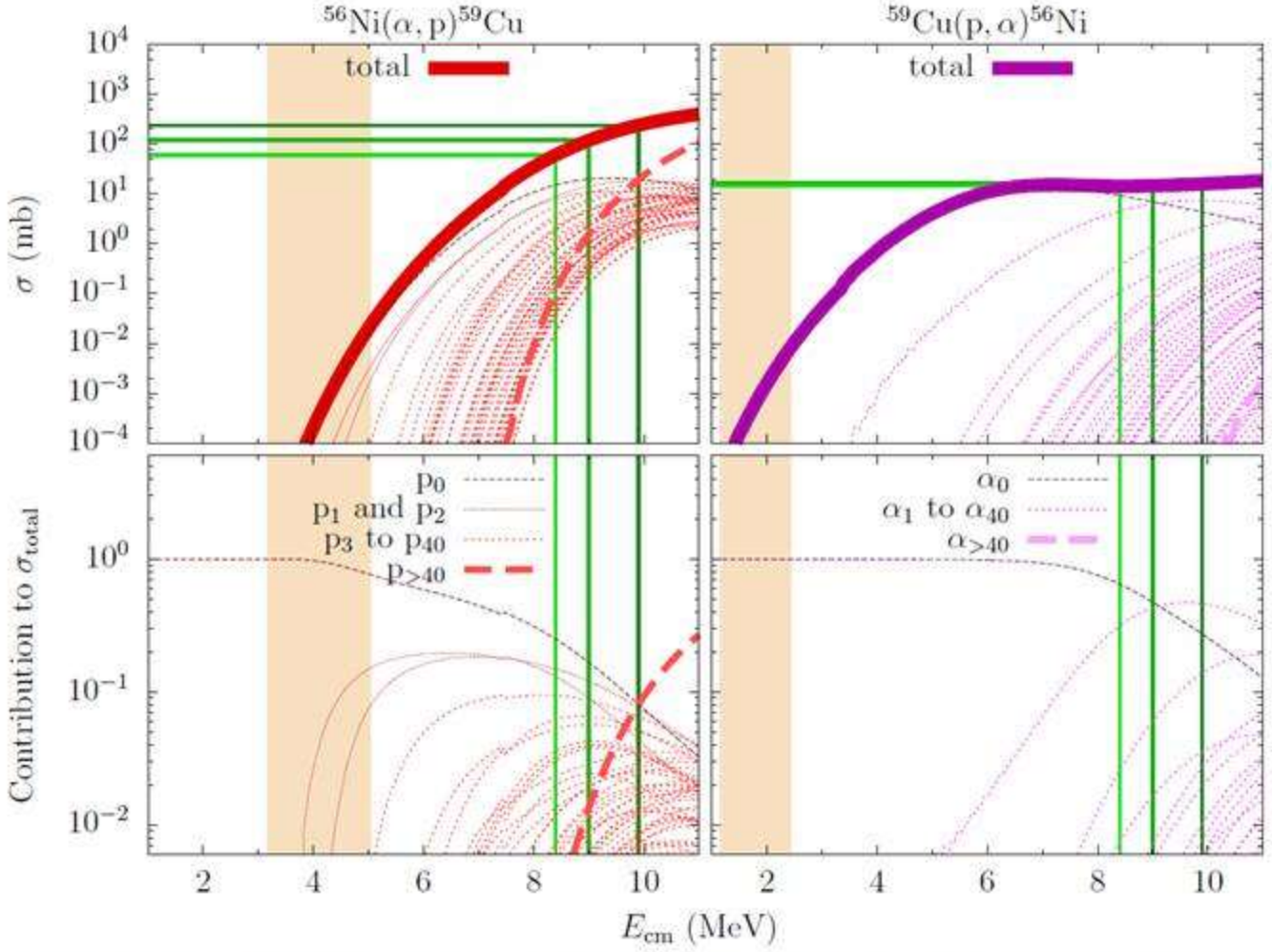


The ^{56}Ni(α,p)^{59}Cu reaction









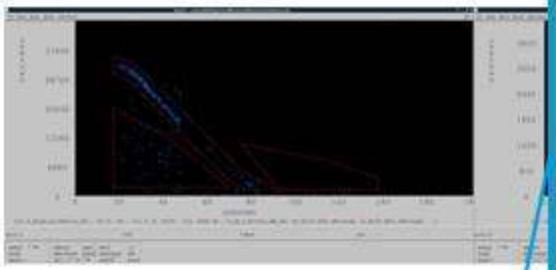
forward and reverse cross sections are directly related via detailed balance

Preliminary results from the online analysis (Dec. 2018)

2.65 MeV/u

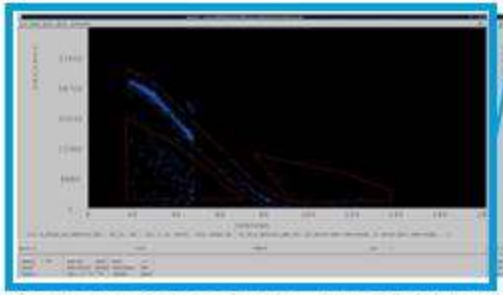
In the gates in the IC spectra, there 58 and 5 protons.

2.40 MeV/u

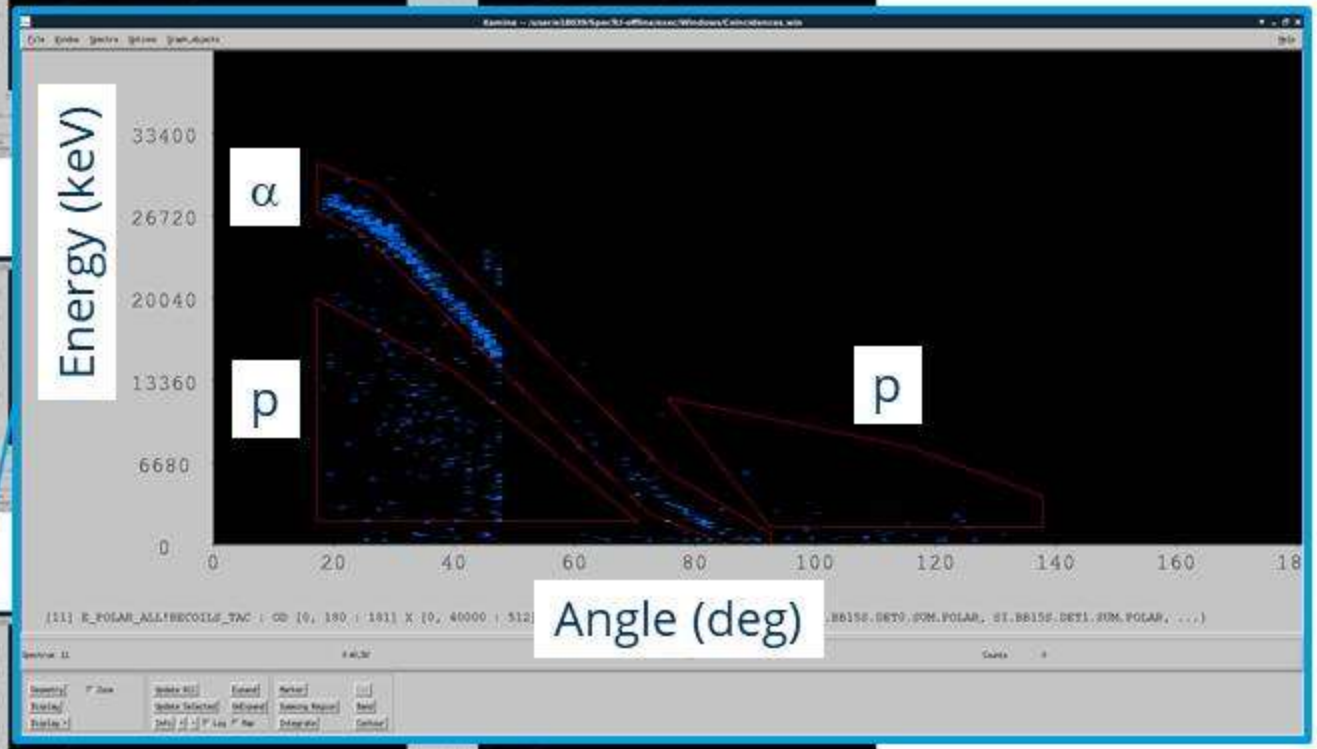


In the gates in the IC spectra, there 67 and 6 protons.

2.25 MeV/u



In the gates in the IC spectra, there 131 and 6 protons.



Capture reaction studies with JENSA

For (α,p)
Si detectors work

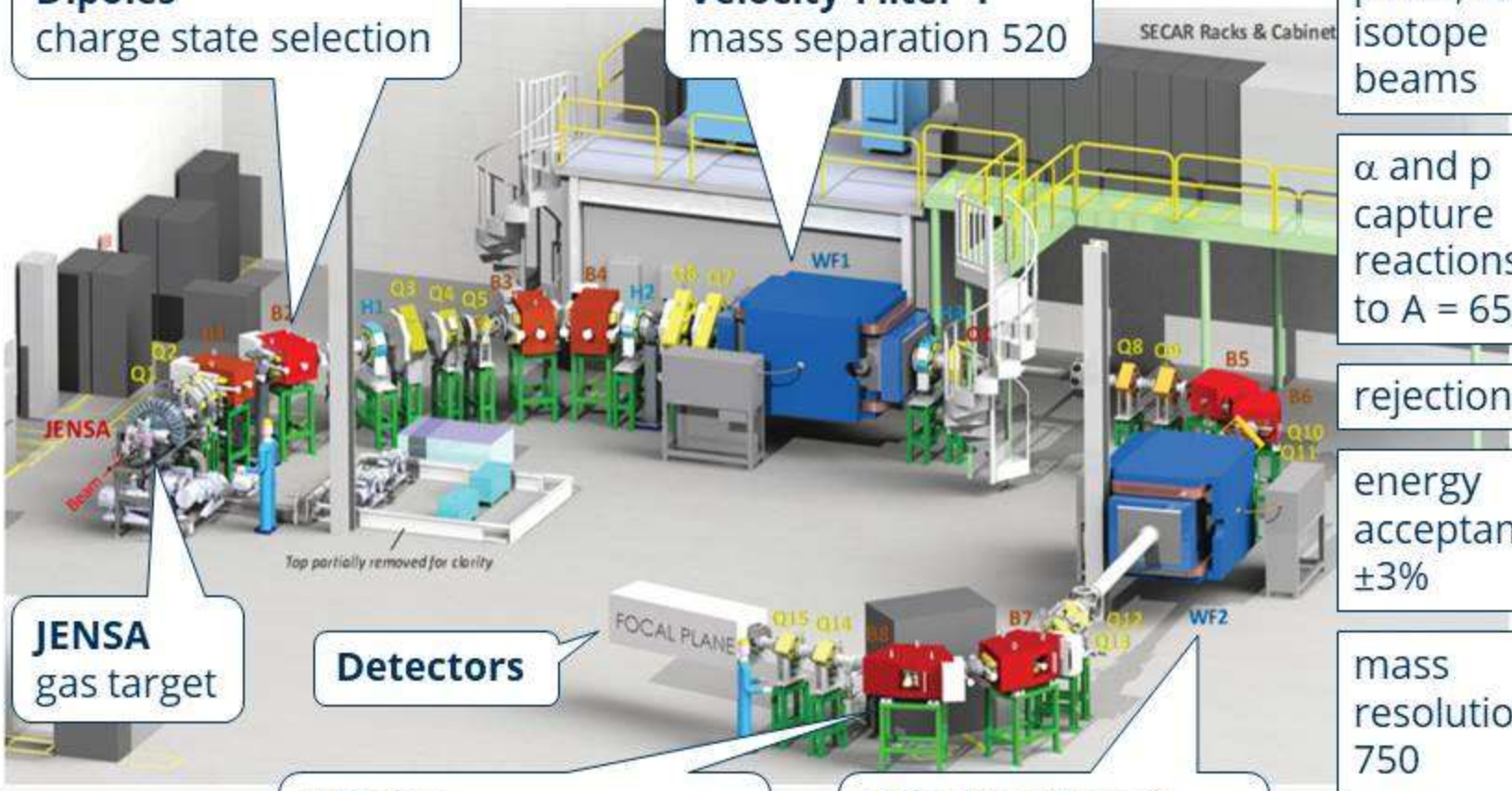
For (α,γ) and (p,γ)
not enough sensitivity with γ-ray detectors

Must use recoil separator with JENSA

Part 5
The future of JENSA

SECAR

*Recoil **Se**parator for **Ca**pture in **R**eactions*



Dipoles
charge state selection

Velocity Filter 1
mass separation 520

JENSA
gas target

Detectors

Dipoles
cleanup scattered beam

Velocity Filter 2
mass separation 775

p rich, rare isotope beams

α and p capture reactions up to A = 65

rejection: 10^{17}

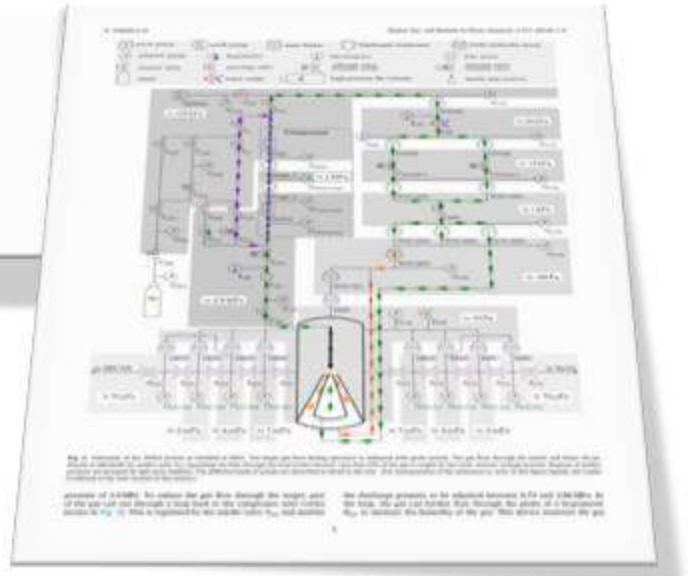
energy acceptance: ±3%

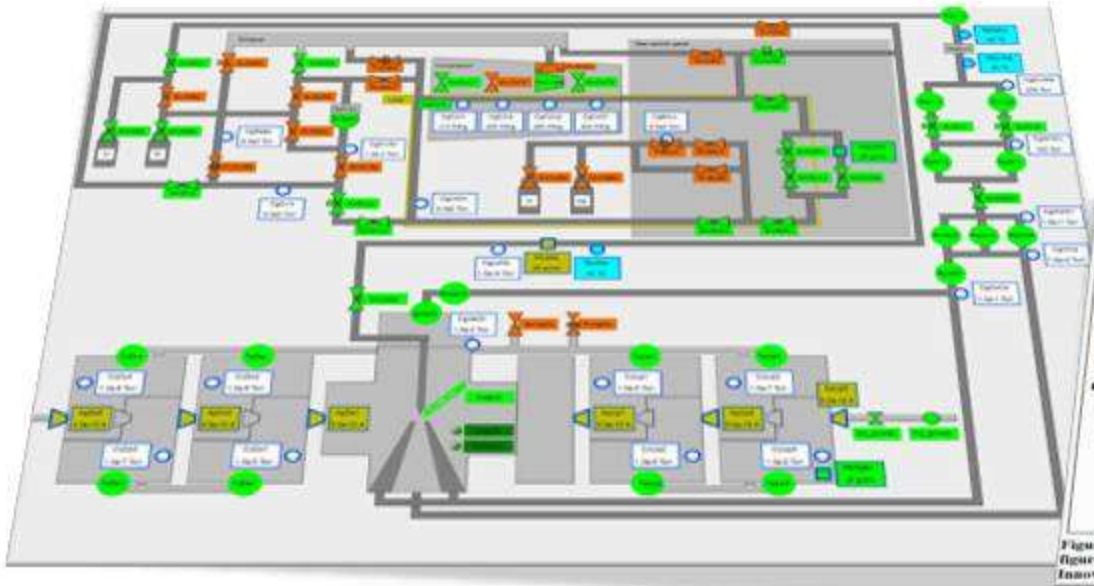
mass resolution: 750

JENSA is currently upgraded for ^{3}He and hydrogen

Facility for Rare Isotope Beams
National Superconducting Cyclotron Laboratory
JENSA Operation with Hydrogen Activity Hazard Document

JENSA Operation with Hydrogen Activity Hazard Document





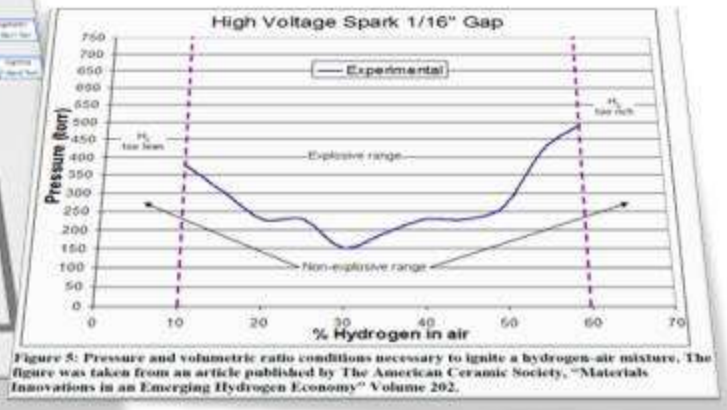
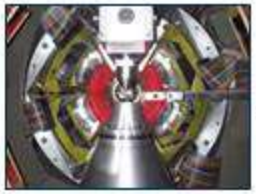


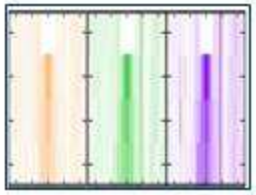
Figure 5: Pressure and volumetric ratio conditions necessary to ignite a hydrogen-air mixture. The figure was taken from an article published by The American Ceramic Society, "Materials Innovations in an Emerging Hydrogen Economy" Volume 202.

Summary

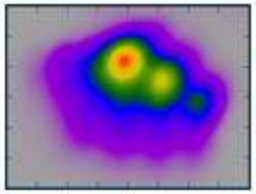
JENSA is able to study reactions important for nuclear astrophysics



JENSA has been successfully commissioned



JENSA is the world's densest gas-jet target in nuclear astrophysics with helium densities of 10^{19} atoms/cm^2



JENSA enabled first direct reaction studies of ^{34}Ar(α,p)^{37}K and ^{56}Ni (α,p) ^{59}Cu

JENSA will be the main target for SECAR enabling (α,γ) and (p,γ) capture reaction measurements