The EXL Experiment @ FAIR
&
the ESR plans

(Exotic nuclei studied in Light-ion induced reactions)

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KVI, University of Groningen

Physics prospects at the ESR and HITRAP
Eisenach, Germany
June 30, 2010

KVI

GSI

university of groningen

The EXL Collaboration

Univ. São Paulo

TRIUMF Vancouver

IMP Lanzhou

VTT Helsinki

IPN Orsay, CEA Saclay

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INR Debrecen

SINP Kolkata, BARC Mumbai

KVI Groningen

INFN/Univ. Milano

Univ. Teheran

Univ. Osaka

JINR Dubna, PNPI Gatchina, KRI St. Petersburg, Ioffe Inst. St. Petersburg, Kurchatov Inst. Moscow

CSIC Madrid, Univ. Madrid

Univ. Lund, Mid Sweden Univ., Univ. Uppsala, Chalmers Inst. Göteborg

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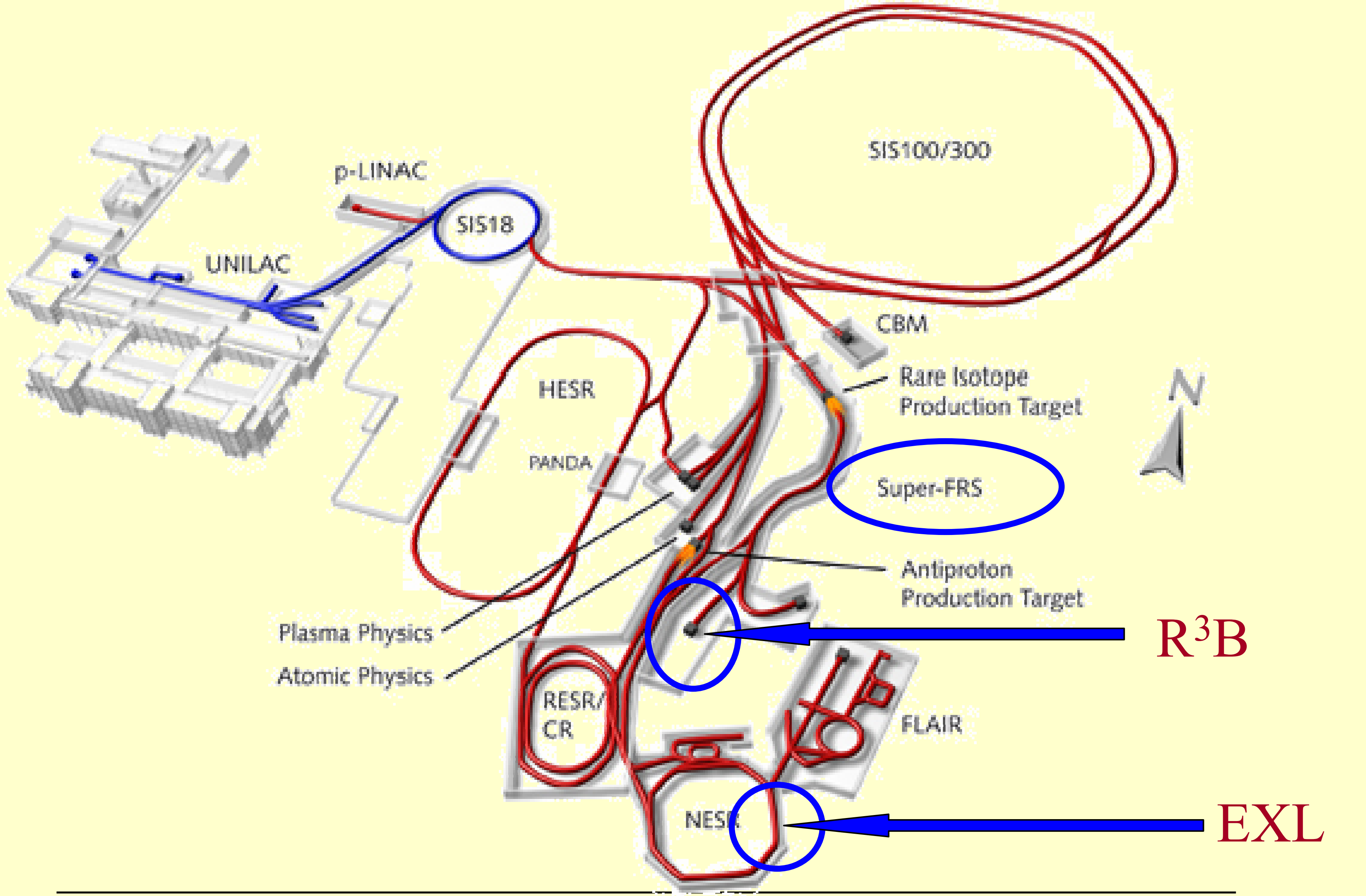
Vancouver, Canada, TRIUMF - R. Kanungo

EXL and R^3B

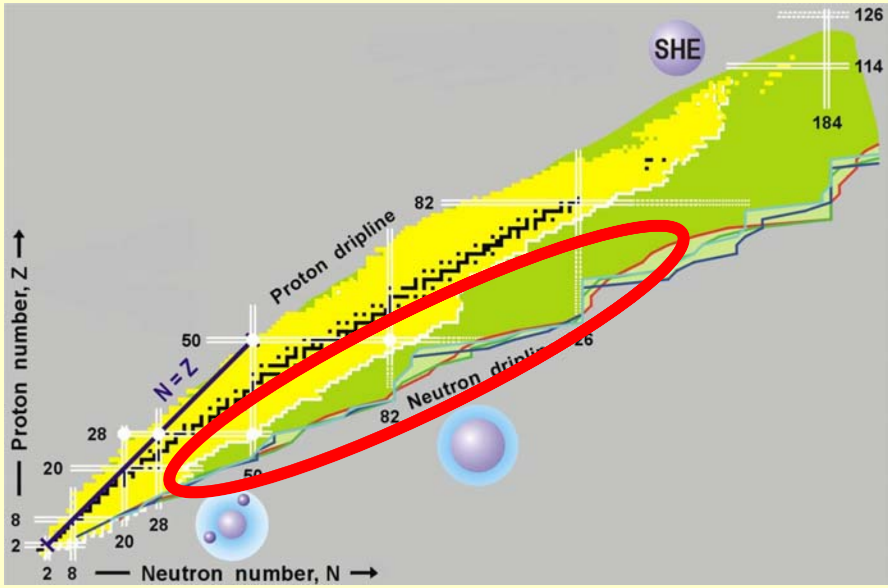


SIS100/300
p-LINAC
SIS18
UNILAC
CBM
HESR
Rare Isotope
Production Target
PANDA
Super-FRS
Antiproton
Production Target
Plasma Physics
Atomic Physics
RESR/
CR
FLAIR
NESR
R3B
EXL

Main Physics Goals

regions of interest:

⇒ towards the driplines for light, medium, medium heavy and heavy nuclei



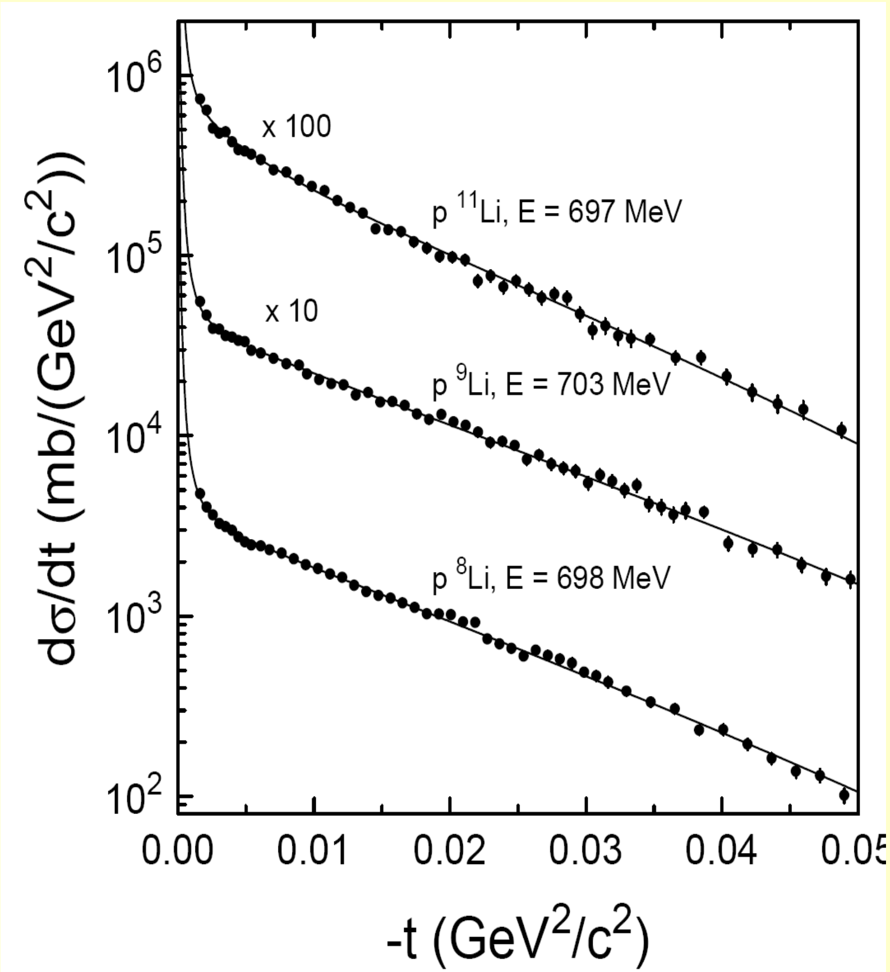
physics interest:

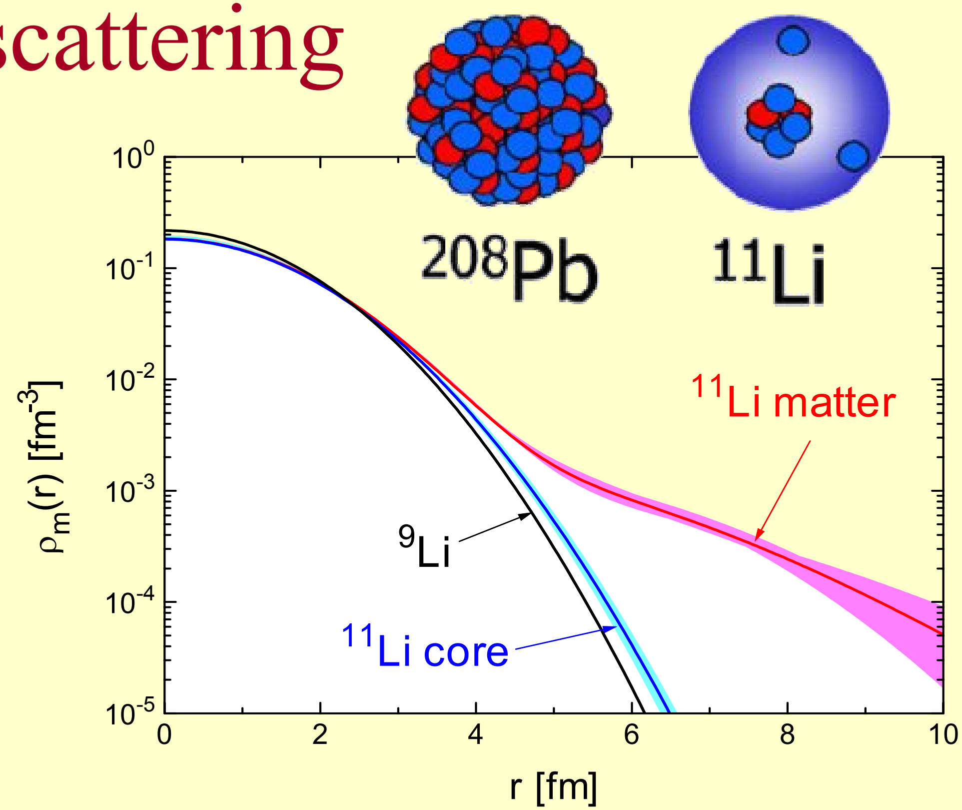
- matter distributions (halo, skin…)
- single-particle structure evolution (new magic numbers, new shell gaps, spetroscopic factors)
- NN correlations, pairing and clusterization phenomena
- new collective modes (different deformations for p and n, giant resonance strength)
- parameters of the nuclear equation of state
- in-medium interactions in asymmetric and low-density matter
- astrophysical r and rp processes, understanding of supernovae

Light-ion induced direct reactions

- Elastic scattering (p,p), (α,α), …
  Nuclear matter distribution $\rho_{matter}(r)$, skins, halo structures
- Inelastic scattering (p,p'), (α,α'), …
  Deformation parameters, B(E2) values, transition densities, giant resonances
- Charge exchange reactions (p,n), (^{3}He,t), (d,^{2}He), …
  Gamow-Teller strength
- Transfer reactions (p,d), (p,t), (p, ^{3}He), (d,p), …
  Single particle structure, spectroscopic factors
  Spectroscopy beyond the driplines
  Neutron pair correlations
  Neutron (proton) capture cross sections
- Knock-out reactions (p,2p), (p,pn), (p,p^{4}He), …
  Ground state configurations, nucleon momentum dist., cluster correlations

Example 1:
Elastic scattering





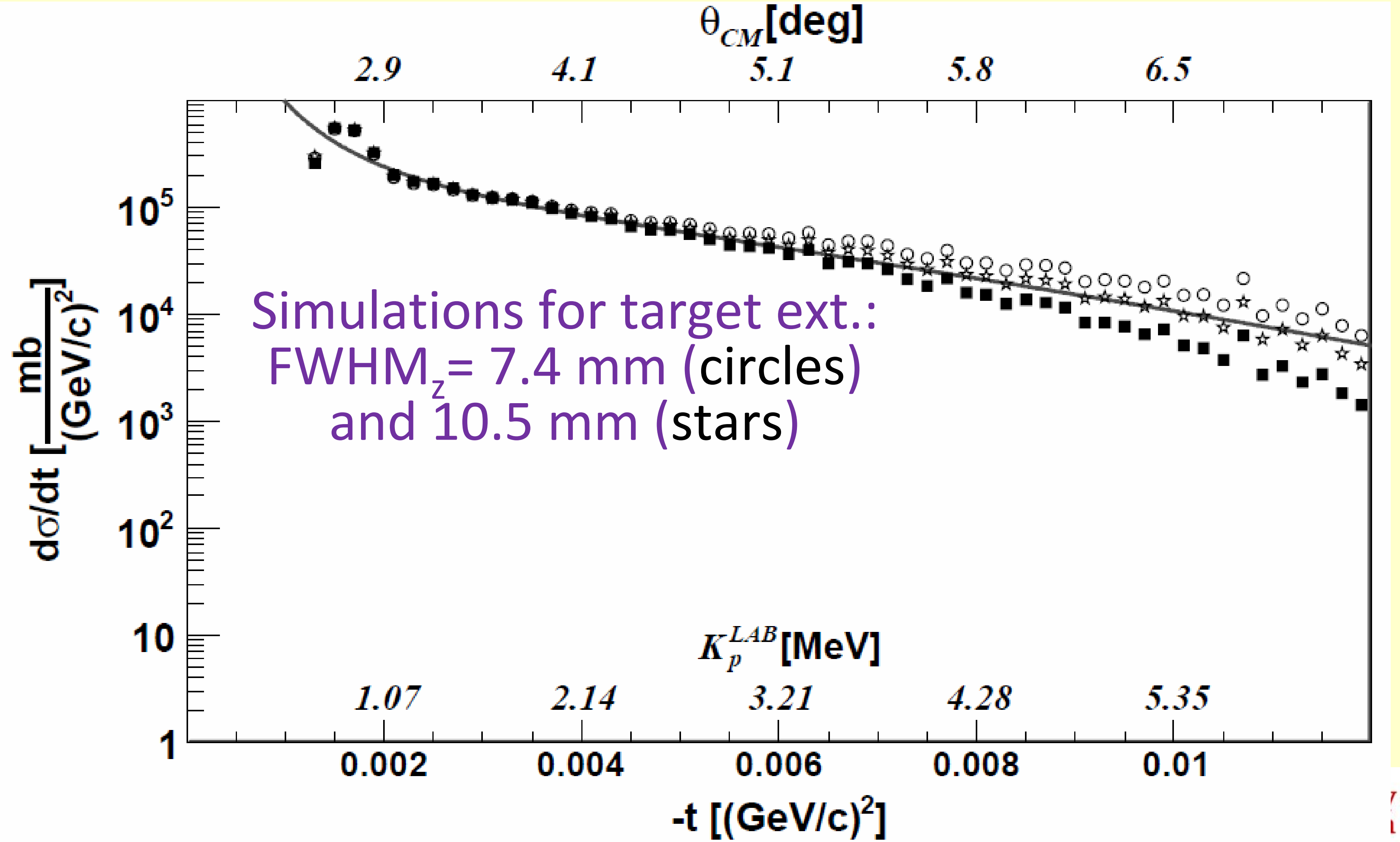
Small-angle proton elastic scattering ⇒ nuclear matter distribution

P. Egelhof et al., Eur. Phys. J. A 15, 27 (2002)

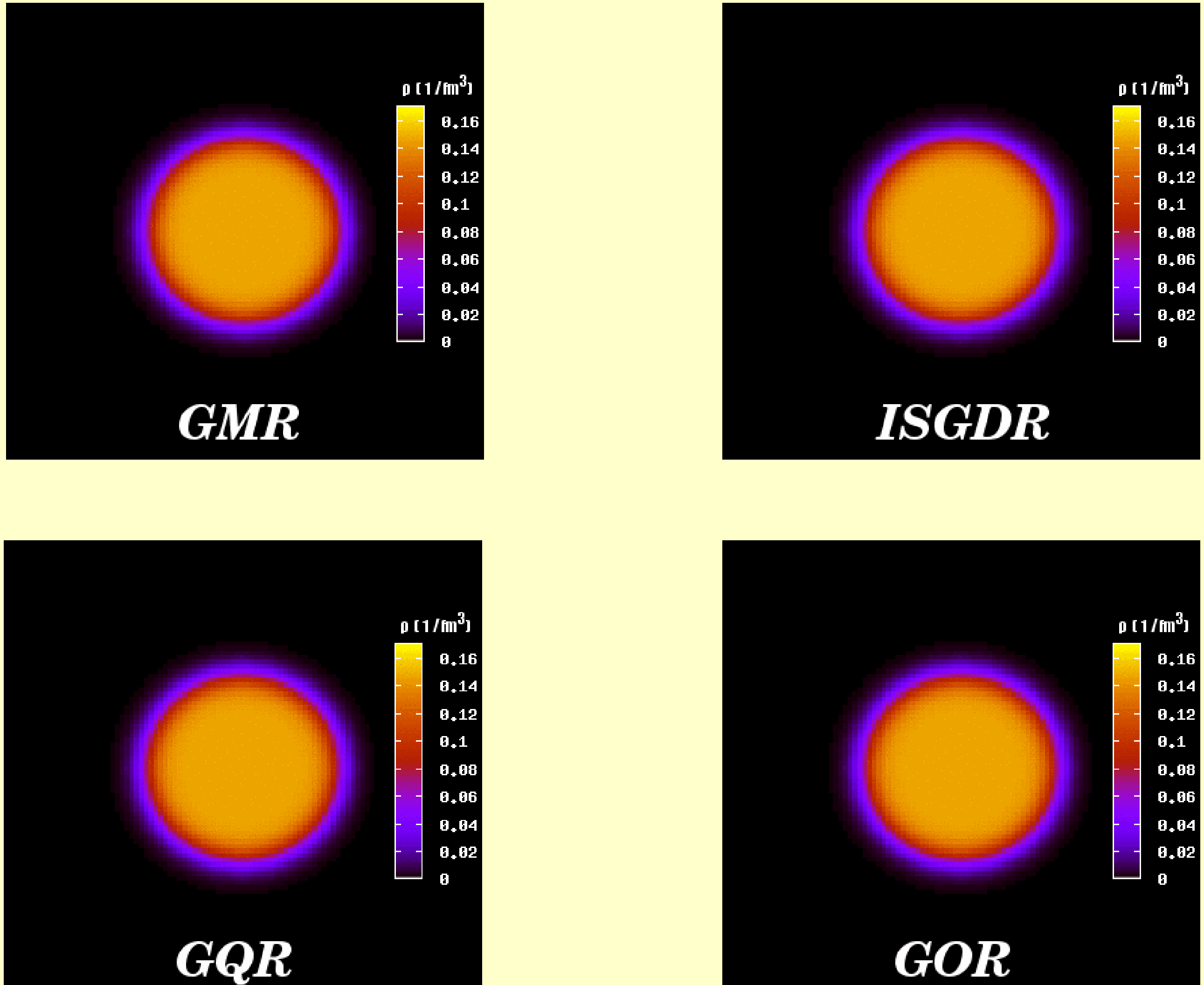
Elastic Scattering Cross Section (E>500keV)

First feasibility measurement at ESR in 2005. H. Moeini, S. Ilieva et al.

$H(^{136}Xe,p)^{136}Xe$ @350 AMeV



Example 2:
Giant Resonances



M. Itoh

Compression modes ISGMR+ISGDR

$$E_{GMR} = \hbar\sqrt{\frac{K_A}{m < r^2 >}}$$

- Incompressibility $K_\infty = (240 \pm 10)$ MeV
- Asymmetry term $K_\tau = (-550 \pm 100)$ MeV

Why low momentum transfers hadronic scattering?

✓ Investigation of Nuclear Matter Distributions along Isotopic Chains:

⇒ halo, skin structure

⇒ probe in-medium interactions at extreme isospin (almost pure neutron matter)

⇒ in combination with electron scattering (ELISe project @ FAIR): separate neutron/proton content of nuclear matter (deduce neutron skins)

method: elastic proton scattering at low q: high sensitivity to nuclear periphery

✓ Investigation of Giant Monopole Resonance:

⇒ gives access to nuclear compressibility ⇒ key parameters of the EOS

⇒ new collective modes (breathing mode of neutron skin)

method: inelastic α scattering at low q

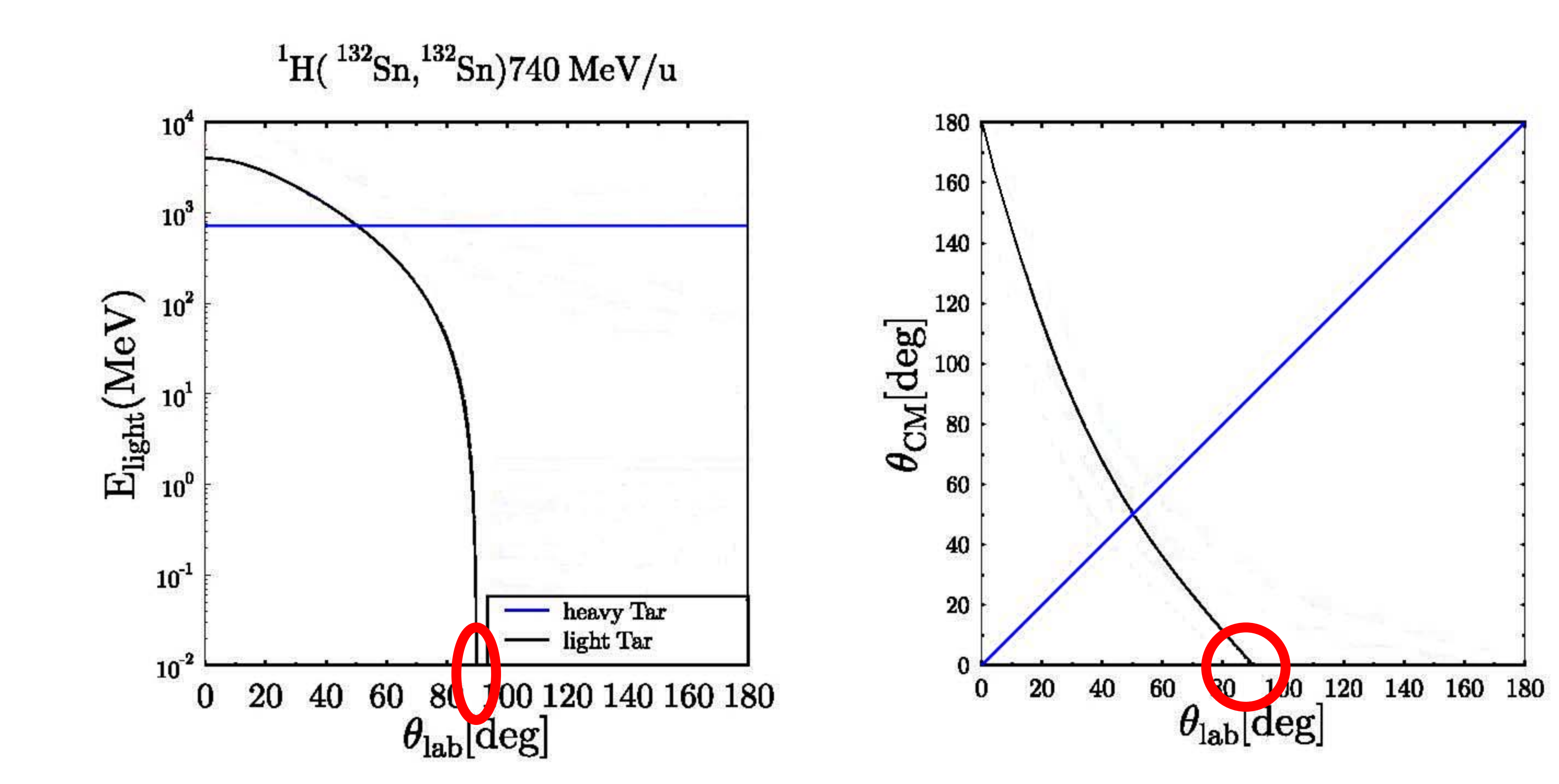
✓ Investigation of Gamow-Teller Transitions:

⇒ weak interaction rates for N = Z waiting point nuclei in the rp-process

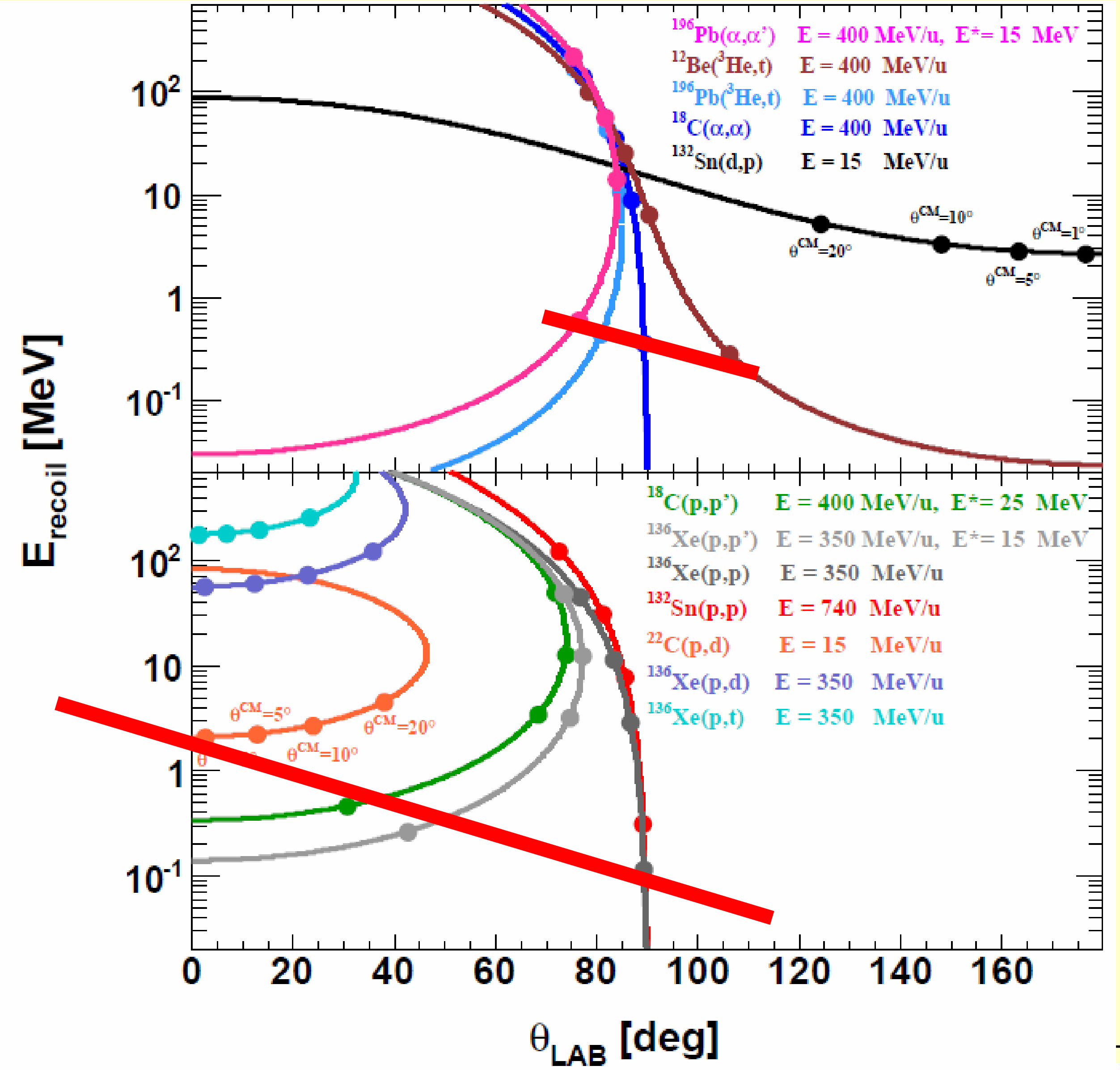
⇒ electron capture rates in the pre-supernova evolution (core collapse)

method: (^{3}He,t), (d,^{2}He) charge exchange reactions at low q

Kinematics for collision of protons with exotic nuclei (with fixed heavy/light target)



Kinematics for inverse reaction



Advantages and disadvantages of storage-ring experiments

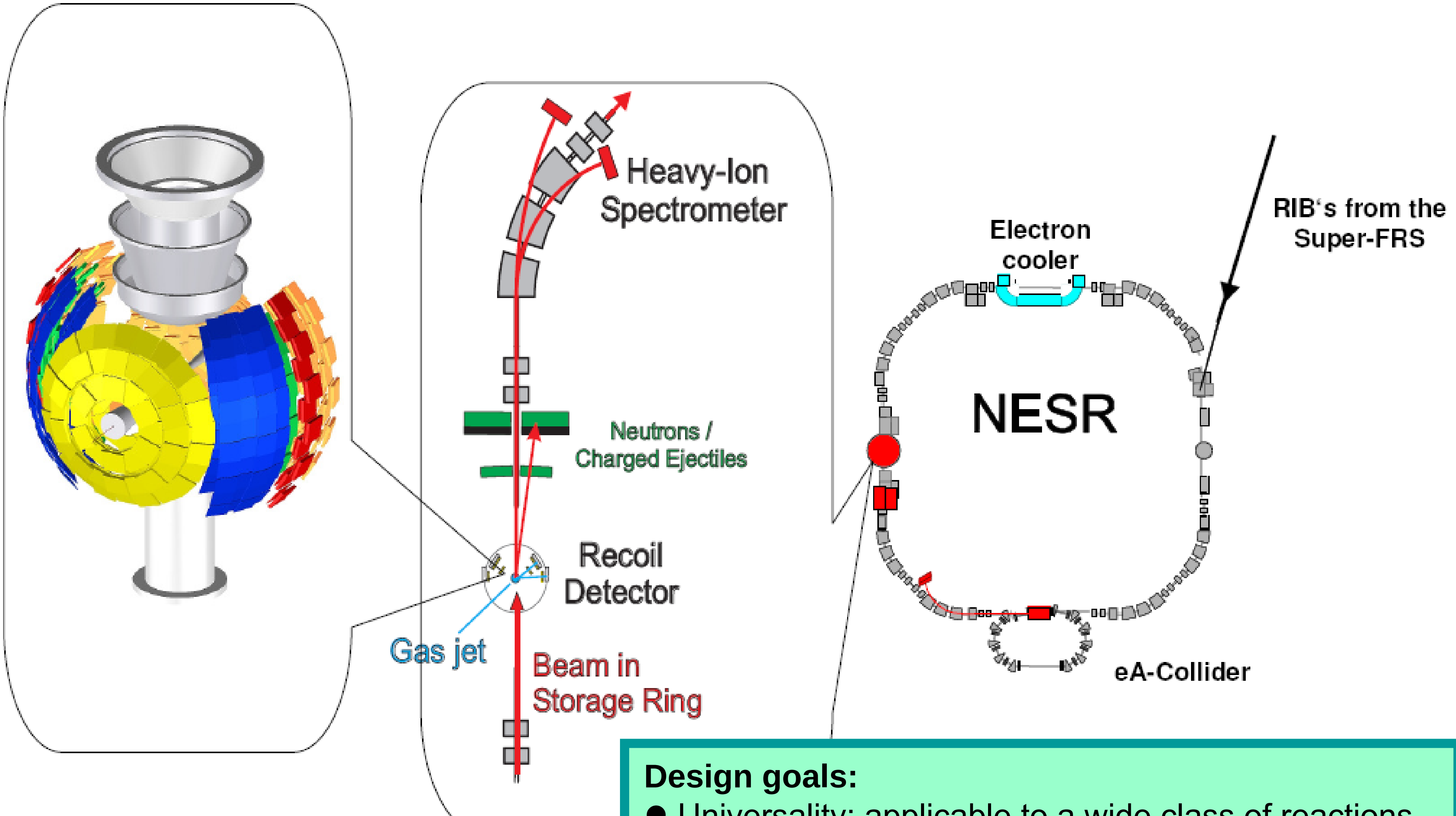
Advantages:

- Large intensities in the ring
- Little energy loss in the target
- No target window (no background)
- High resolution of the beam (cooling)
- Forward focusing for high-energy particles

Disadvantages:

- Ultra high vacuum
- Very small recoil energies for low q
- Thin targets

Details of the EXL setup



Detection systems for:

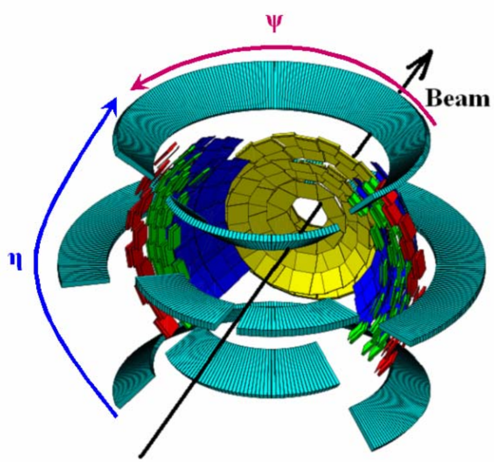
- Target recoils and gammas (p,α,n,γ)
- Forward ejectiles (p,n)
- Beam-like heavy ions

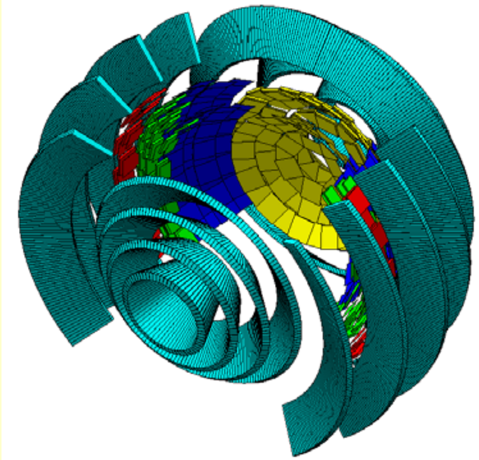
Design goals:

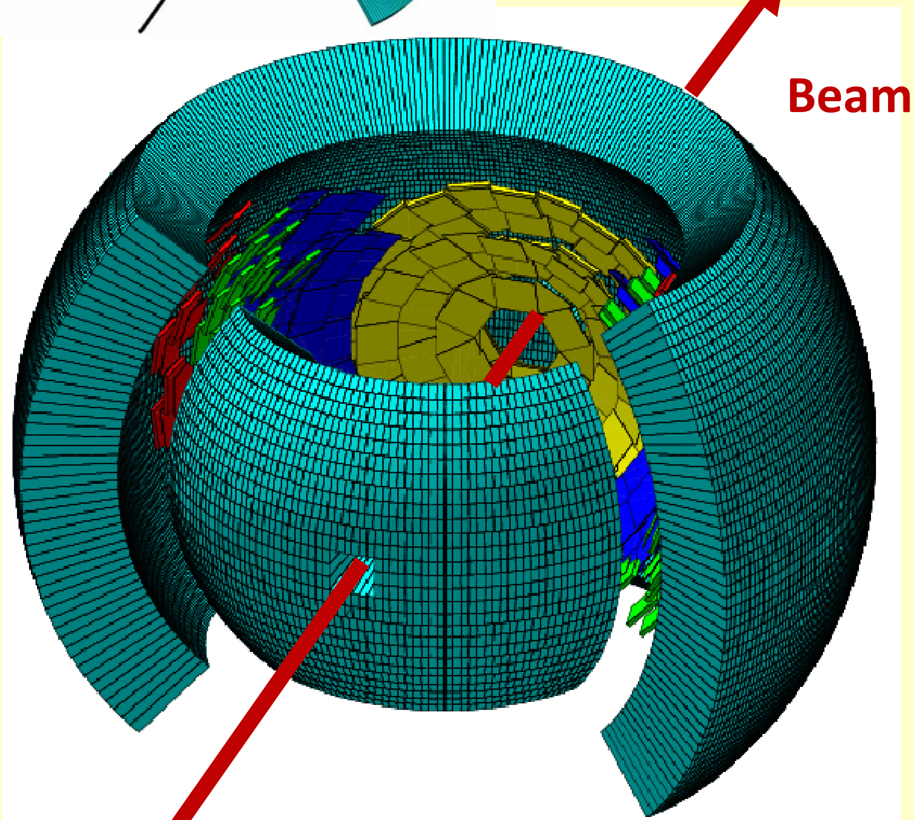
- Universality: applicable to a wide class of reactions
- Good energy and angular resolution
- Large solid angle acceptance
- Specially dedicated for low q measurements with high luminosity (> 10^{28} cm^{-2} s^{-1})

EXL calorimeter

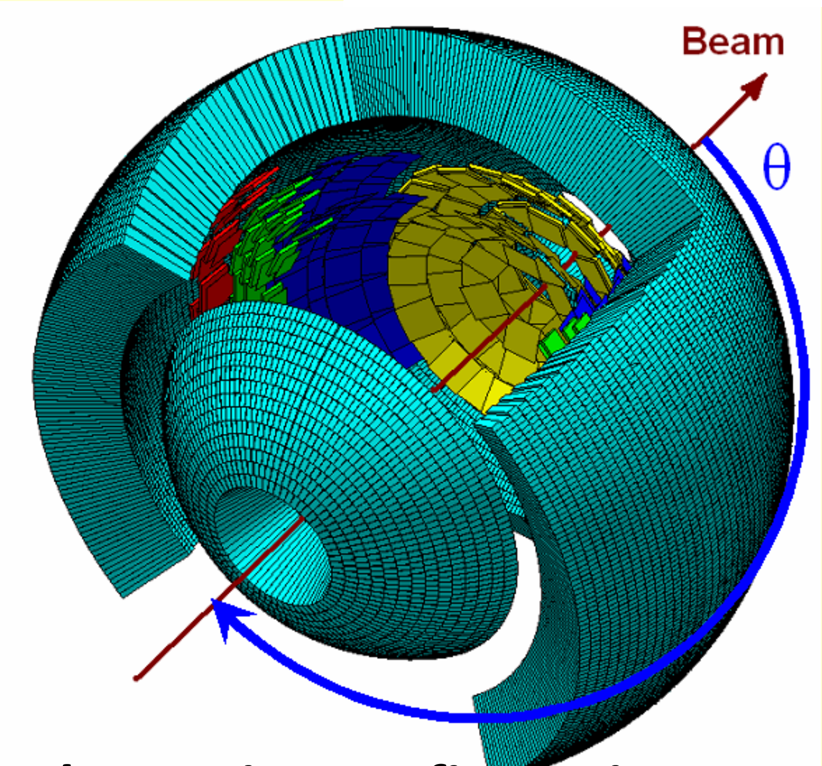
Simulations done by H. Moeini







Proposed configuration

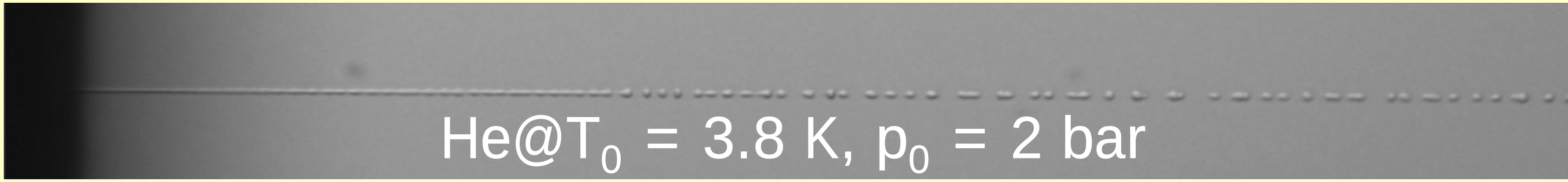


Alternative configuration

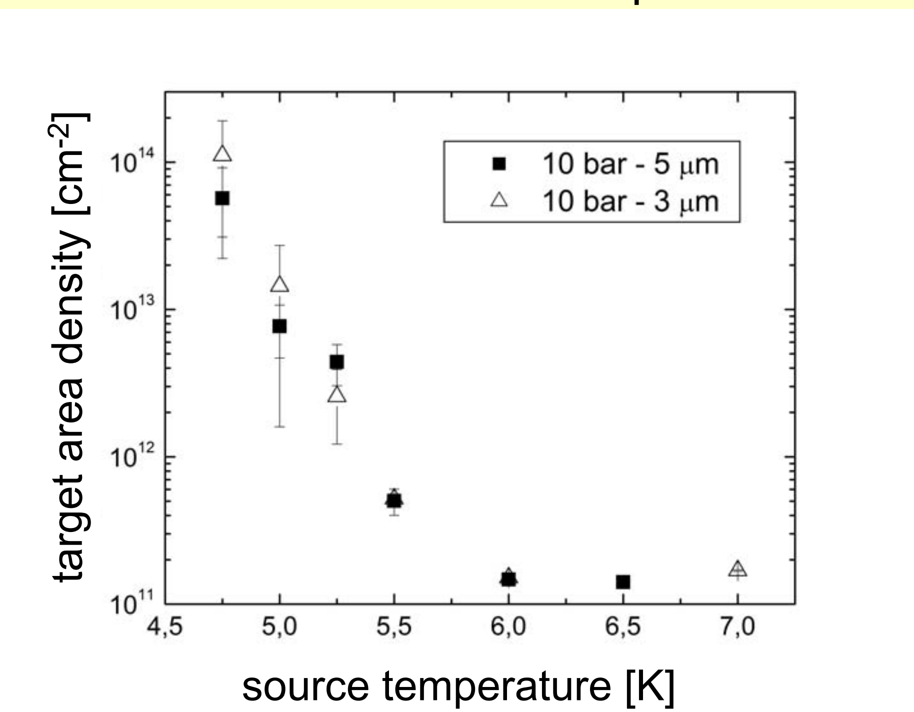
New Low-Z internal target

R. Grisenti et al., Frankfurt

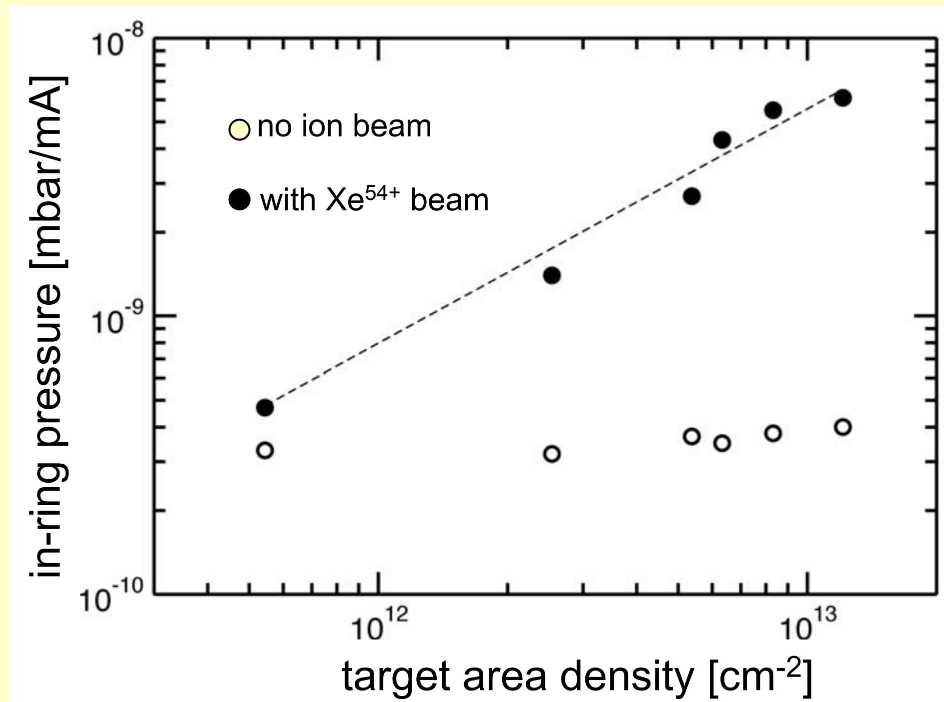
Cryogenically cooled liquid helium microjet

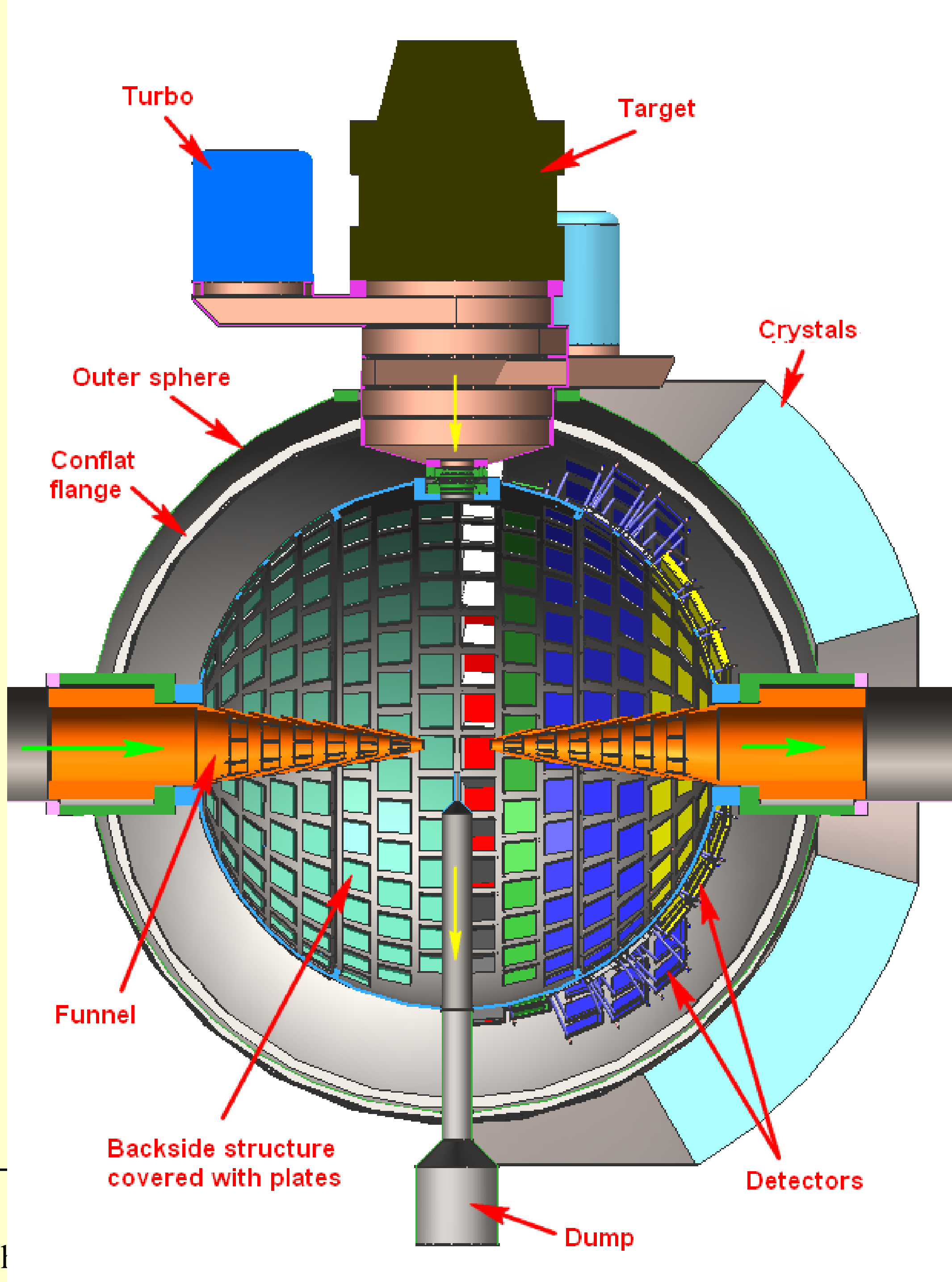


Measured target areal densities at different nozzle diameters and temperatures



Pressure in the scattering chamber as a function of the target areal density

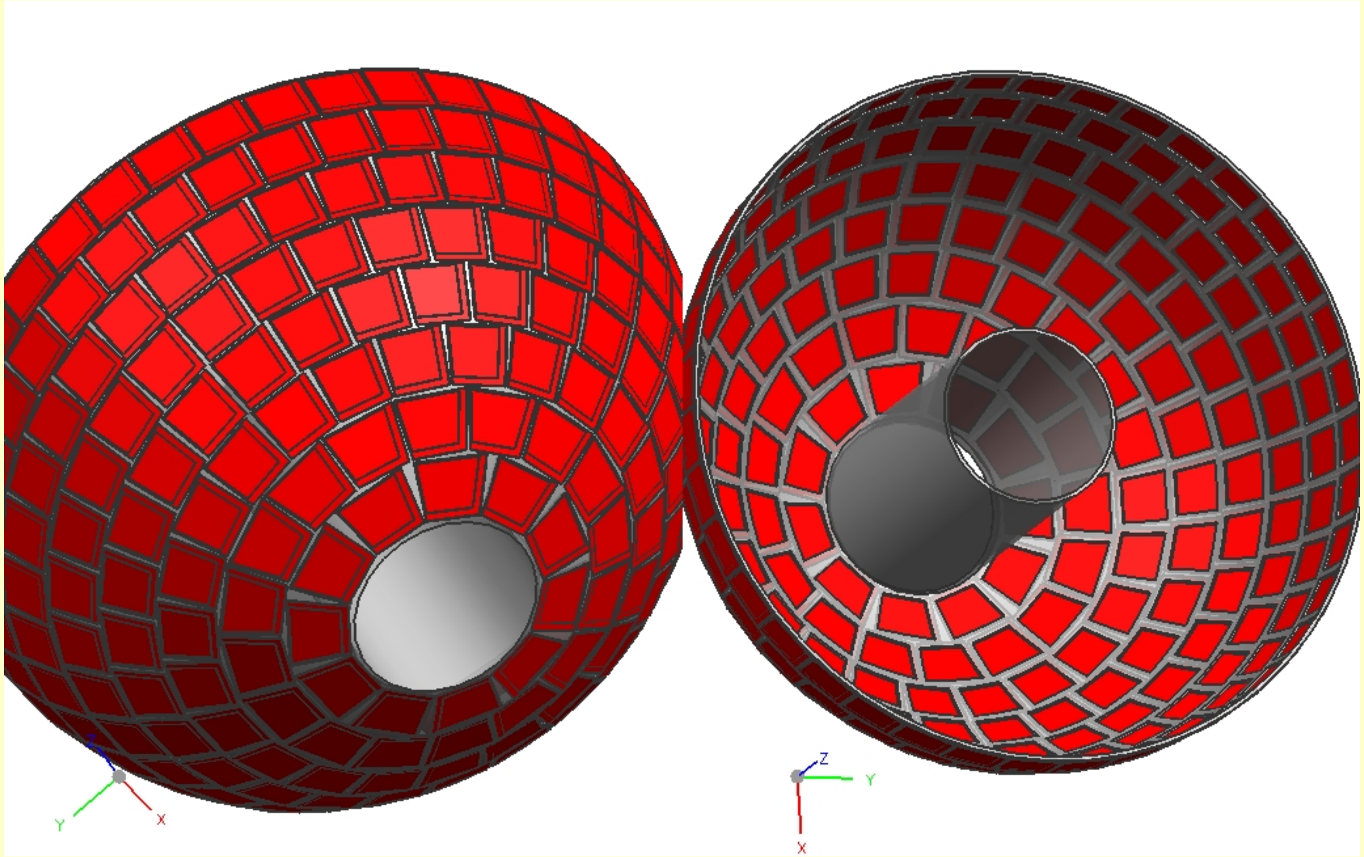



Turbo
Target
Crystals
Outer sphere
Conflat flange
Funnel
Backside structure covered with plates
Detectors
Dump

"Honey-comb" structure

M. Mutterer, M. Lindemulder

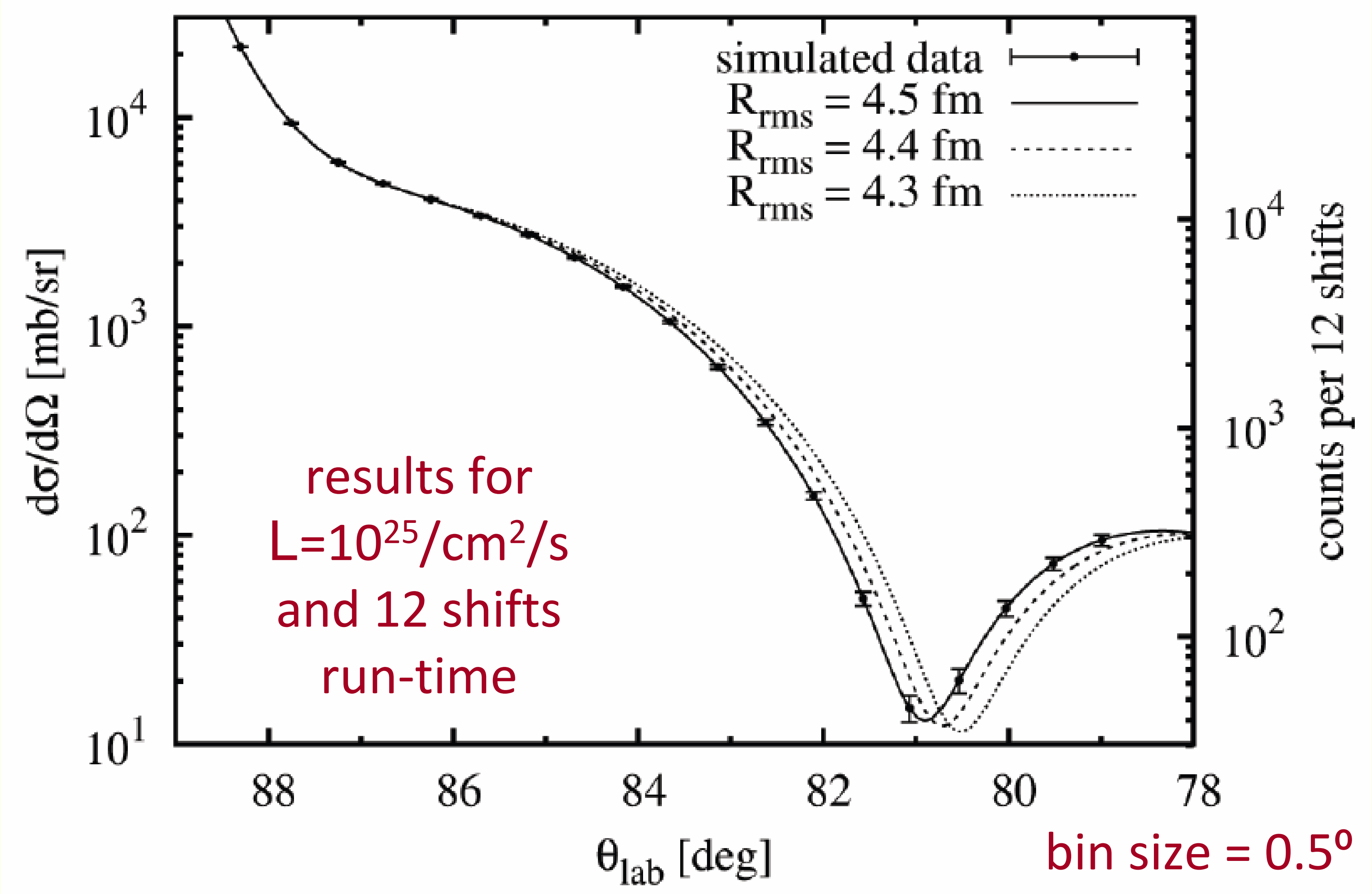
See talk by B. Streicher, M. Mutterer



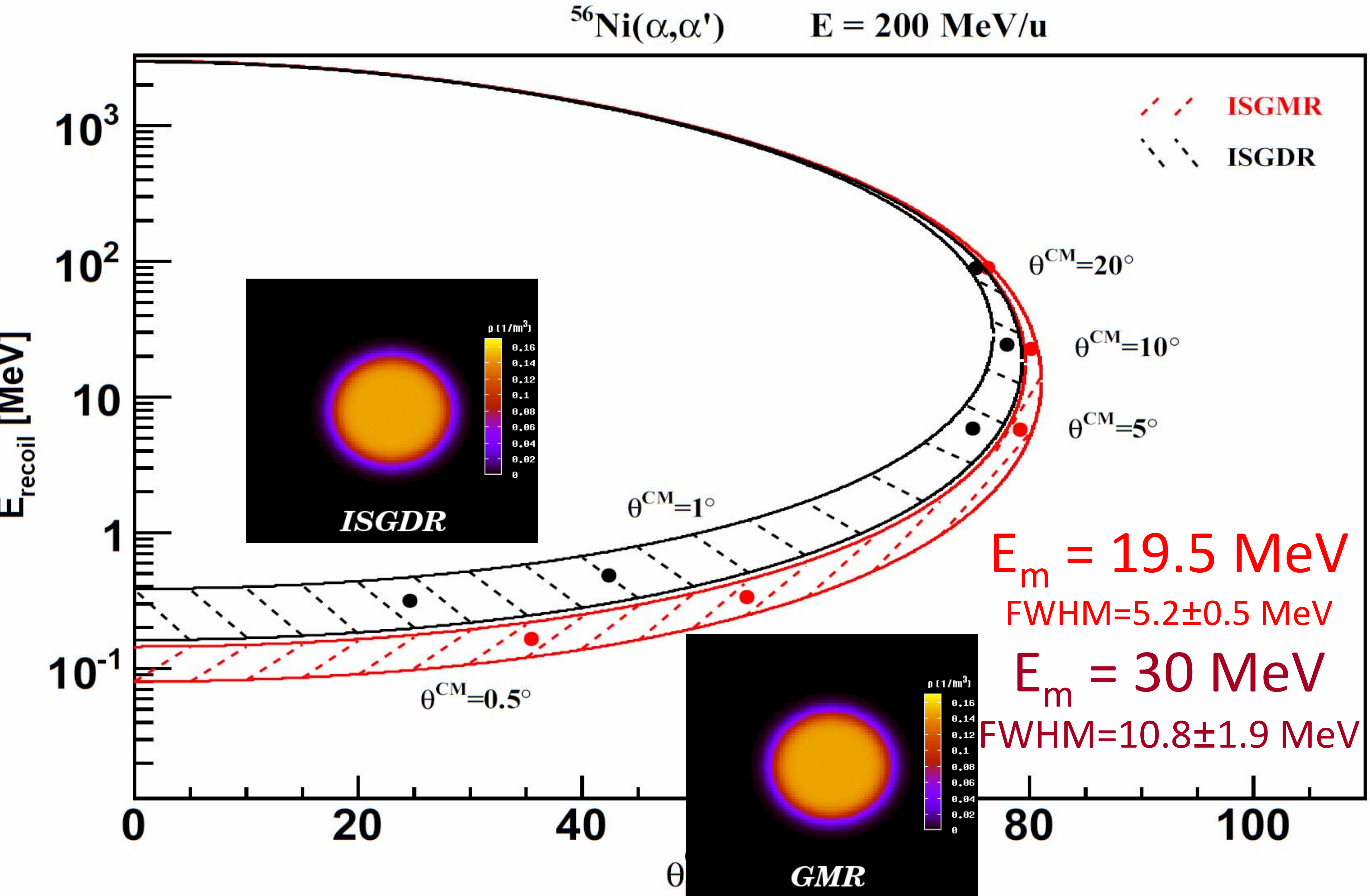
QuickTime™ and a
Microsoft Video 1 decompressor
are needed to see this picture.

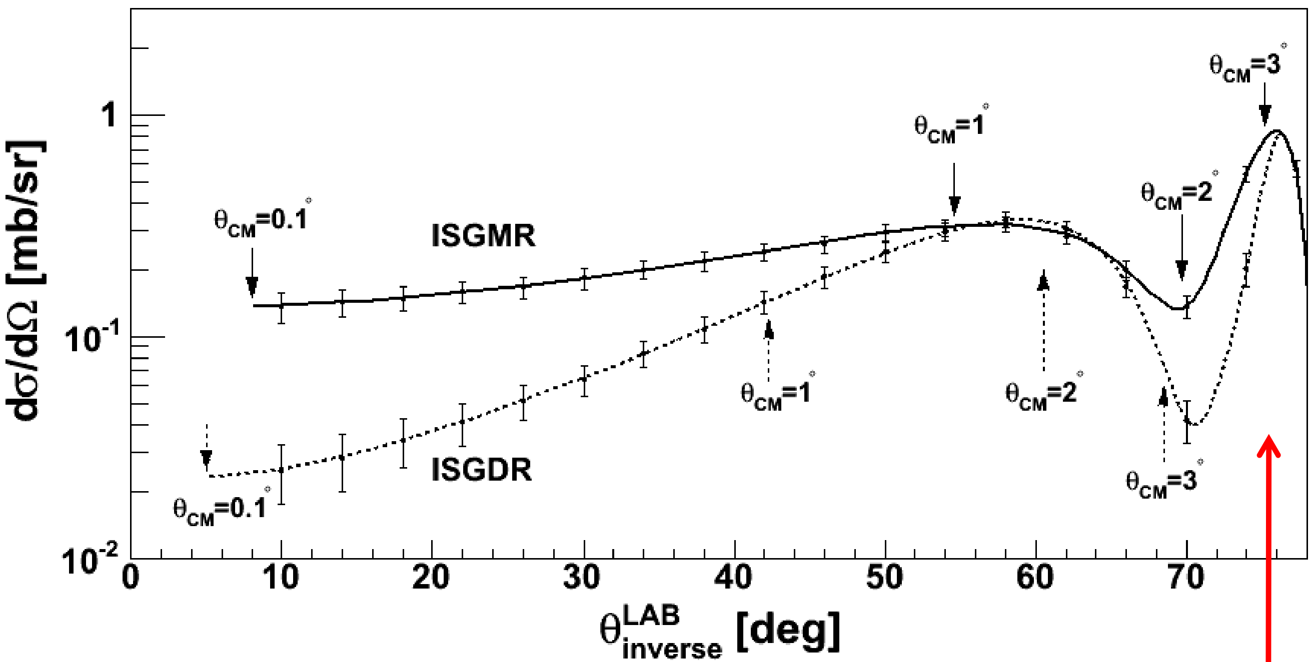
ESR Plans

Proton elastic-scattering cross sections at 400 MeV/u



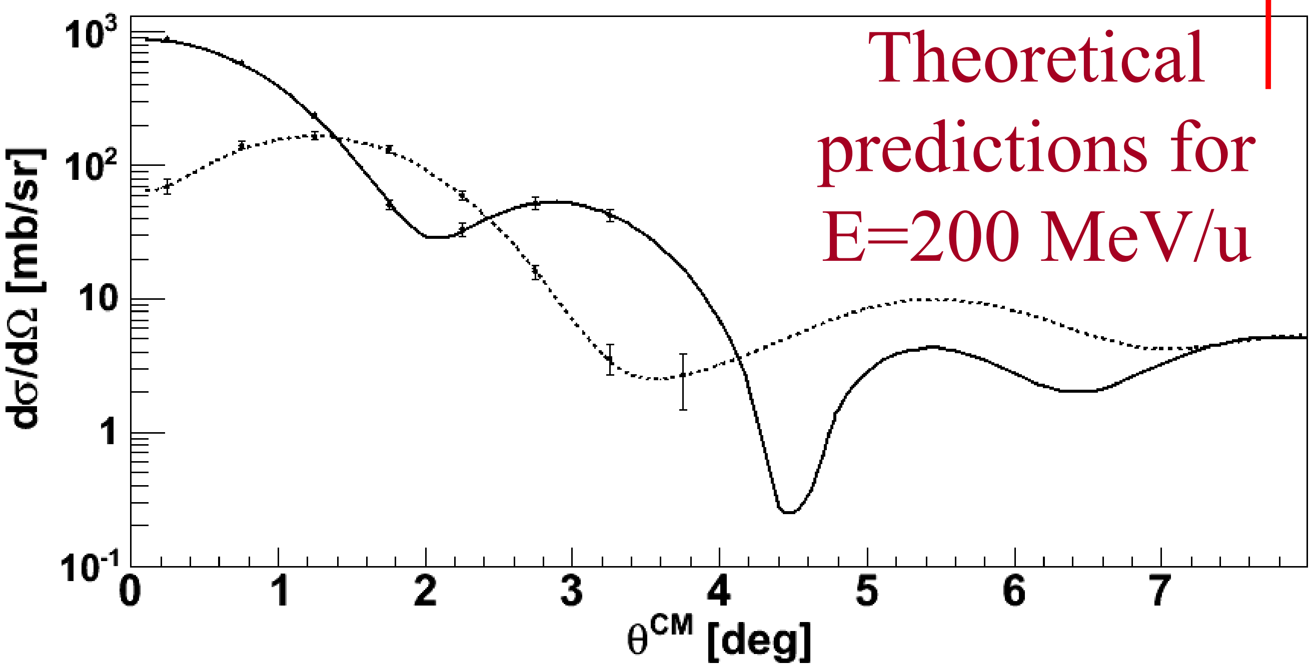
ISGMR/ISGDR channels in ^{56}Ni with (α,α')



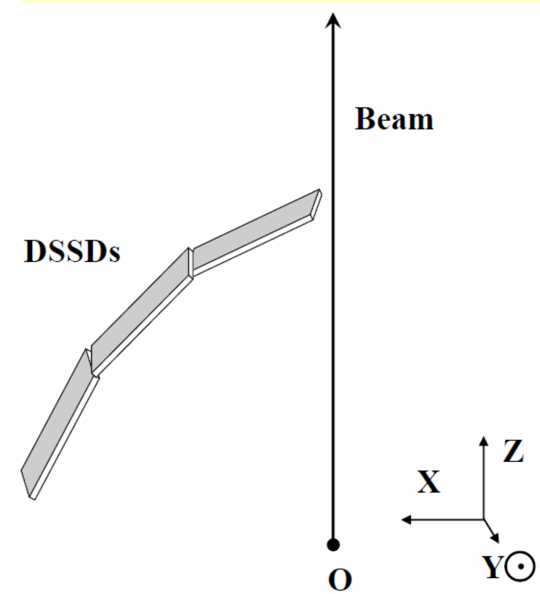


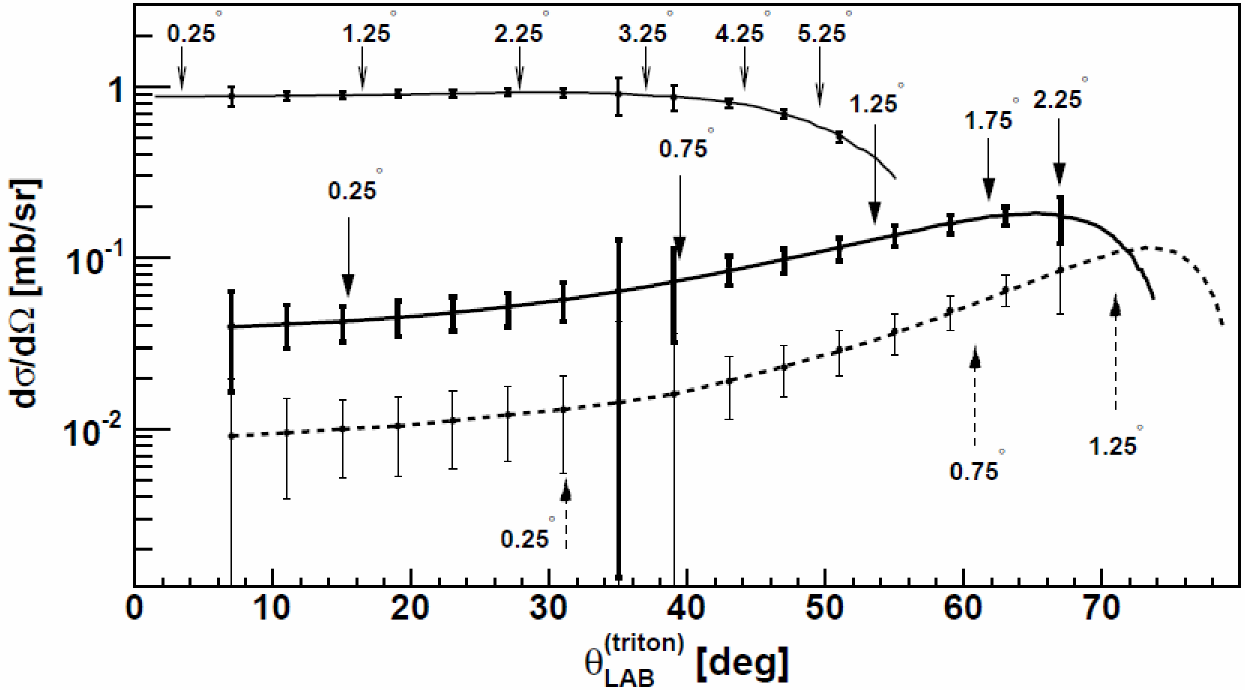
Simulation results for $L=10^{25}/cm^2/s$ and 15 days run-time

$/J_{1,inv.}$



Theoretical predictions for E=200 MeV/u



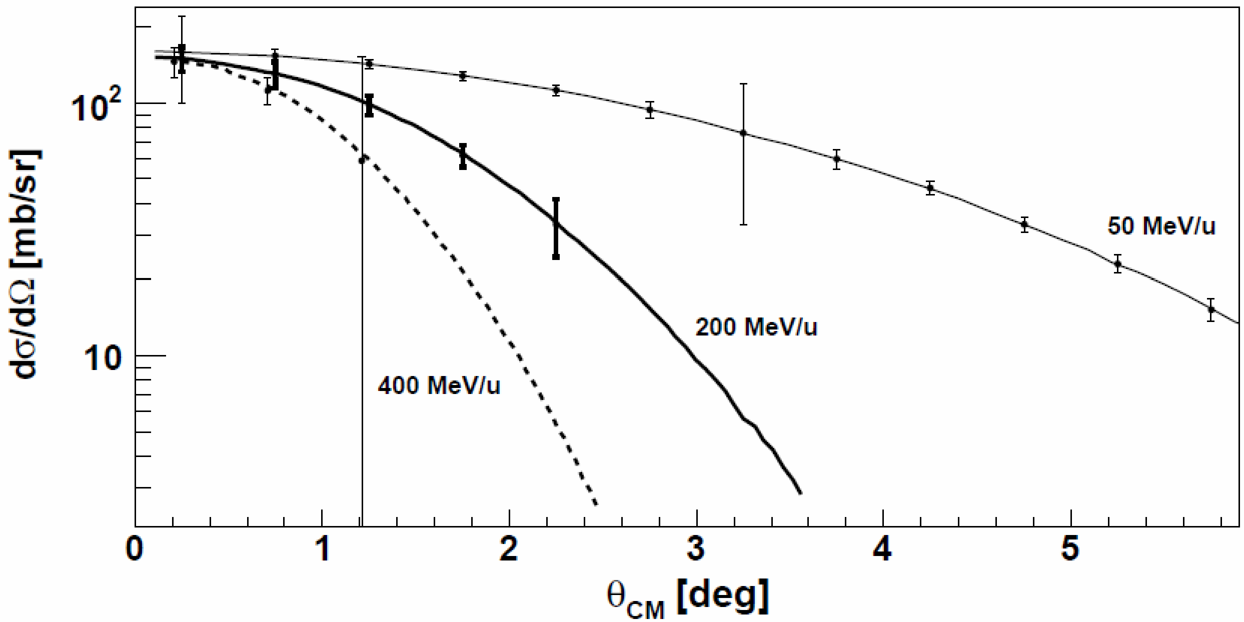


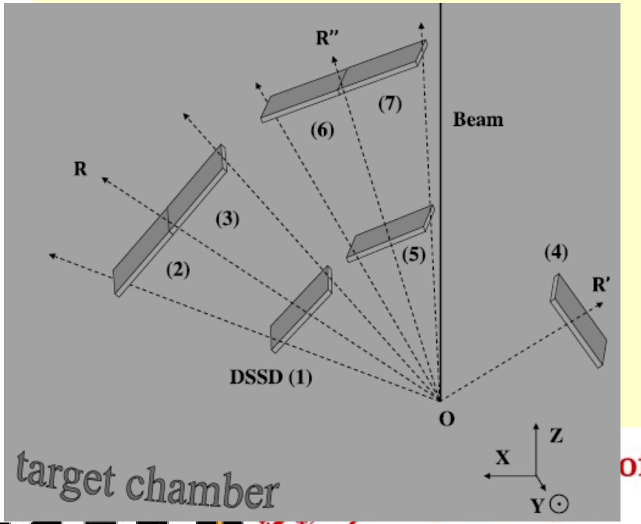
Error estimation

15 days run-time

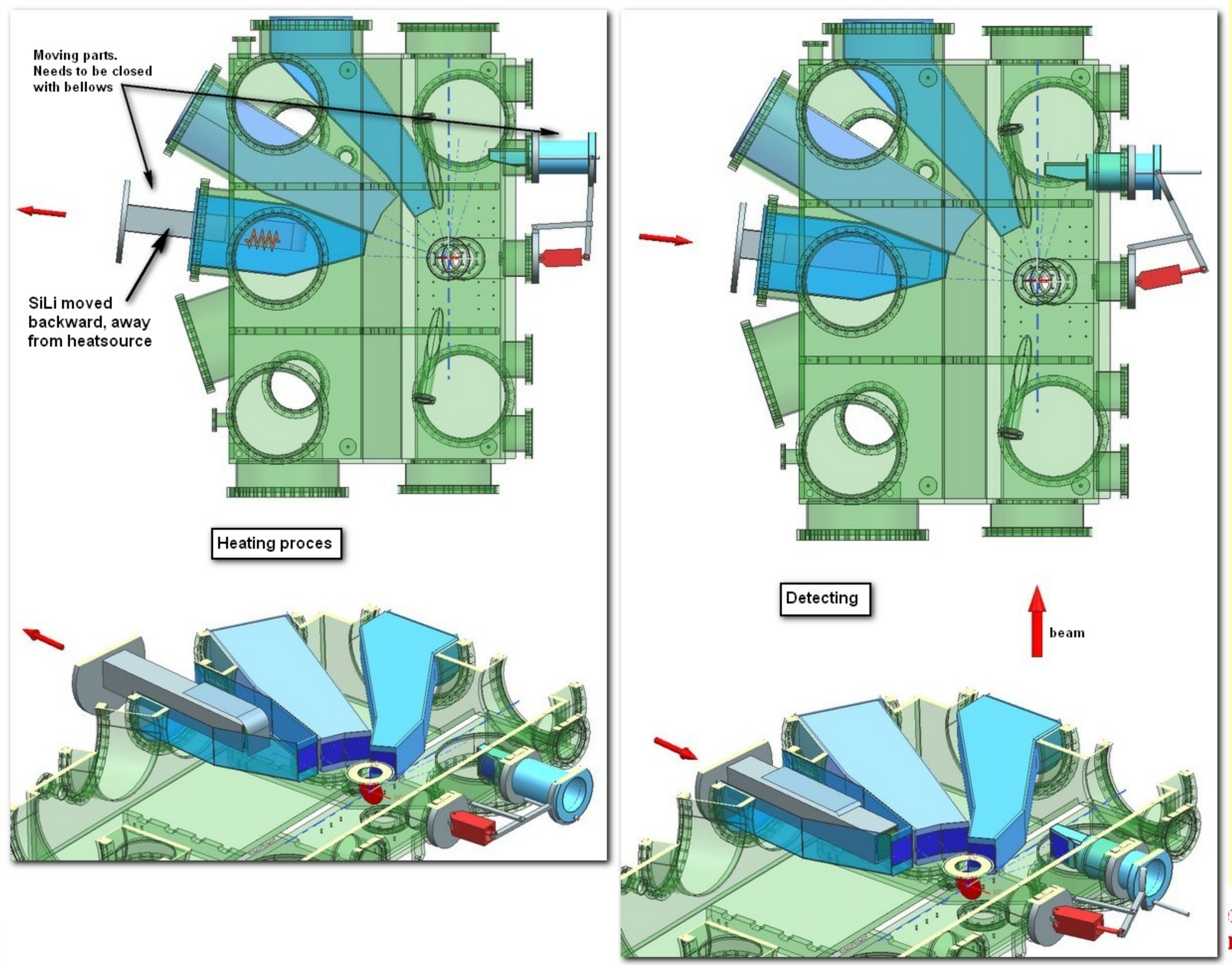
$^{56}Ni(^{3}He,t)\,^{56}Cu$

4 MeV excitation





The new ESR Scattering chamber



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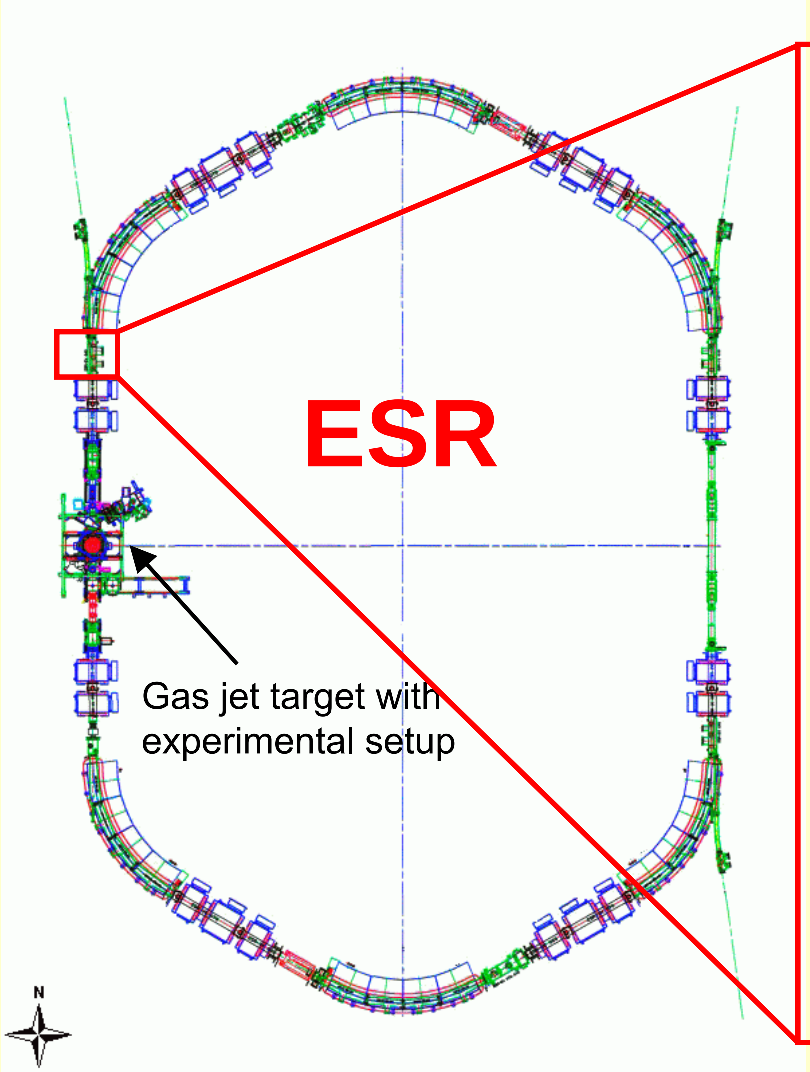
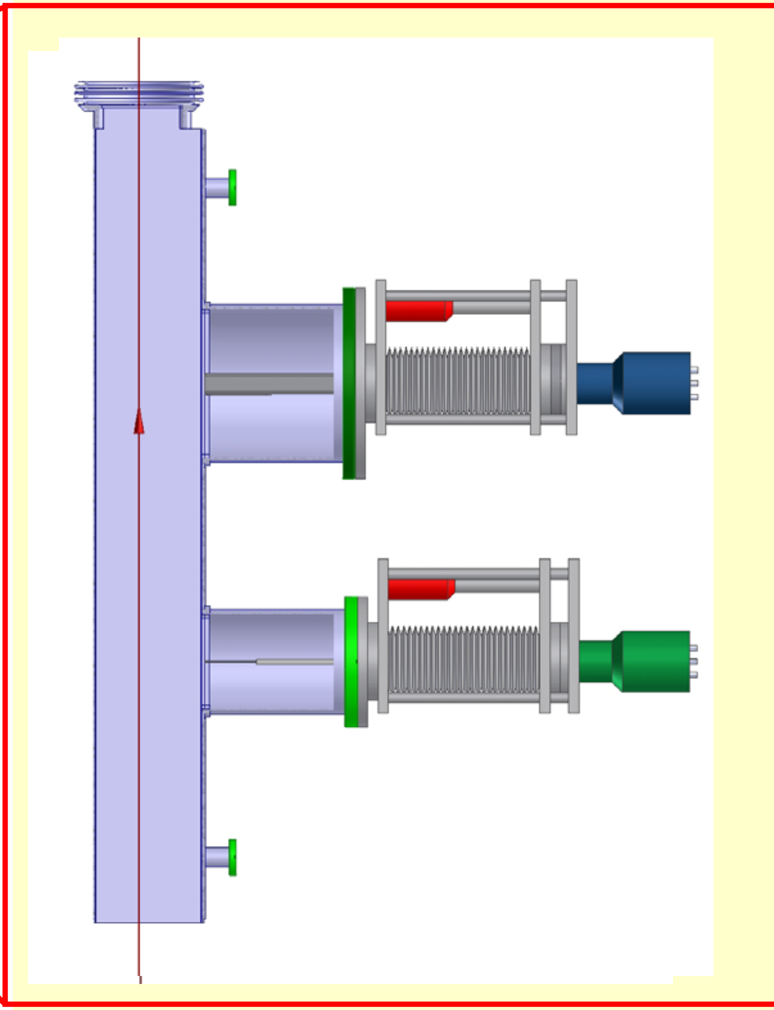
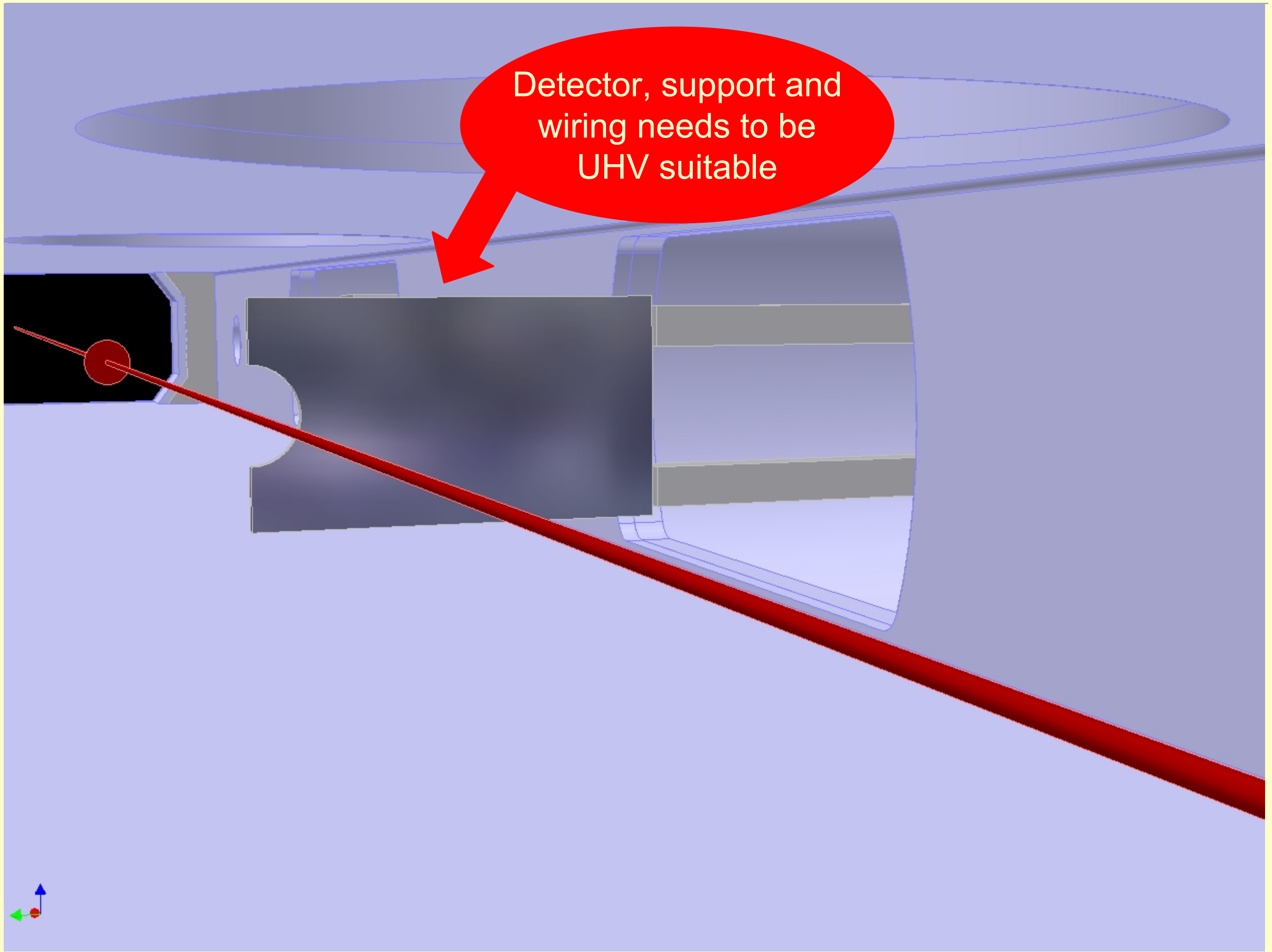
Concept for In-Ring Tagging Detectors at the ESR (and NESR)





Concept for an In-Ring Detector setup for detection of beam like particles

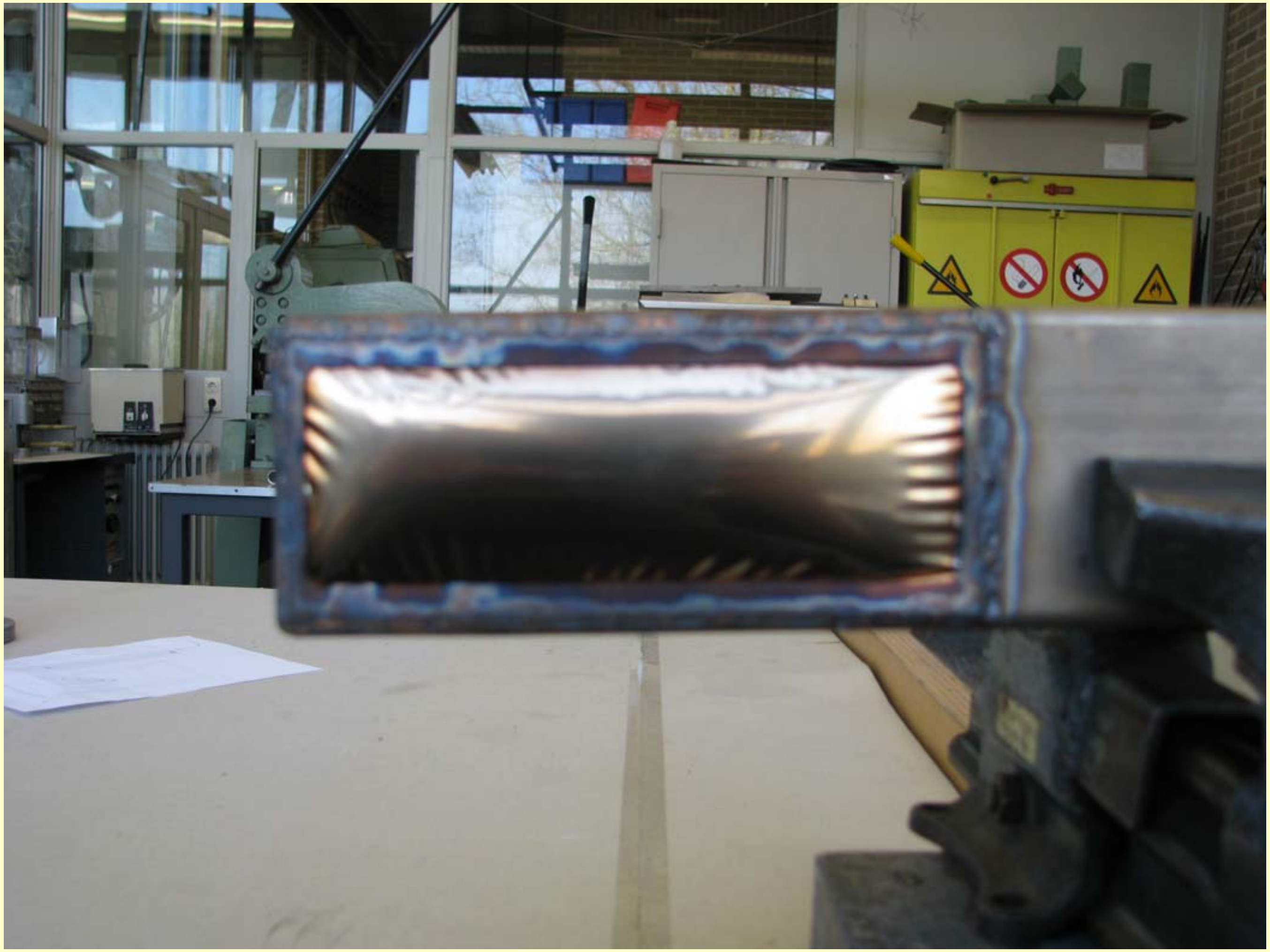


Bare detector close to beam.

Challenge:

Employment of a fully UHV suitable and driven in-ring detector.

Vacuum pockets



H. Kiewiet, H. Smit, D. Tilman

Conclusions and outlook

- The EXL physics program covers a large part of nuclear structure and reactions.
- Bulk properties (radius, compressibility etc.), shell structure and correlations will be studied in asymmetric matter.
- The goal is to go towards the medium heavy and heavy nuclei (astrophysical processes).
- R&D is well underway for EXL. TDR expected by the end of 2012.
- First physics measurements are proposed to GSI-PAC and phase-wise approved within the present ESR program.

Thank you!

Elastic Scattering Cross Section (E>500keV)