EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007-2013

Sectoral Operational Programme
„Increase of Economic Competitiveness"
"Investments for Your Future"

Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

Project co-financed by the European Regional Development Fund

Photofission experiments and the IGISOL Facility at ELI-NP

Dimiter L. Balabanski

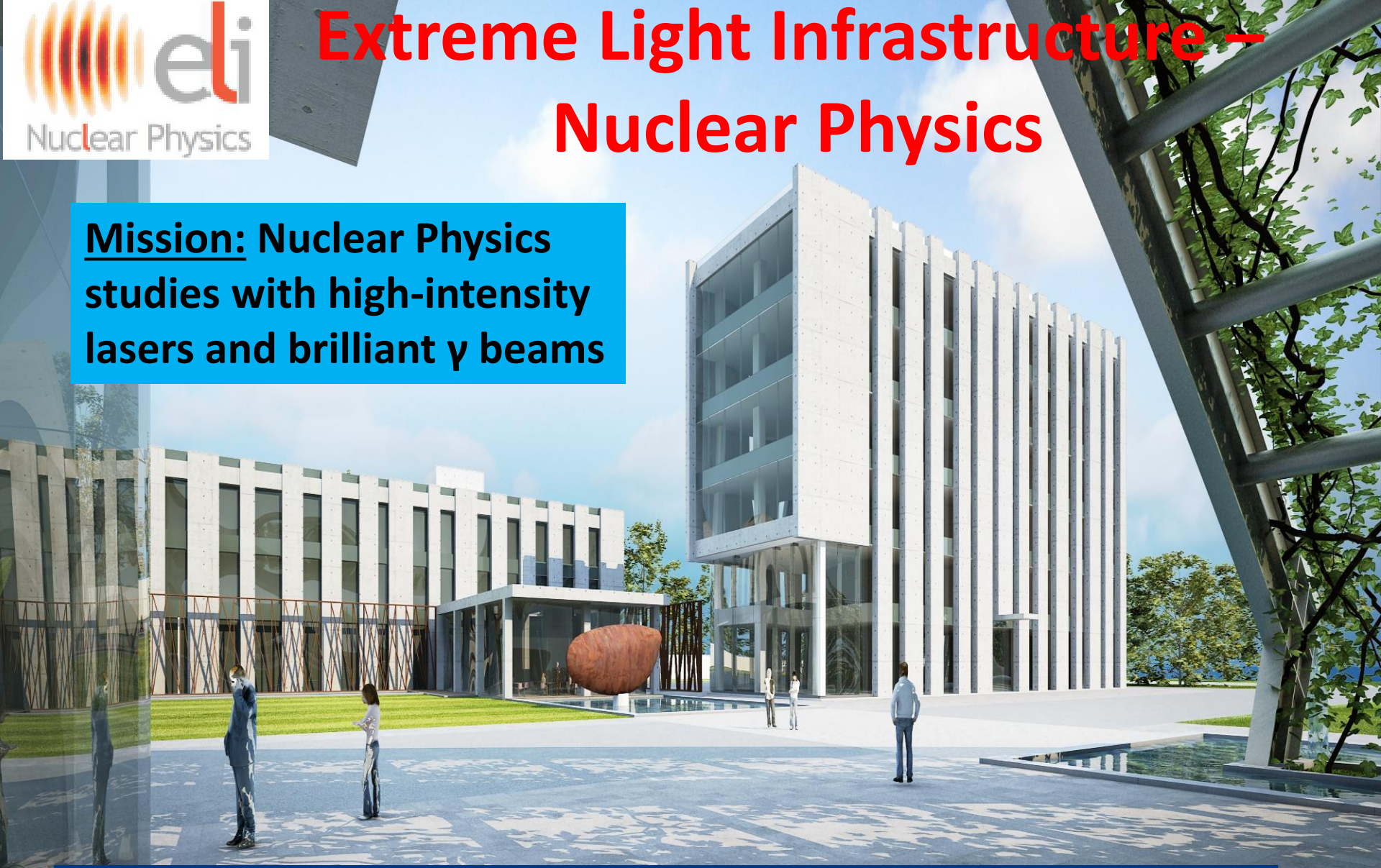
ISOLDE workshop 2015, CERN

Nuclear Physics

IFIN-HH

Extreme Light Infrastructure – Nuclear Physics

Mission: Nuclear Physics studies with high-intensity lasers and brilliant γ beams



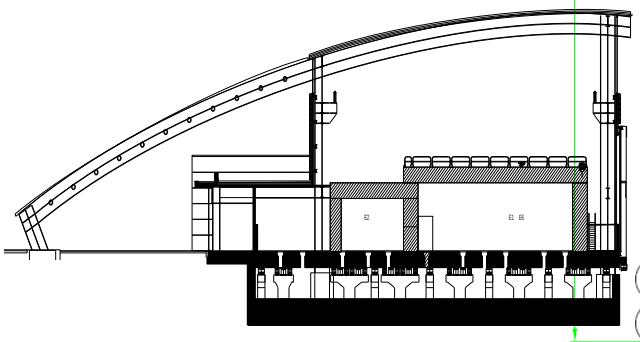
"The content of this document does not necessarily represent the official position of the European Union or of the Government of Romania"

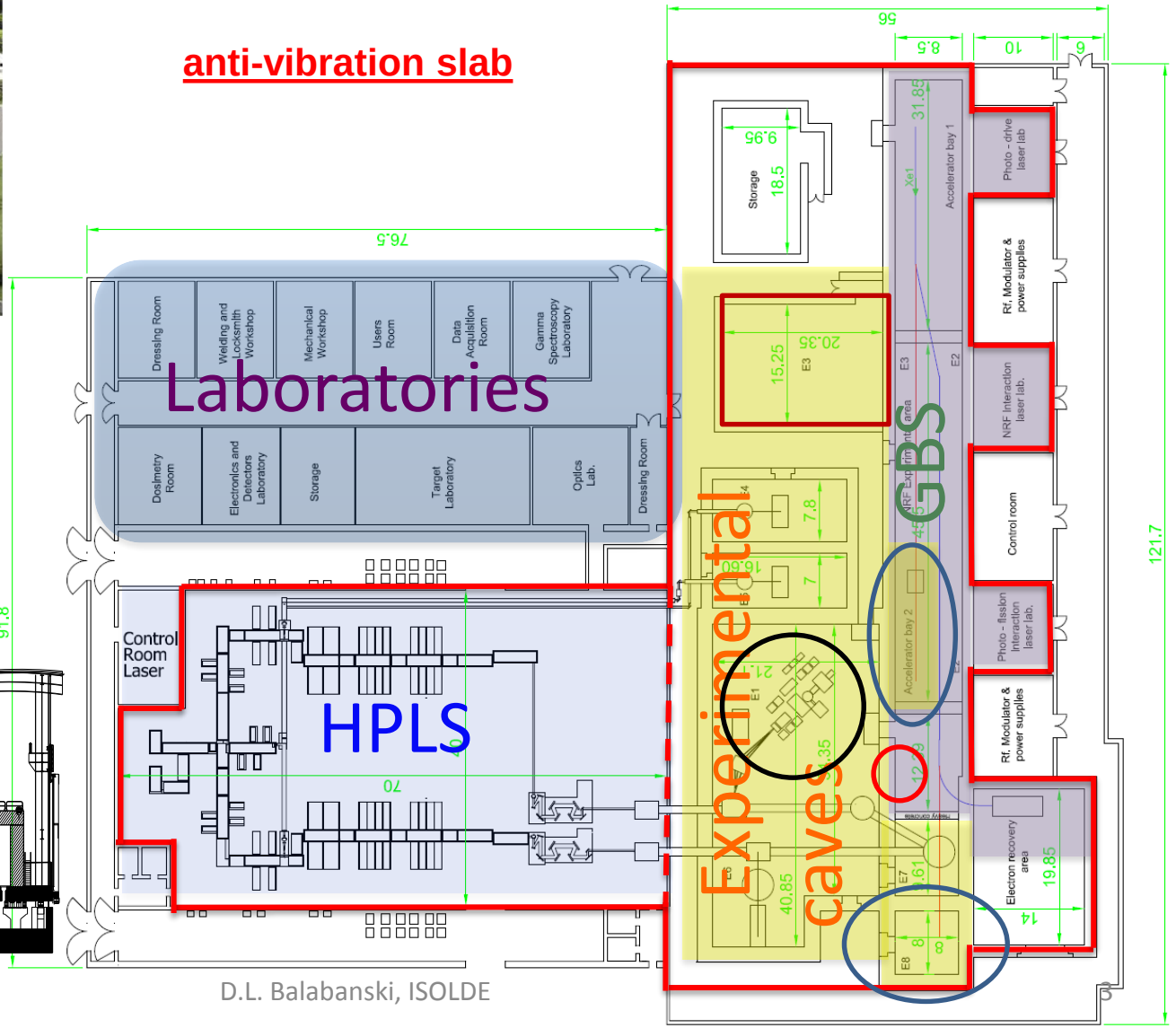
For detailed information regarding the other programmes co-financed by the European Union please visit *www.fonduri-ue.ro, www.ancs.ro, http://amposcce.minind.ro*

ELI–NP: Experimental Building

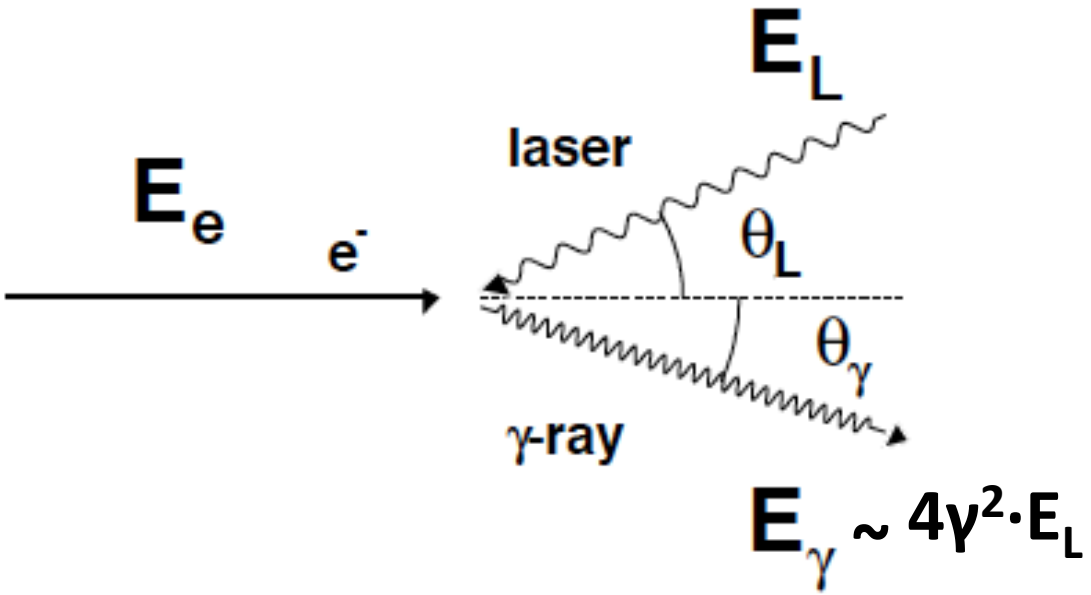
anti-vibration slab

±1 μm @ < 10 Hzg





ELI-NP Gamma Beam System (GBS)

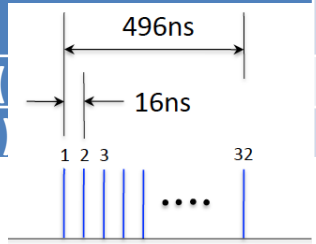


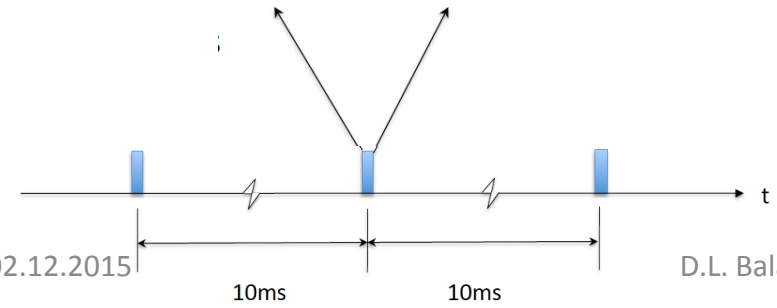
Laser Compton backscattering (LCB)

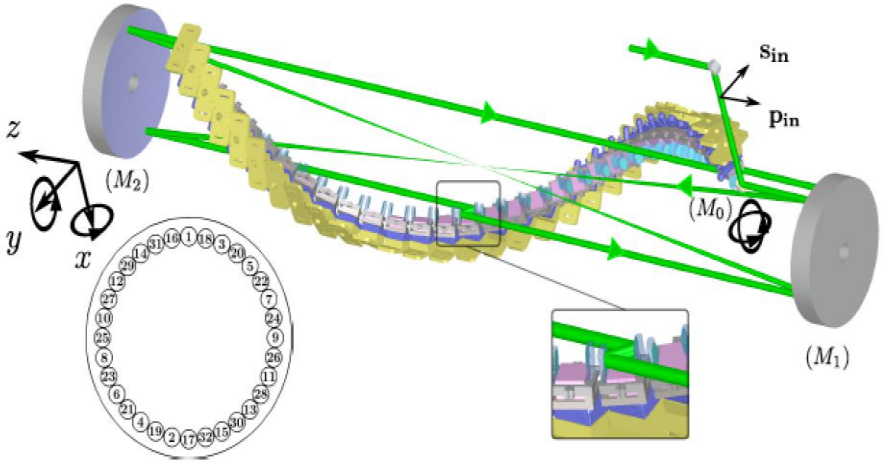
Narrow bandwidth (≤0.3%) gamma-beams up to 19.5 MeV

A r.t. RF linac *vs* pulsed laser source

Electron beam parameter at IP	
Energy (MeV)	180-750
Bunch charge (pC)	25-400
Bunch length (µm)	100-400
$\varepsilon_{n\_x,y}$ (mm-mrad)	0.2-0.6
Bunch Energy spread (%)	0.04-0.1
Focal spot size (µm)	15-30
# bunches in the train	> 31
Bunch separation (nsec)	16
energy variation along the train	0.1 %
Energy jitter shot-to-shot	0.1 %
Emittance dilution due to beam breakup	< 10%
Time arrival jitter (	< 0.5
Pointing jitter (µm)	1

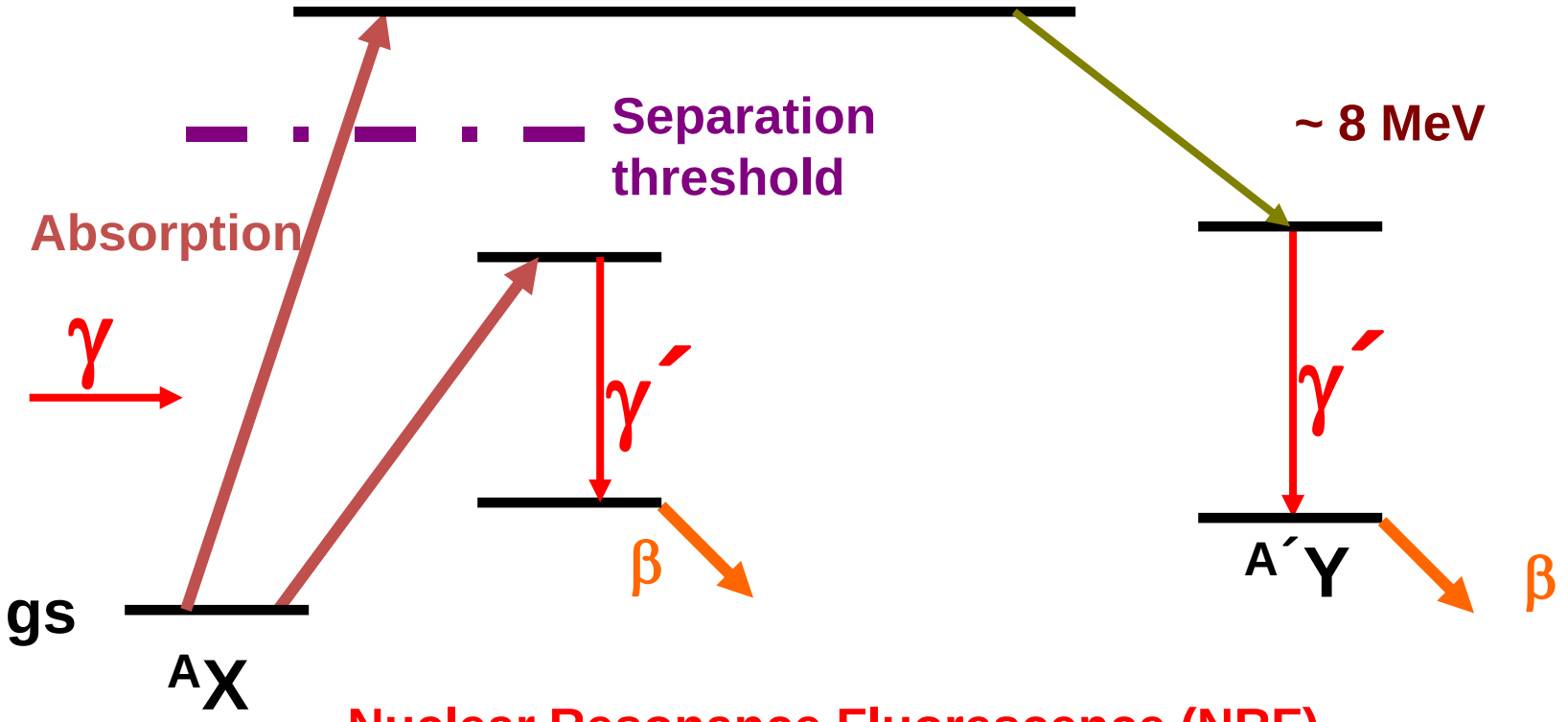






Pulse energy (J)	0.2	0.5
Wavelength (eV)	2.4	2.4
FWHM pulse length (ps)	2-4	2-4
Repetition Rate (Hz)	100	100
M^2	≥ 1.2	≥ 1.2
Focal spot size w_0 (µm)	> 25	25
Bandwidth (rms)	0.05 %	0.05 %
Pointing Stability (µrad)	1	1
Sinchronization to an ext. clock	< 1 psec	< 1 psec
Pulse energy stability	1 %	1 %

Photonuclear Reactions



Nuclear Resonance Fluorescence (NRF)

Photoactivation

Photodesintegration (-activation)

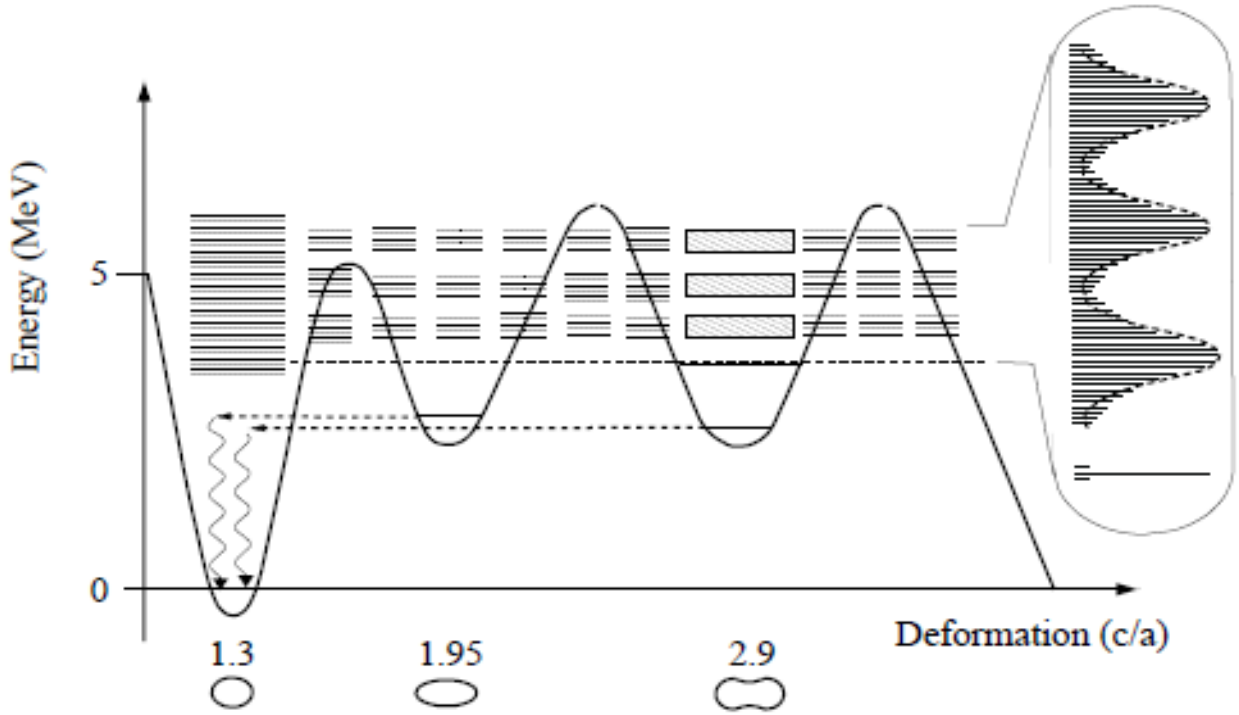
Photofission

Photofission

tenders for 5 BICs, 8 Si DSSD, THGEM array, electronics and support infrastructure are open or in preparation

1. Studies in the 2^{nd} and 3^{rd} minimum of the fission barrier: transmission resonances
2. Rare fission modes: ternary fission
3. Structure of neutron-rich nuclei: the rare-earth neutron-rich deformed region

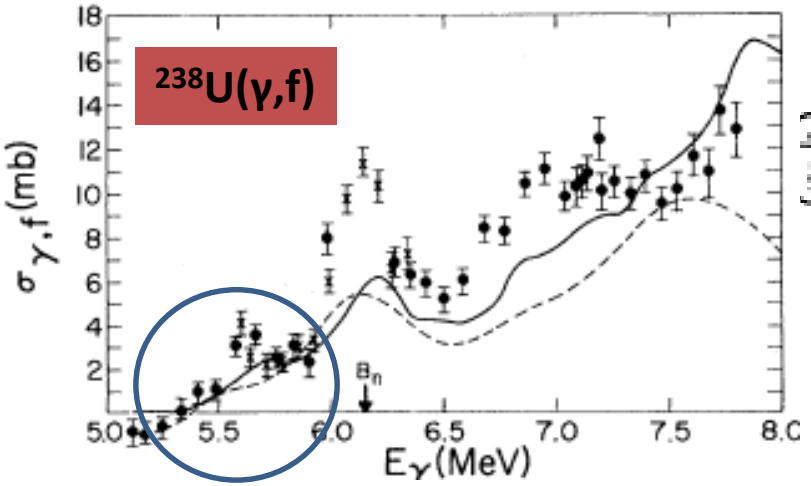
Studies of the 2nd and 3rd minimum

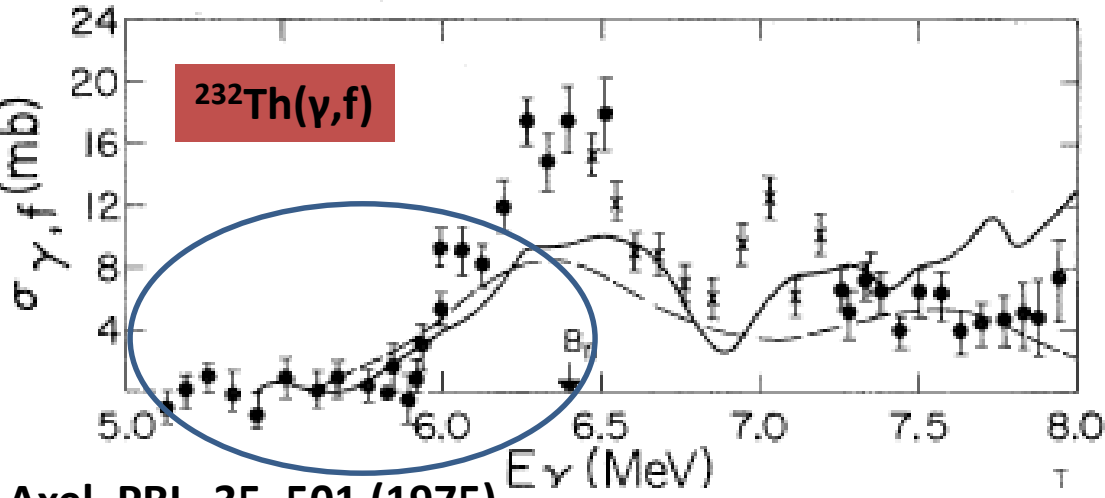


schematical description of the occurrence of transmission resonances

P.G. Thirolf et al., EPJ Web of Conferences 38, 08001 (2012)

Transitional Resonances: Status

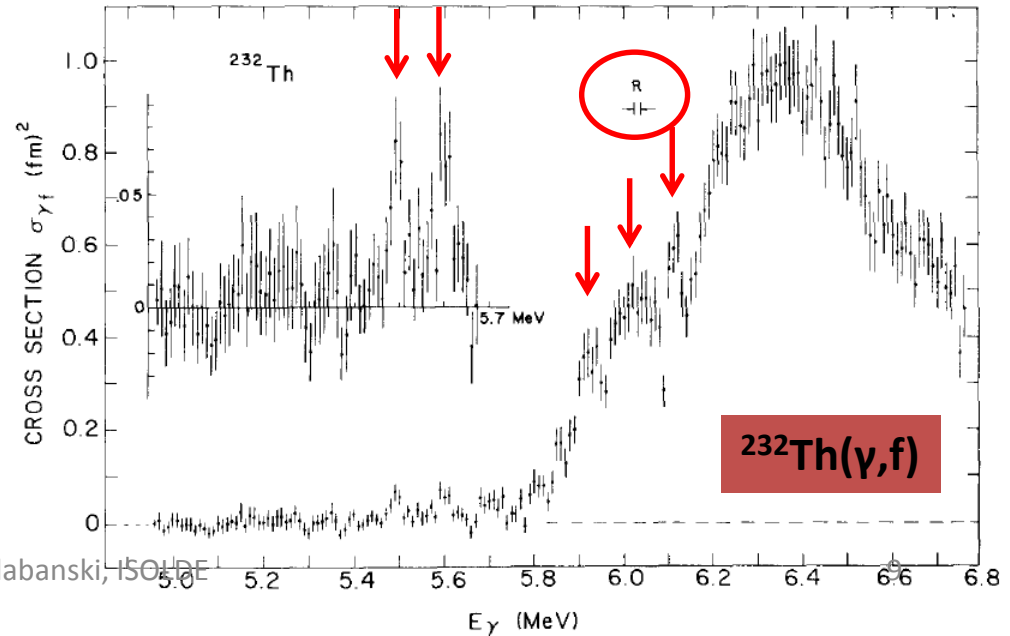




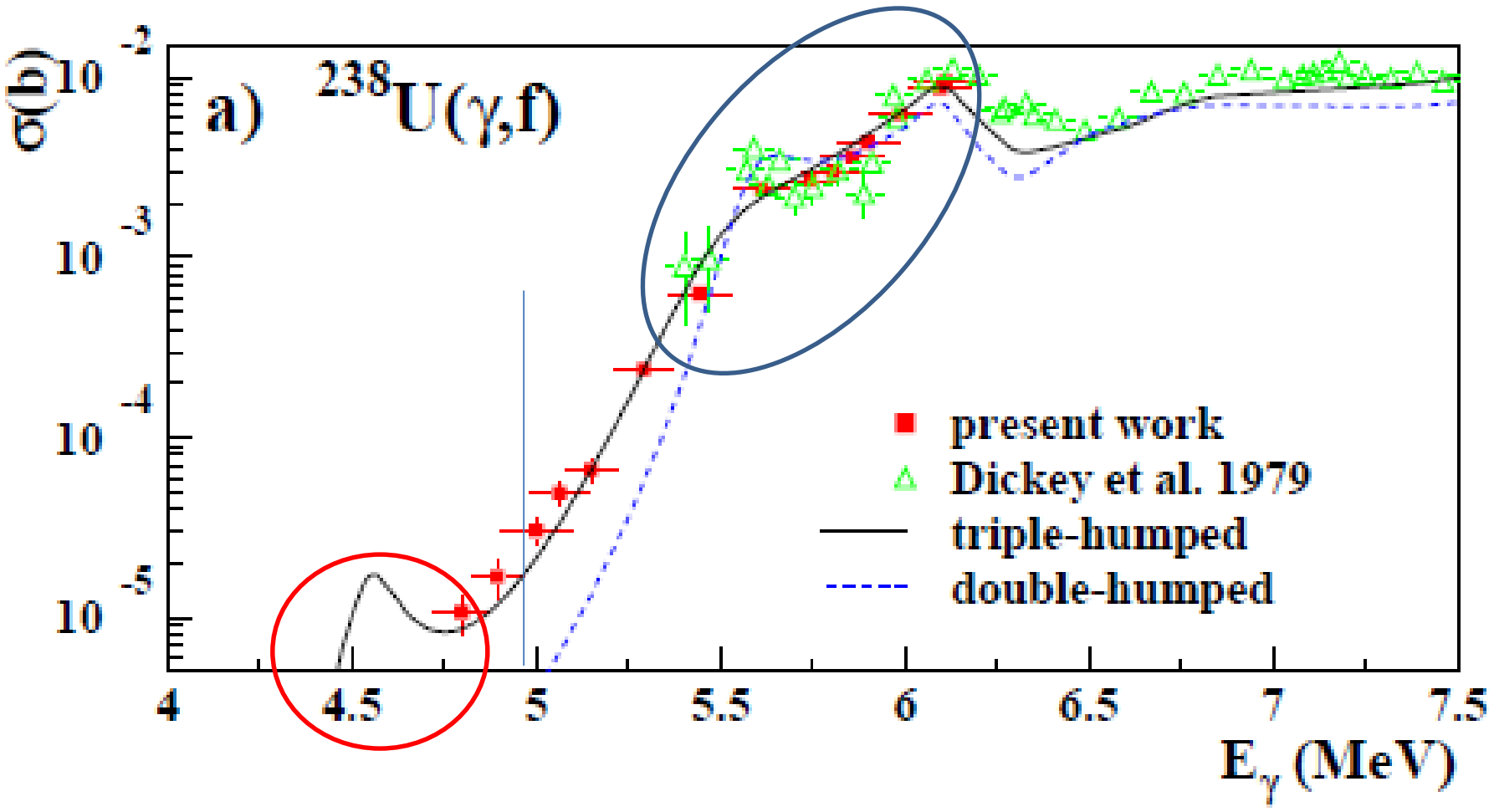
P. A. Dickey, P. Axel, PRL, 35, 501 (1975)

J. W. Knowles et al, PLB 116, 315 (1982)

bandwidth *R* = 12 – 14 keV

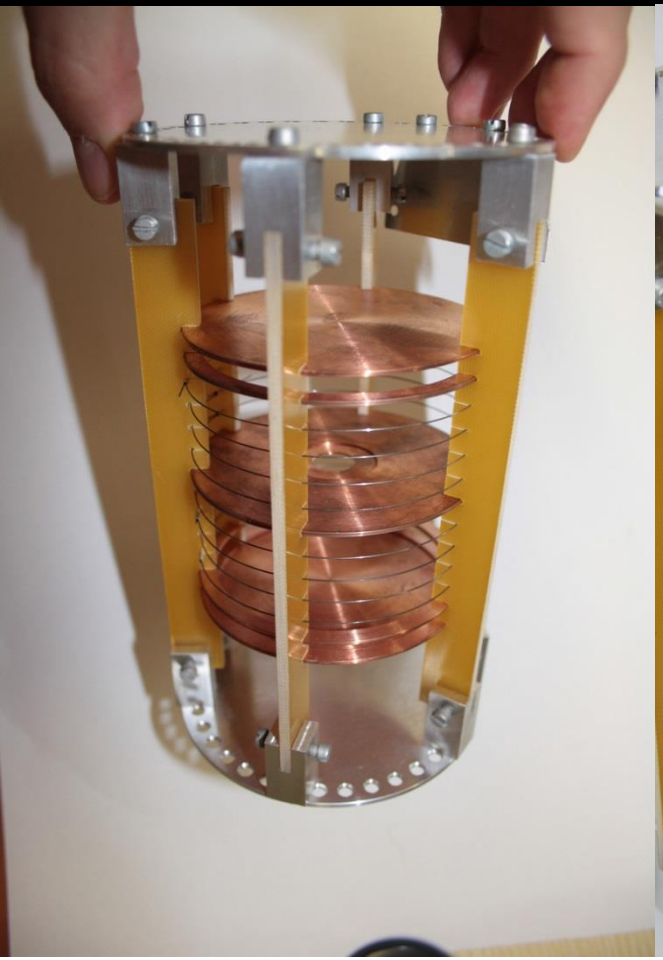


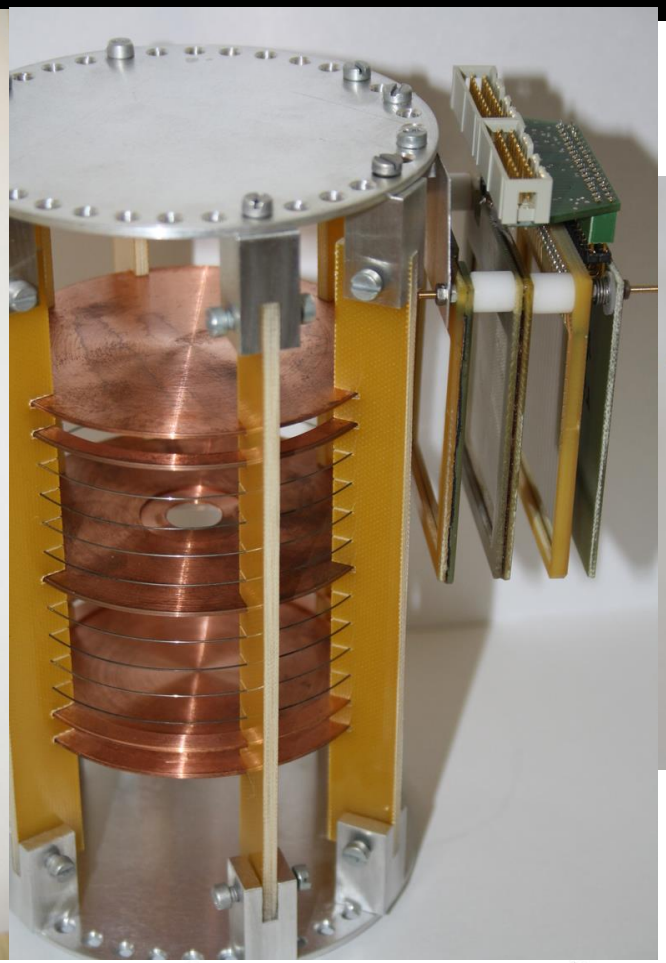
Transitional Resonances: Current study

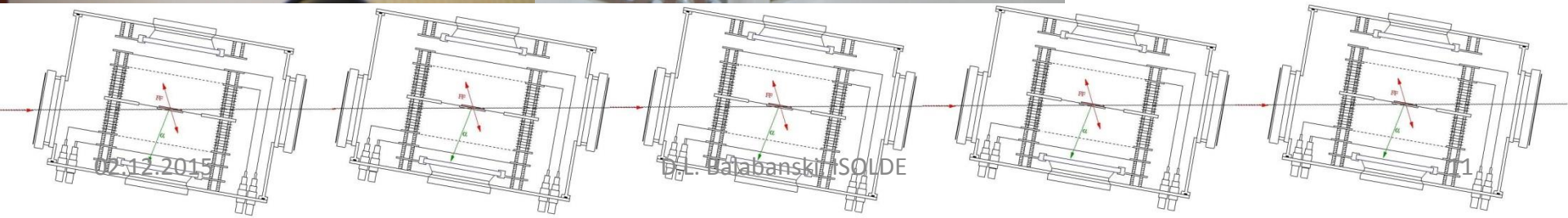


(γ,f) experiment at HIγS: Csige et al., Phys. Rev. C 87, 044321 (2013)

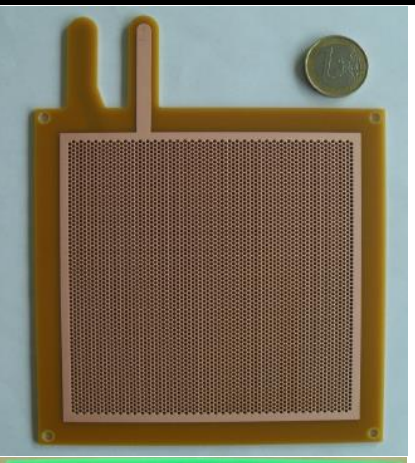
GBS TDR3 PhF: Double Bragg TPC

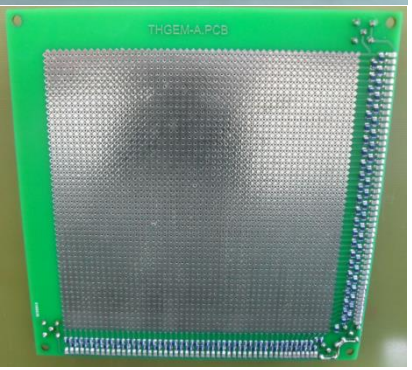




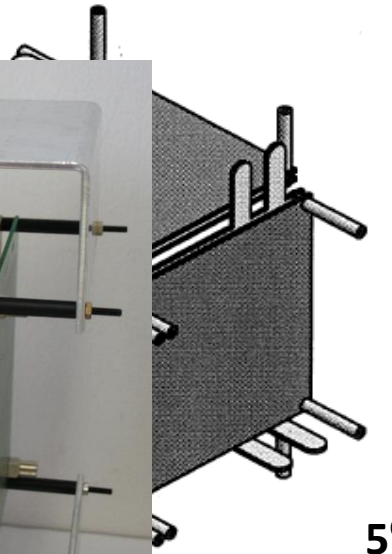


GBS TDR3 PhF: THGEM array



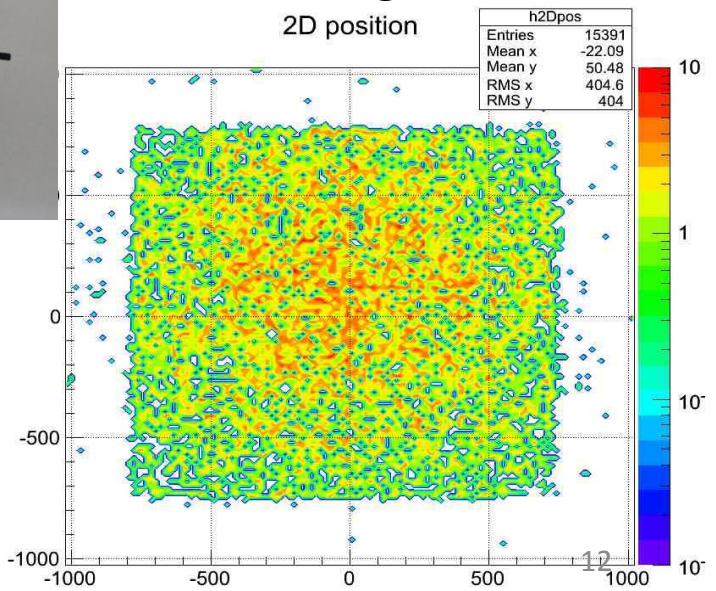


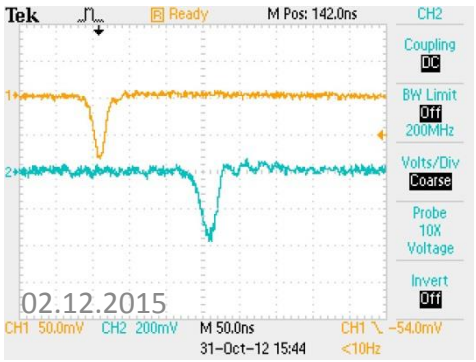
ten targets along the beam axis

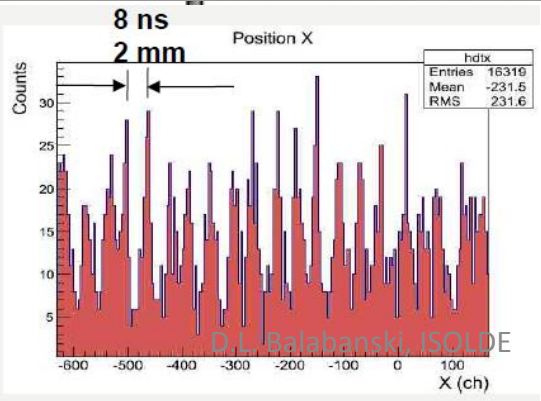


technical design and tests at MTA ATOMKI, Debrecen

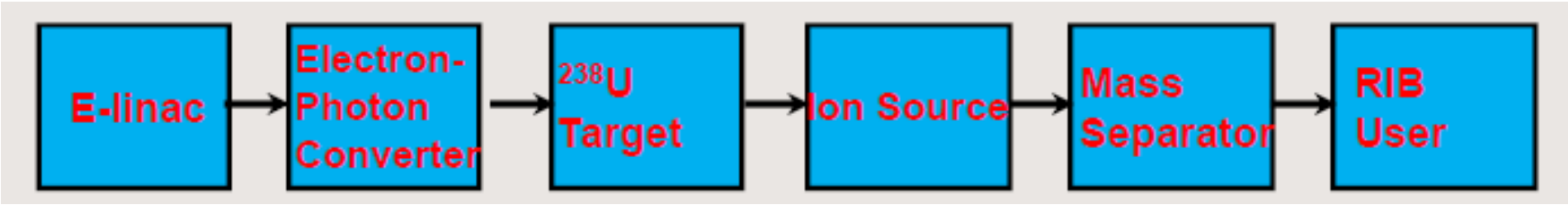
5^{o} angular resolution



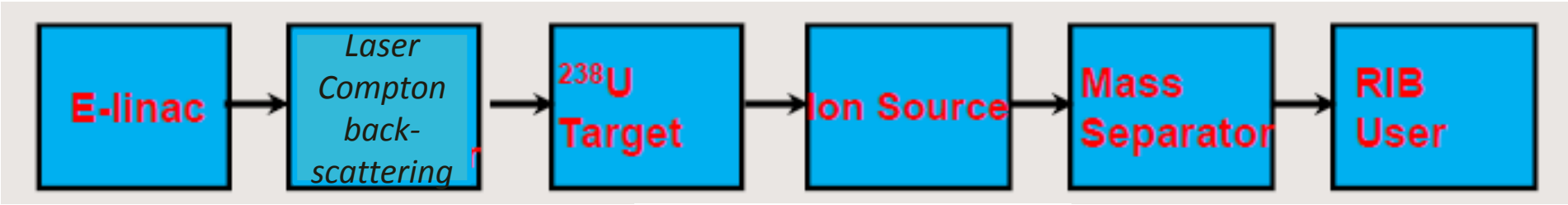


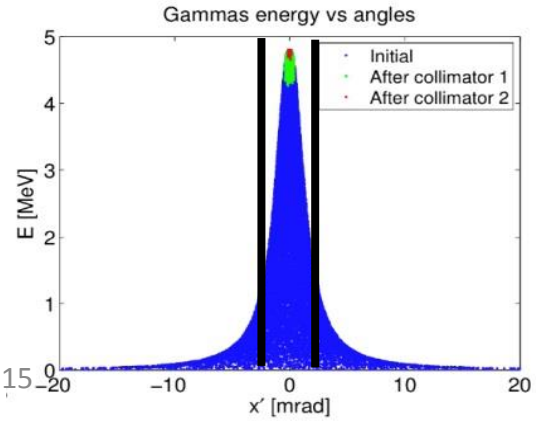


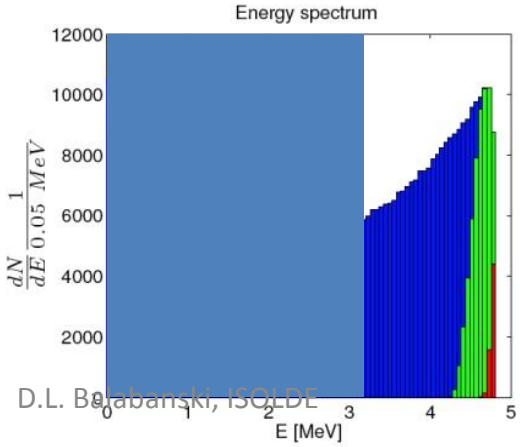
ALTO, ARIEL, etc.



ELI-NP





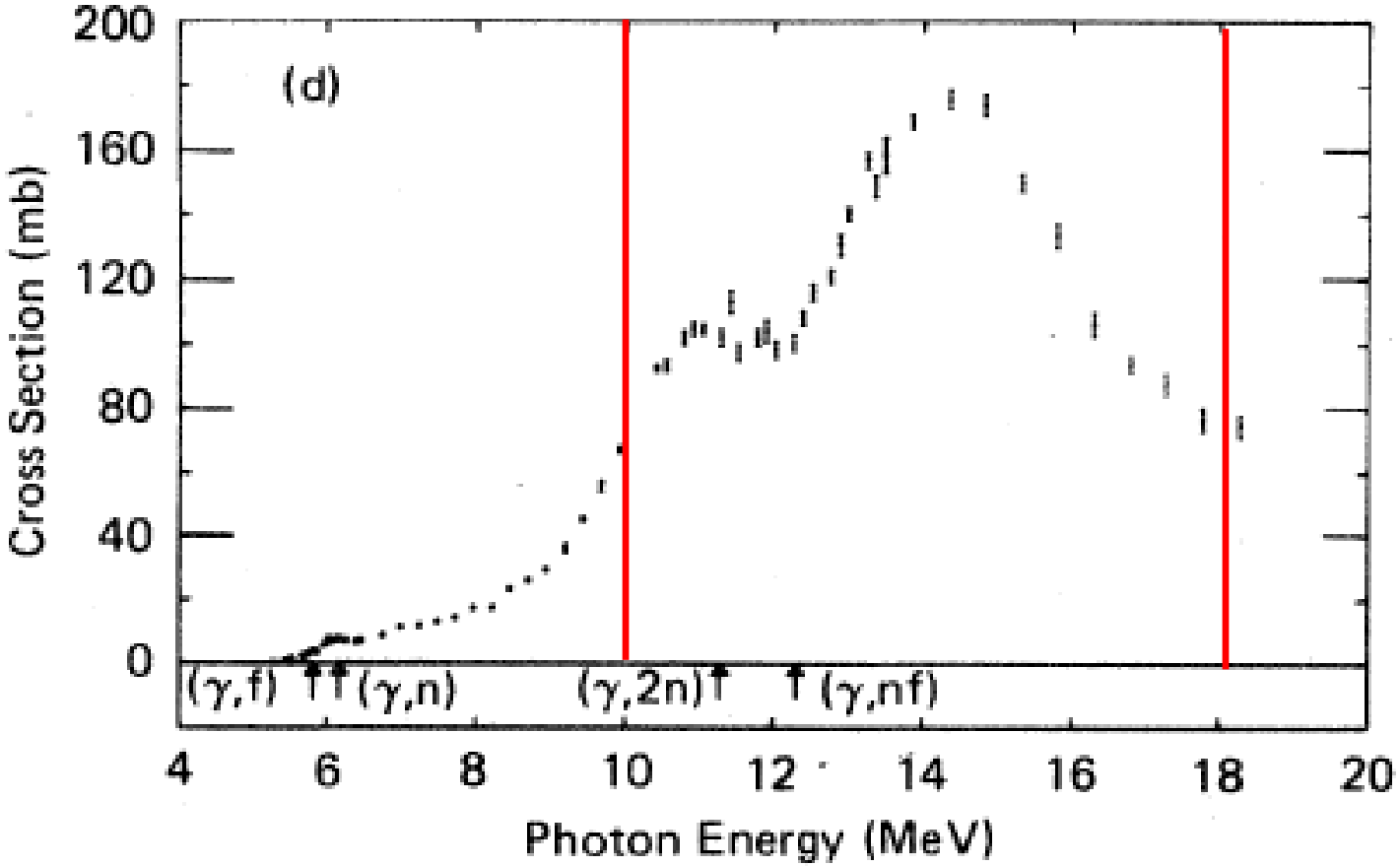


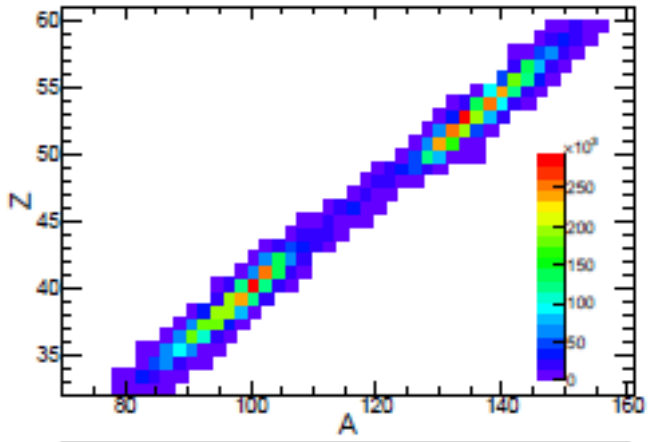
γ–beam spectrum at the IP (without collimator)

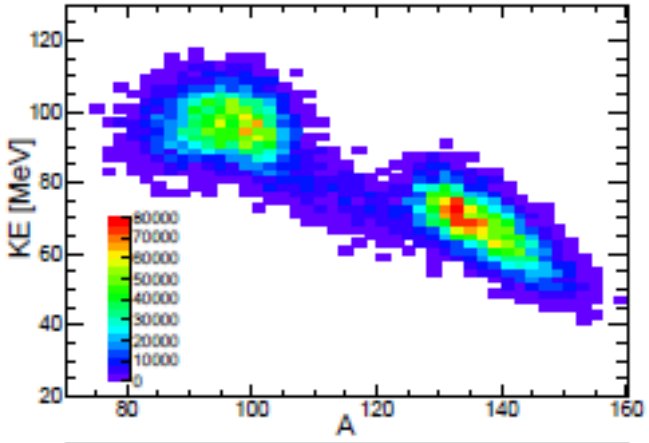
~ 10^{11} γ/s

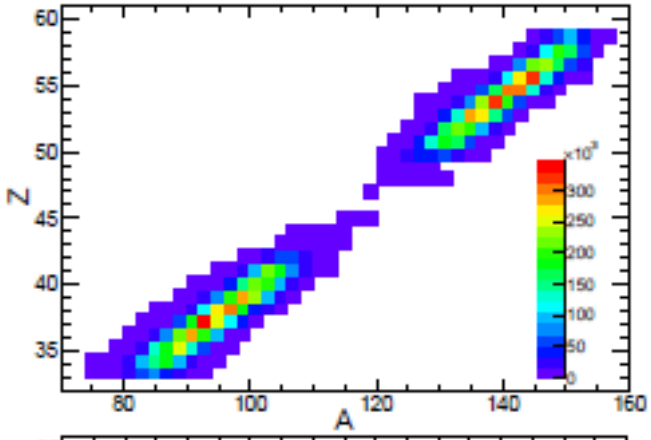
Photofission cross section for ^{238}U

Caldwell *et al.*, Phys. Rev. C **21** (1980) 1215




Z
A


KE [MeV]
A


Z
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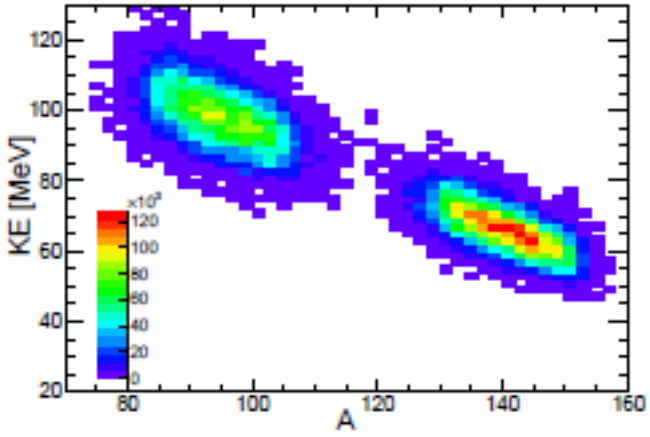
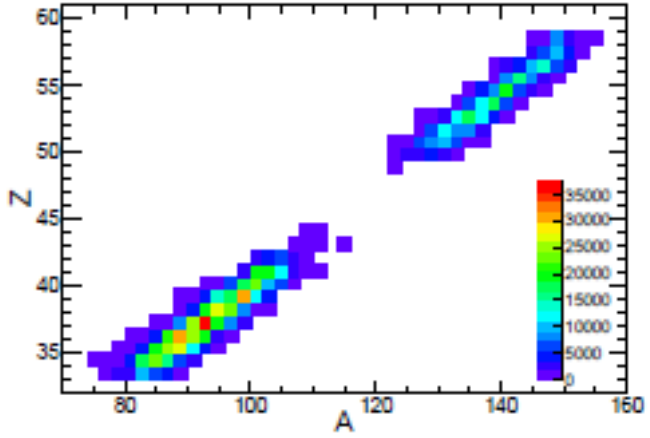

KE [MeV]
A


Z
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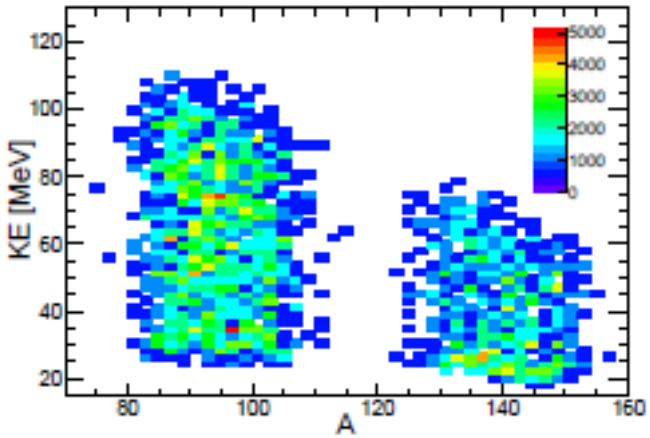

KE [MeV]
A

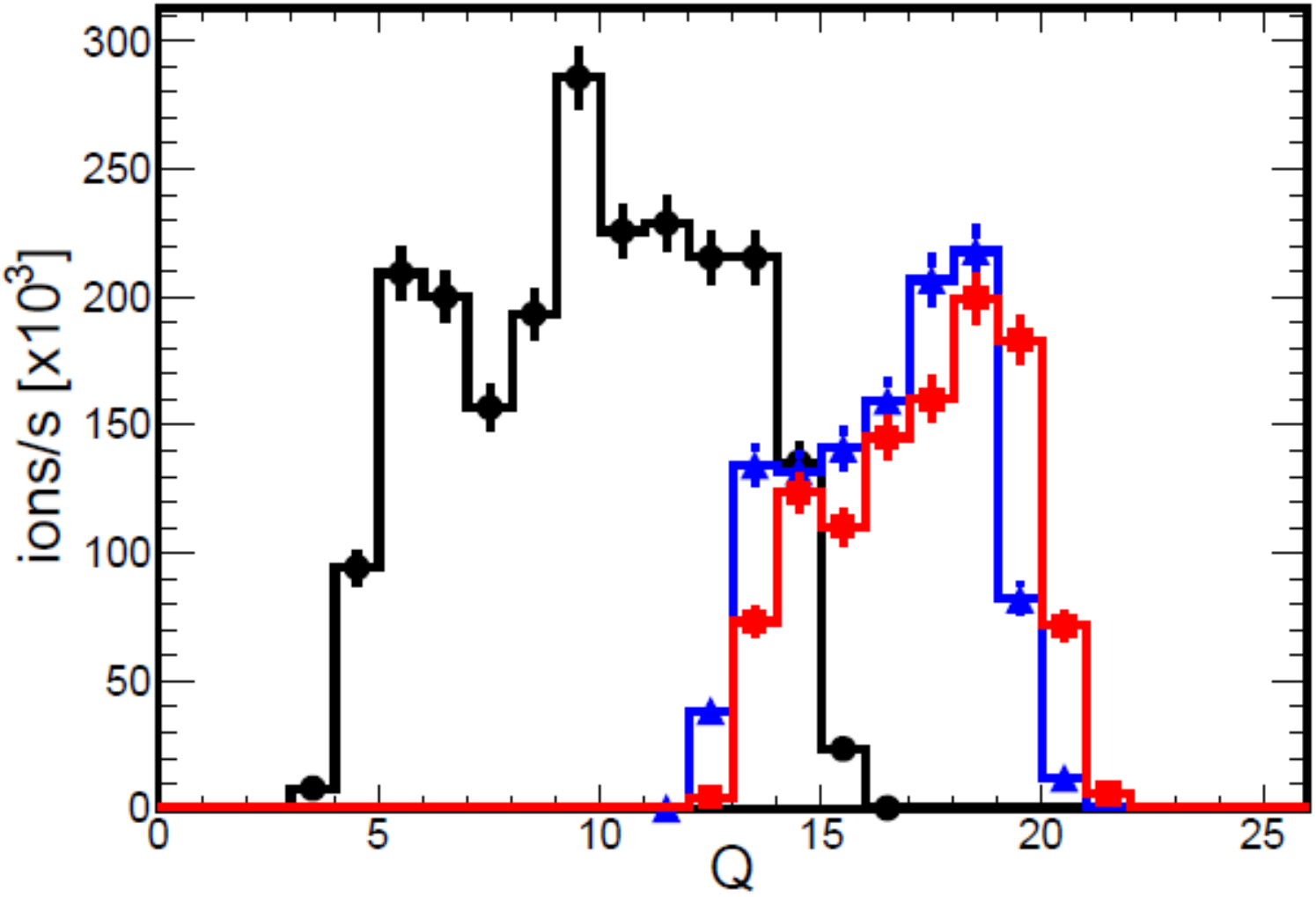


Figure 5: The dependence of fragment release rate from a 13 mg/cm^2 ^{238}U target on the ionic charge Q with Ziegler (black circles), Shima (blue triangles) and Schiwietz (red squares) parameterizations of the ionic charge state q.

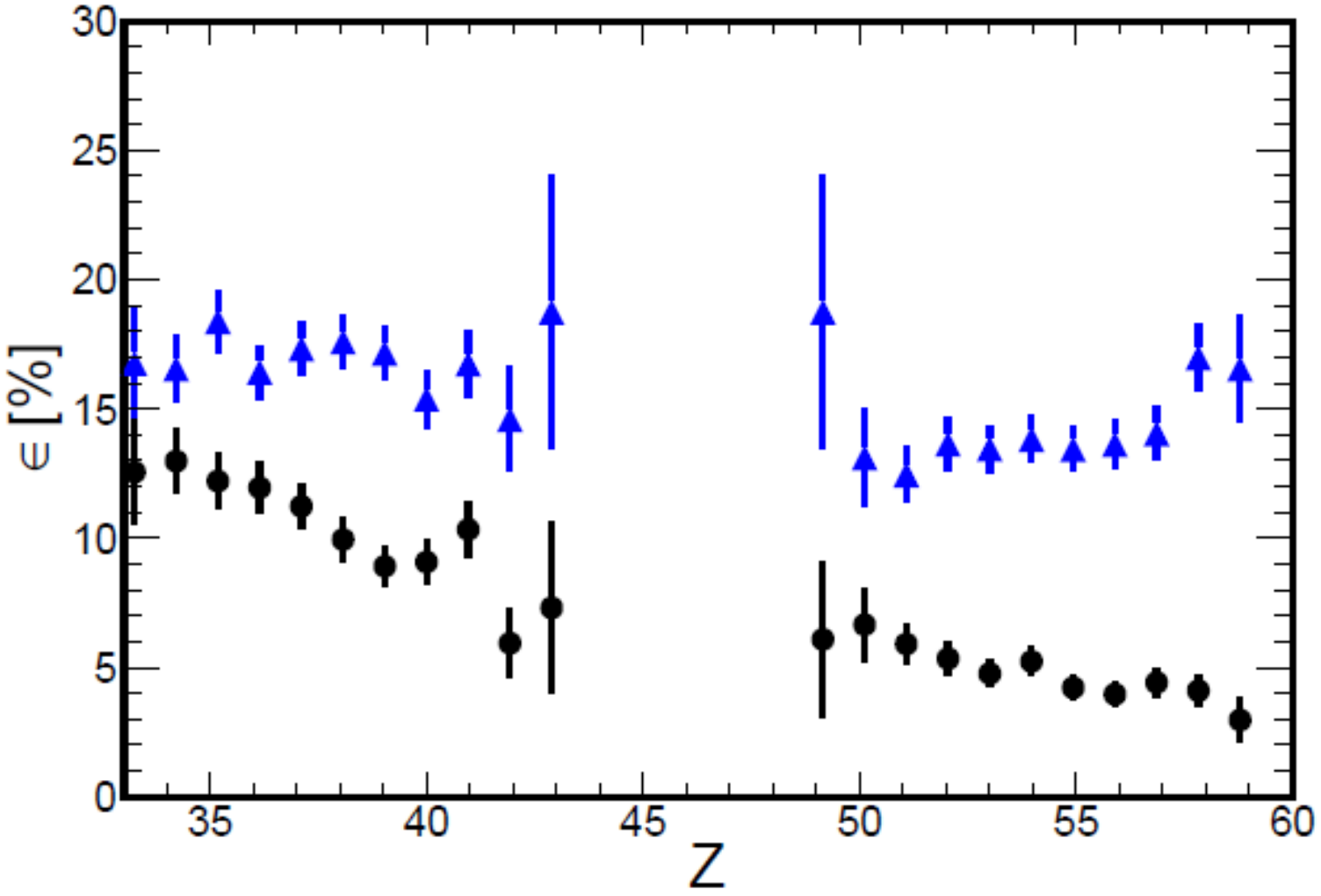


Figure 10: Single release efficiency versus nuclear charge Z with the Schiwietz parameterization (black circles) and with the Ziegler parameterization (blue triangles).

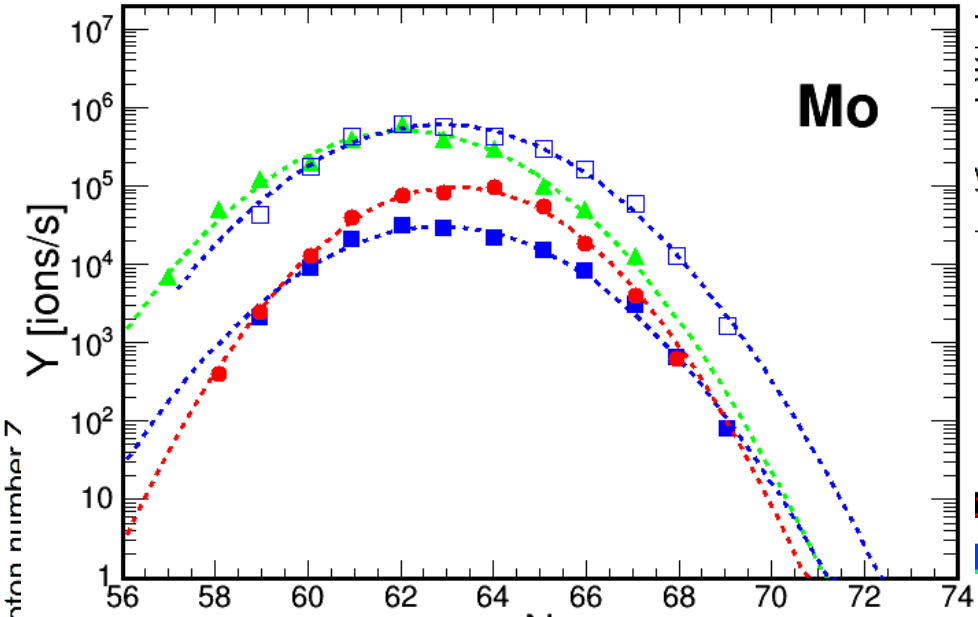
Target production

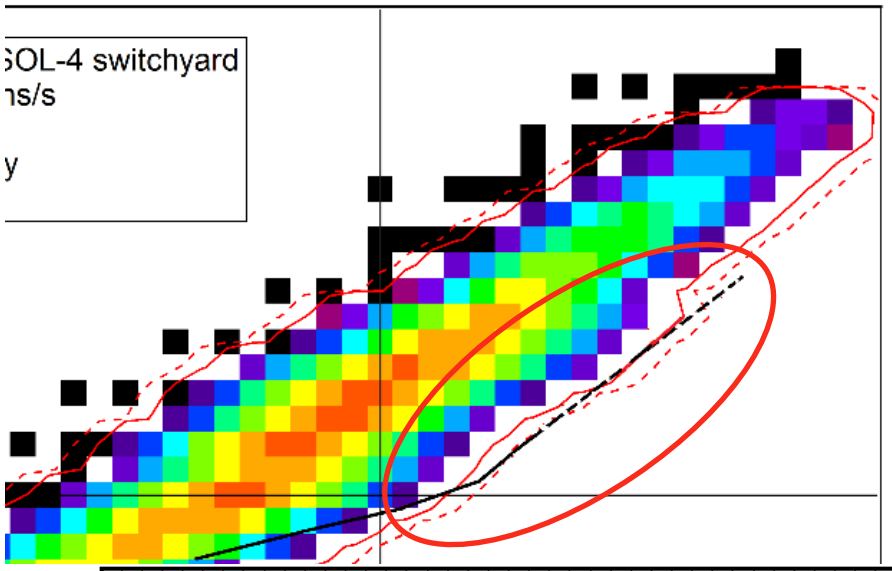
- 10^7 fissions/s in the CSC target;
- $6 \cdot 10^4$ fissions/s in the ELIADE target;
- $(0.3\text{-}2) \cdot 10^3$ fissions/s in the THGEM target ing on beam energy;
- 8 fissions/s in the BIC target.

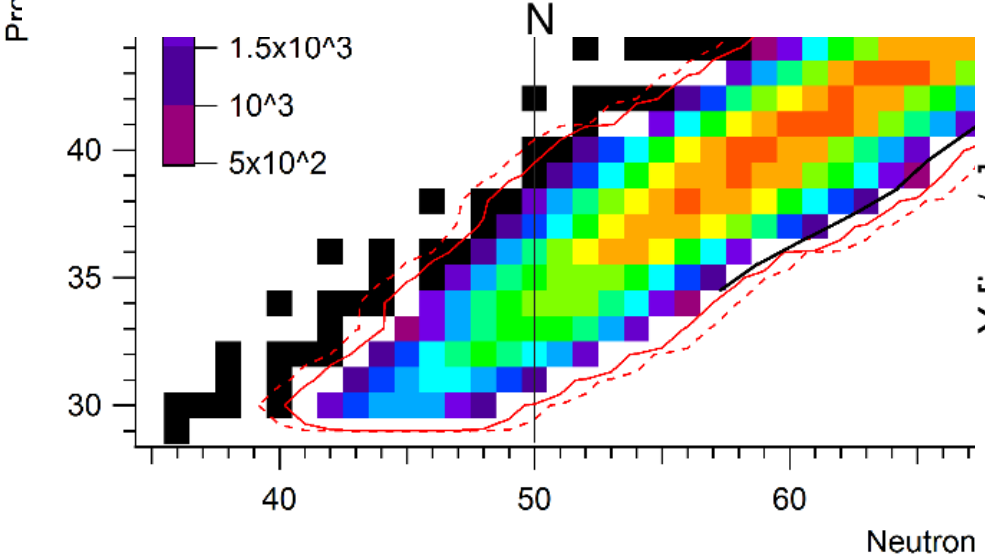
Fragment release

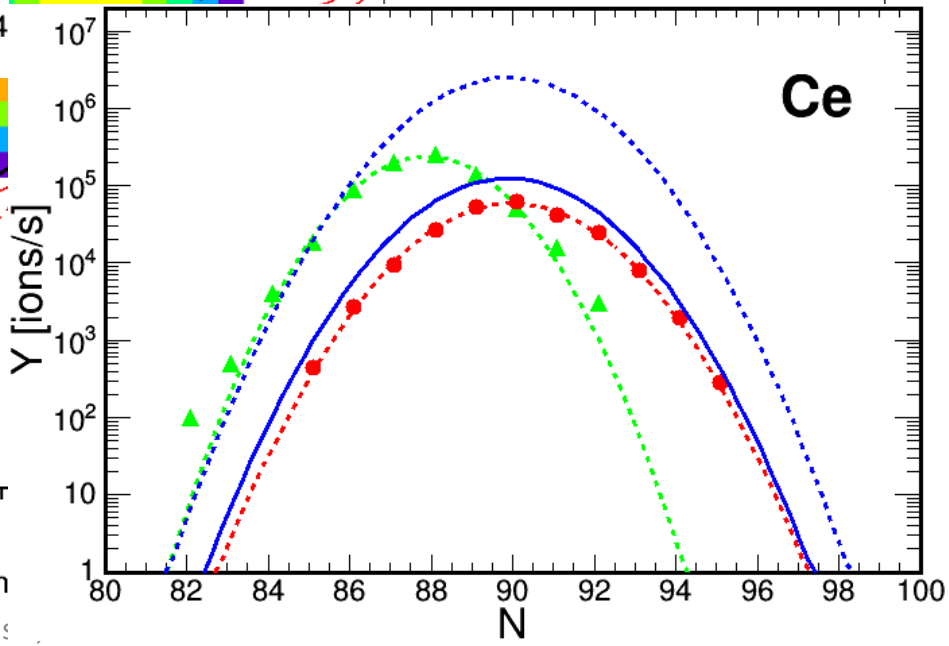
- $(0.6\text{-}2.2) \cdot 10^6$ fragments/s in the CSC;
- $(0.7\text{-}6) \cdot 10^4$ fragments/s in the ELIADE array;
- $(0.1\text{-}1.2) \cdot 10^3$ pairs/s in the THGEM array;
- 6-8 pairs/s in the BIC array.

Fragment Yields at the IGISOL-4 facility at JYFL







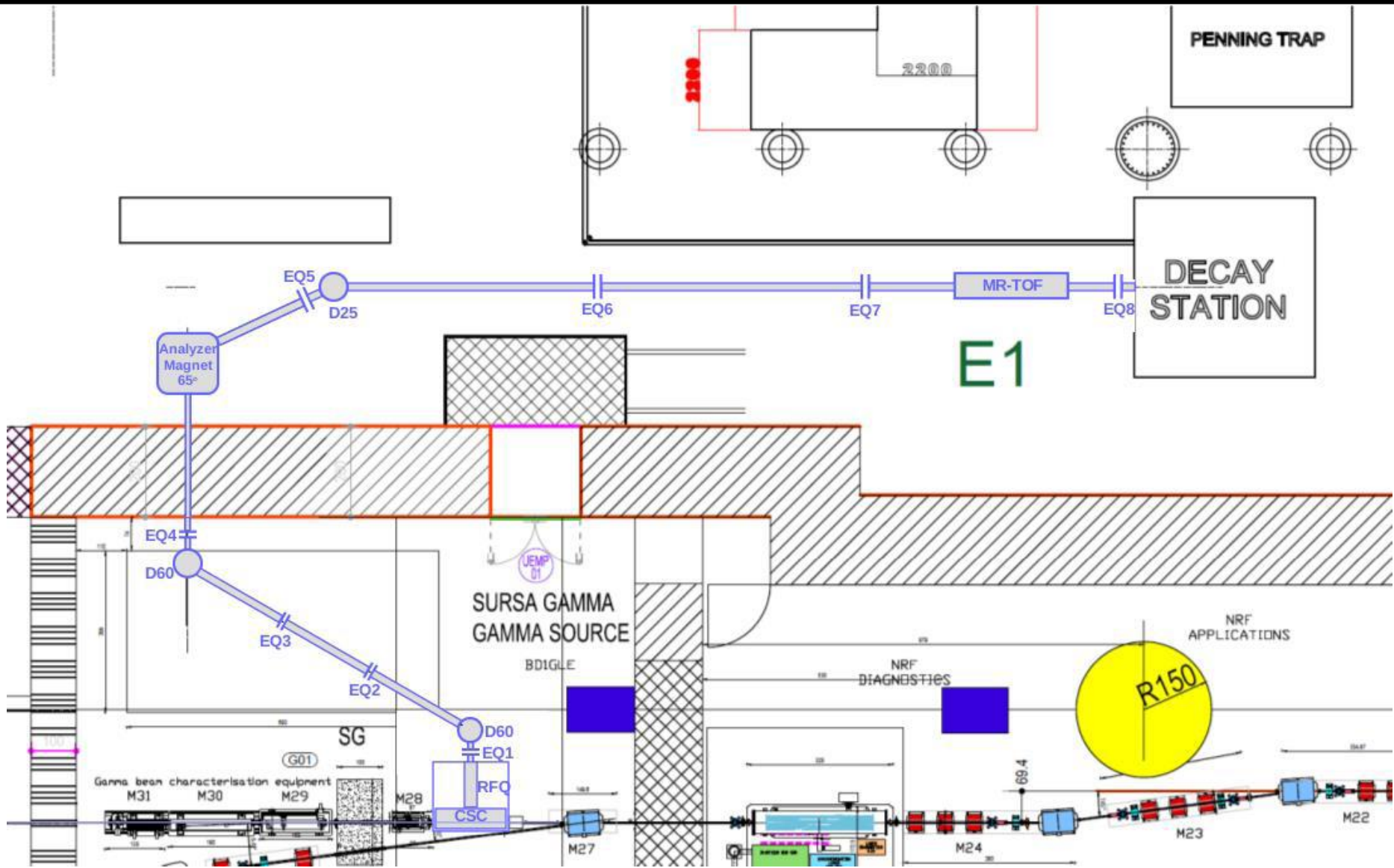


GBS TDR3 Photofission: IGISOL beam line

the conceptual design for the ELI-NP IGISOL facility is ready

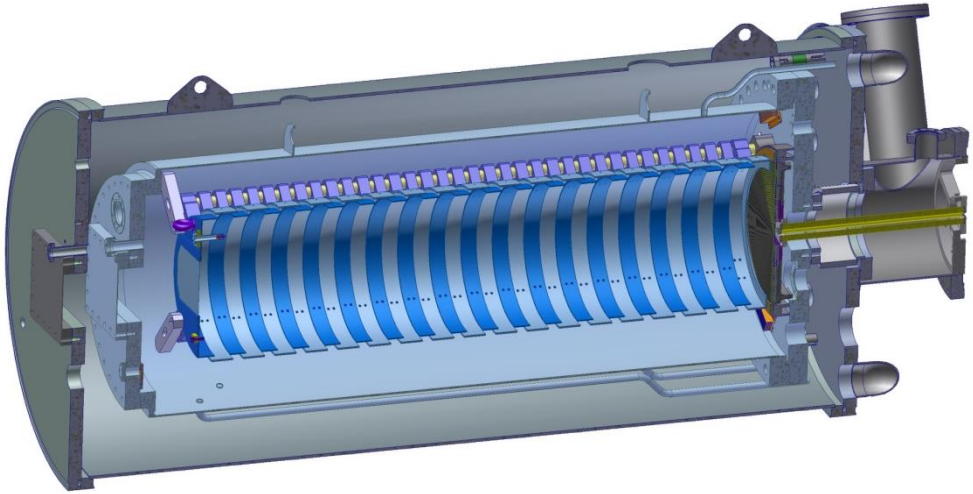
- Isotope production yields
- Gas cell geometry and gas-transport simulations
- RFQ beam cooling
- Laser Ion Source (not first priority)
- Multi-reflection time-of-flight trap (isobaric purification)
- Measurement stations (common with HPLS TDR1)
  - β decay experiments
  - mass measurements (precision MR-ToF)
  - charge radii and nuclear moment measurements

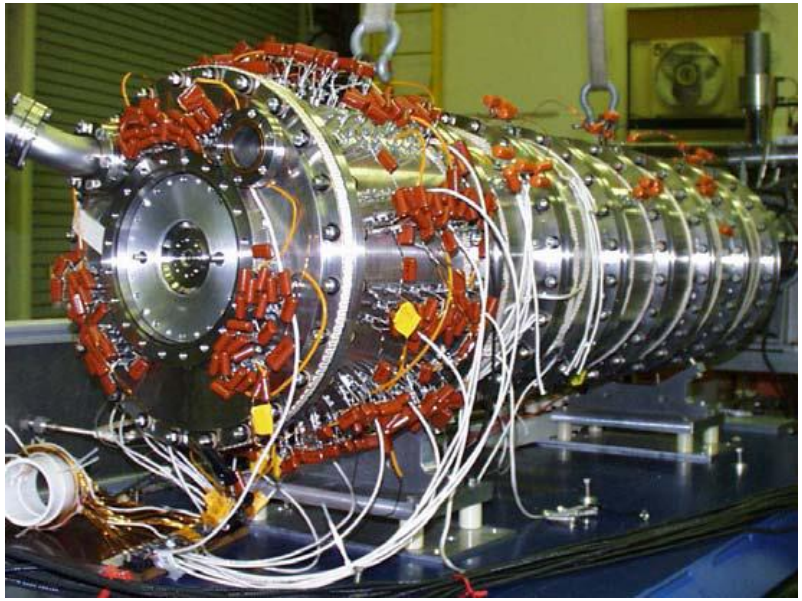
Location of the IGISOL gas catcher



State-of-the-art: Cryogenic Stopping Cell

25% efficiency, 25 ms extraction time

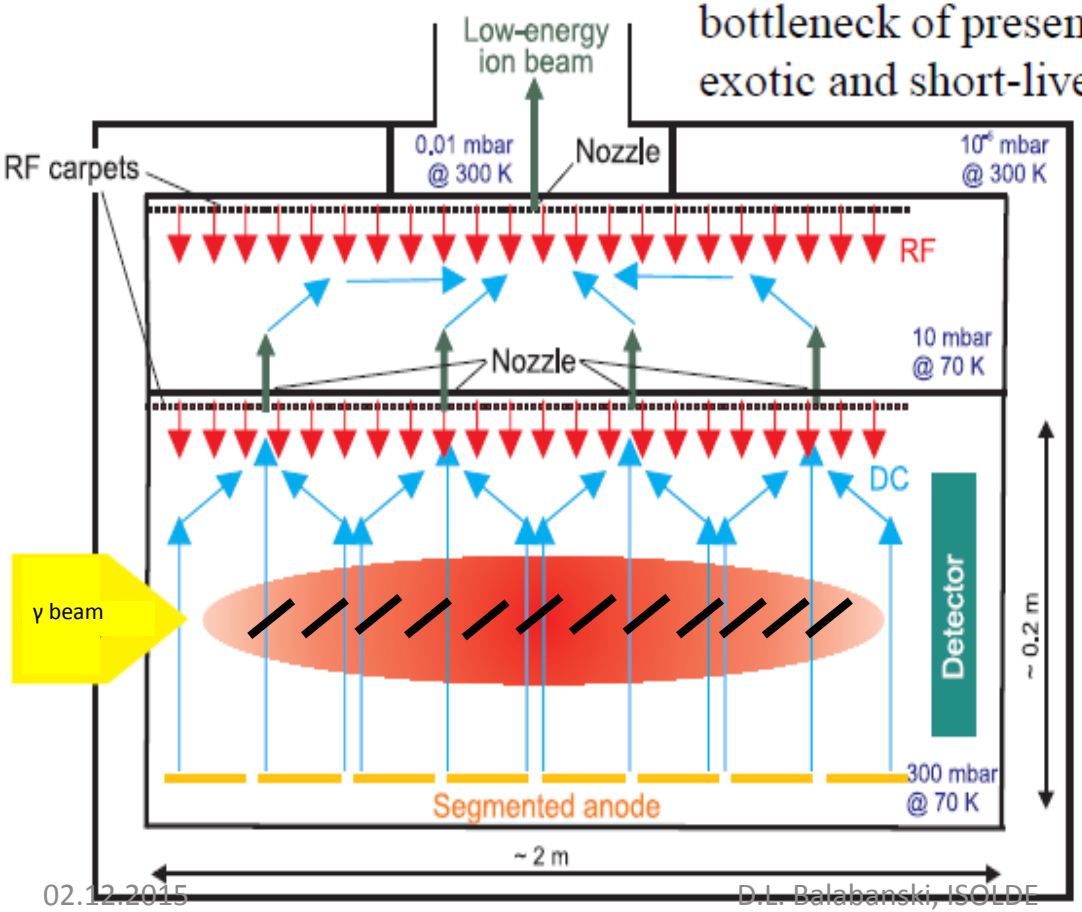




ELI-NP Cryogenic Stopping Cell

50% efficiency,
5 ms extraction time
at a rate of ~ 10^7 ions/s

nuclei. Ion survival and extraction effciencies of better than 50% are expected. The extraction time of the ions will be about 5 ms, shorted by a factor of 5 compared to the present CSC. The novel CSC will thus remove the performance bottleneck of present stopping cells and give access to very exotic and short-lived nuclei available at the Super-FRS.



technical design
at GSI, Darmstadt

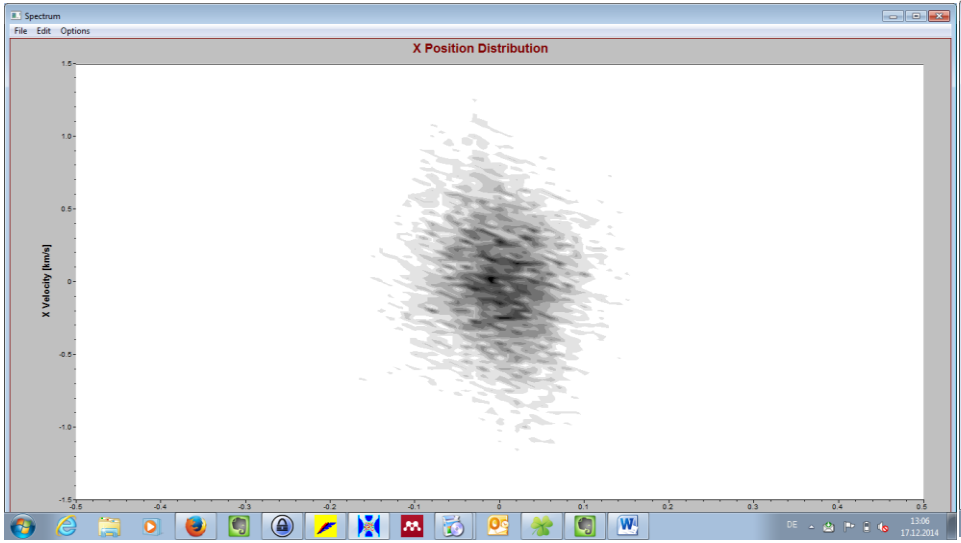
He gas @ 70 K
pressure 300 mb and 10 mb
> 100 V/sm DC field
RF carpet

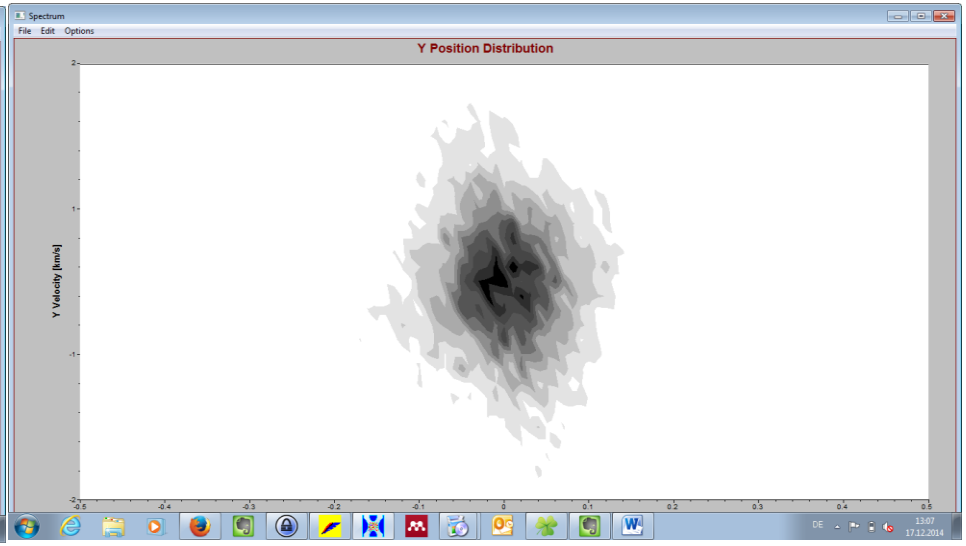
GBS TDR3 Photofission: RFQ Ion cooler

efficiency ≈ 90%

- modular and compact (≈ 1m long);
- beam cooling (20 cm, $3 \cdot 10^{-2}$ mbar);
- mass separation (40 cm, 10^{-4} mbar); and
- bunching (46 cm, $5 \cdot 10^{-3}$ mbar).

exists at GSI, Darmstadt

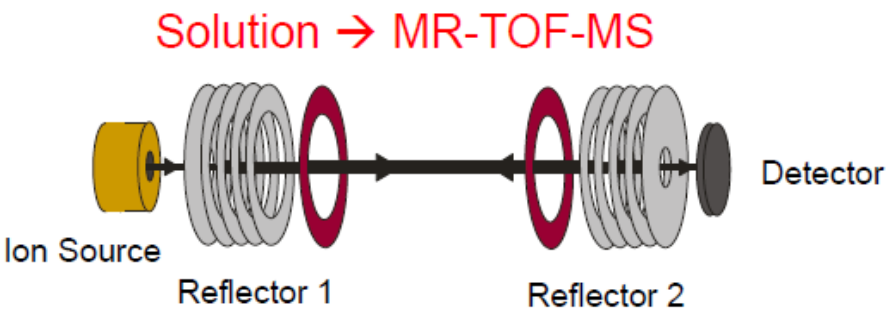


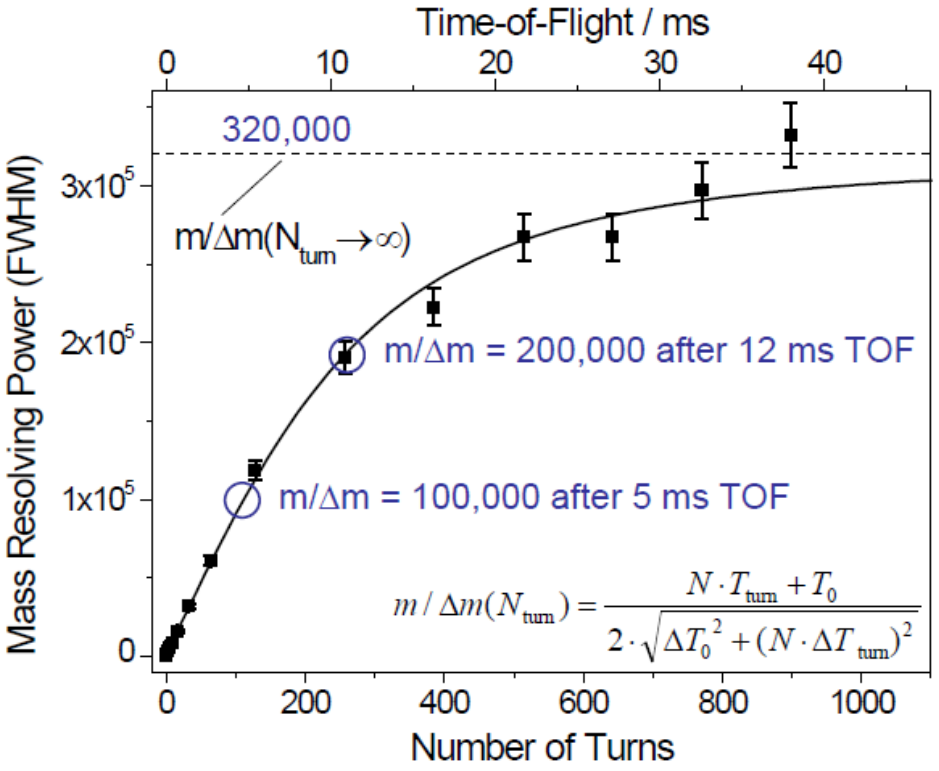


σ_x = 0.65 mm and and σ_{vx} = 0.47 km/s σ_y = 0.069 mm and σ_{vy} = 0.50 km/s.

ELI-NP IGISOL MR-ToF trap

isobaric purification





T. Dickel, PhD Thesis, Univ. Giessen, 2010

- **fast**
- **sensitive (single ions)**
- **broadband/non-scanning**
- **10^{-4} mass resolution**

made and used
at GSI, Darmstadt

H. Wollnik et al., Int. J. Mass Spectrom Ion Proc. 96, 267 (1990)

ELI-NP IGISOL facility: Budget

Total	2350 k€
Vacuum chambers	350 k€
Lifting table	45 k€
RF-Carpets	35 k€
Power supplies	40 k€
Ion Optics/Electrode system	30 k€
Gas regulation and Cleaning System	40 k€
Vacuum Measurment and Corntrol	15 k€
Offline Ion Sources	40 k€
Helium Recovery Unit	150 k€
Pumping for CSC and Extration RFQ	50 k€
Cryostat	750 k€
RFQ-Beamline	
Ion Optics	30 k€
Electronics/Power supplies	50 k€
Vacuum	80 k€
Pumps	30 k€
Detectors and Ion Sources	15 k€
MR-ToF-MS	500 k€
Miscellaeous	
Remote Contraol Hardware	15 k€
Data-aquisition	35 k€
Software Developments	50 k€

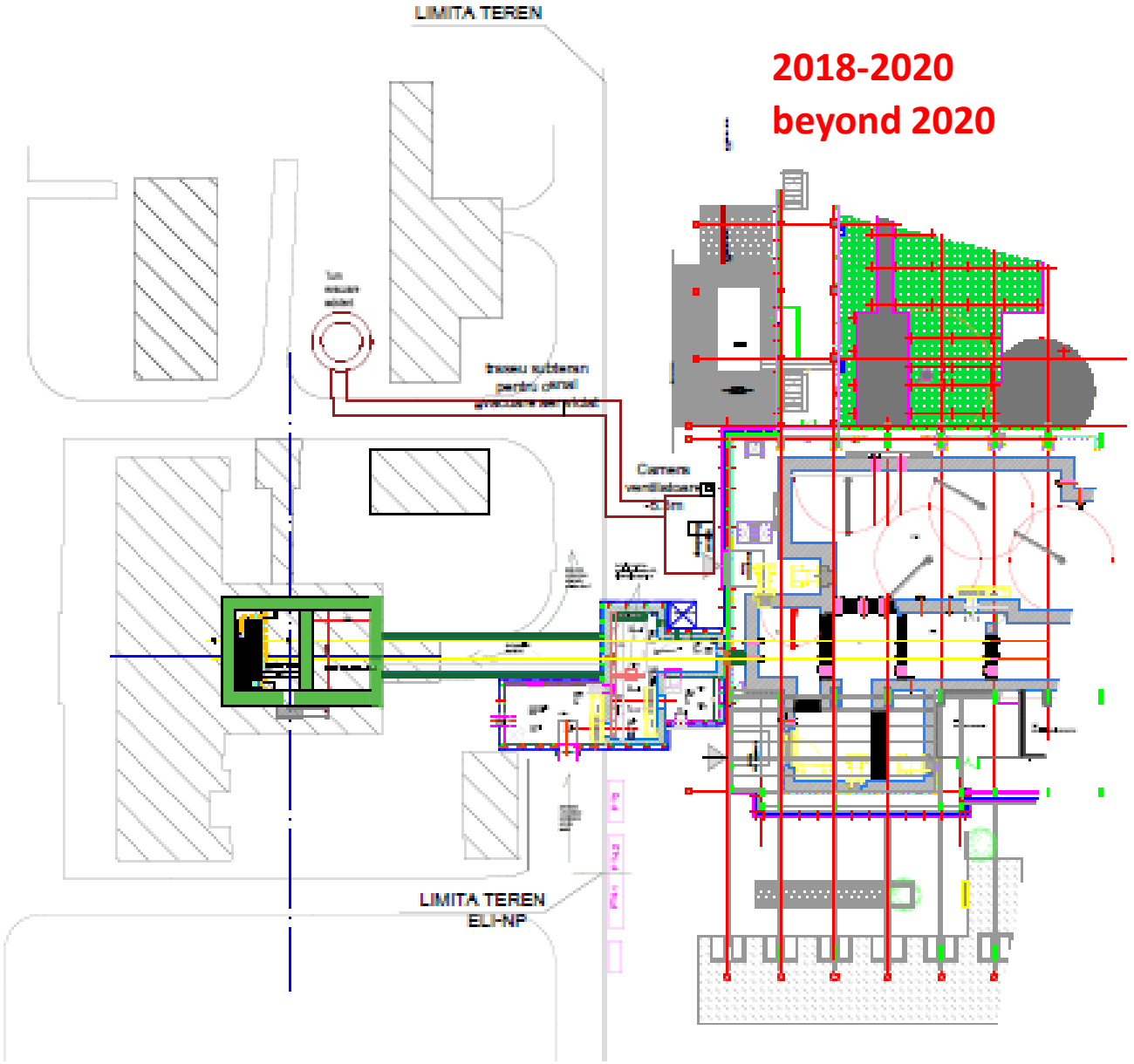
ISAB recommendation, June 2015

GBS TDR3 – Photofission: **IGISOL setup prototype section/cell should be pursued**

Total CSC, RFQ, MR-ToF: 2 350 k€

CSC and cryostat: 1 545k€
RFQ beam line 205k€
MR-ToF 500k€
Miscellaneous 100k€

Next phases of ELI-NP



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Extreme Light Infrastructure - Nuclear Physics (ELI-NP) - Phase I

eli Nuclear Physics

www.eli-np.ro

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Thank you!