



**SORBONNE  
UNIVERSITÉ**

CRÉATEURS DE FUTURS  
DEPUIS 1257



# FISIC

– Atomic Physics of Fast Ion-Slow Ion Collisions –



Physics

FISIC

# Fit-FISIC

Atomic Physics of Fast Ion-Slow Ion Collisions



CiMap

GSI

GANIL  
SPIRAL2

E. Lamour  
D. Schury  
A. Levy  
S. Macé  
C. Prigent  
J.-P. Rozet  
S. Steydli  
M. Trassinelli  
D. Vernhet

J. Rangama  
L. Adoui  
J.Y. Chesnel  
A. Méry  
P. Rousseau  
J.-M. Ramillon



L. Panitzsch



A. Dubois  
J. Caillat

A. Gumberidze  
A. Bräuning-Demian  
H. Bräuning  
S. Hagmann  
U. Spillmann  
N. Tahir  
Th. Stoehlker  
C. Hahn  
T. Köhler  
G. Weber  
C. Trautmann  
M. Bender  
D. Severin



M. Authier  
A. Drouart  
O. Cloue

R. Levallois  
L. Maunoury  
H. Savajols  
F. Lutton  
C. Stodel

JUSTUS-LIEBIG-



UNIVERSITÄT  
GIESSEN

C. Brandau  
A. Müller  
S. Schippers

O. Fojon, J.M. Monti, R. Rivarola, C. Stia, C. Tachino  
S. Otranto  
R. Barrachina, F. Colavecchia, D. Fegenal  
C. Champion

S. Fritzsche  
C. Lemell  
K. Tokesi

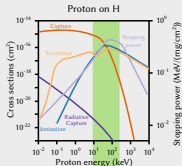
# Main Goals

FISIC → Fast Ion-Slow Ion Collisions

The Fit-FISIC project[s] ultimate goal is to control the experimental conditions and to span from a **pure three-body problem** (collision between a bare ion and a hydrogenic target) to a collision system between **dressed partners** (study of the effect of a **controlled number of additional electrons**, such as electronic correlations)



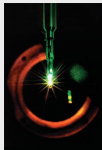
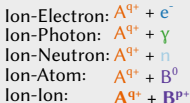
- absolute electronic cross sections for ion-ion collisions
- $K_p = \frac{v_e}{v_p} \times \frac{Z_t}{Z_e} \approx 1$
- $\sigma_{\text{capt,ion,exc}}$  not well known  
stopping power maximum



$K \gg 1$  non-perturbative      $K \approx 1$       $K \ll 1$  perturbative

# Motivation

## → Fundamental Collision Processes

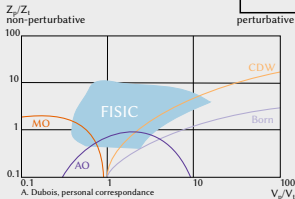
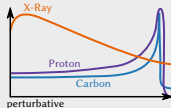
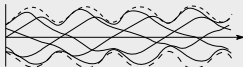


- Plasmas
  - astrophysical
  - fusion

- Intra-beam scattering

- Ion-Matter interaction
  - material damages

- Theory Benchmark



# Ion-Ion Collisions

Target ionization:  $A^{q+} + B^{p+} \rightarrow A^{q+} + B^{(p+1)+} + e^{-}$

Projectile ionization:  $A^{q+} + B^{p+} \rightarrow A^{(q+1)+} + B^{p+} + e^{-}$

Charge transfer:  $A^{q+} + B^{p+} \rightarrow A^{(q-1)+} + B^{(p-1)+}$

Charge transfer:  $A^{q+} + B^{p+} \rightarrow A^{(q+1)+} + B^{(p-1)+}$

Excitation:  $A^{q+} + B^{p+} \rightarrow A^{q+(*)} + B^{p+} \rightarrow A^{q+} + B^{p+} + \gamma$

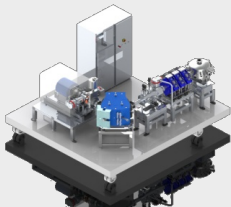
$$\sigma = \frac{R}{\epsilon_1 \epsilon_2} \frac{q_1 q_2}{I_1 I_2} \frac{v_1 v_2 \sin\beta}{V_{rel}} F$$

cross section

2 ion beams

collision volume

# LEB



Charge State Purification

Primary Beam  
Sgl. Capture  
Dbl. Capture

Beam Transport

Product  
Analyser

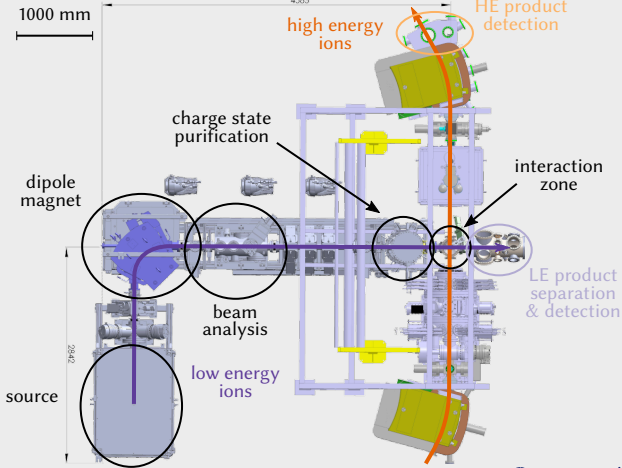
High Energy  
Beam

Primary  
Sgl. Capture  
Dbl. Capture  
Sgl. Ionization  
Dbl. Ionization

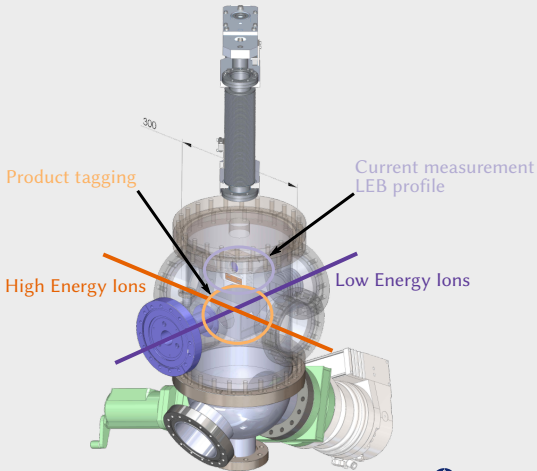
Product  
Detection

# FISIC at CRYRING@ESR

4585



# Interaction Zone



# Rates

$$R \propto \frac{\sigma I_1 I_2}{q_1 q_2}$$

$$I_1 = 50 \mu\text{A}_e \quad p1 = p2 = 1\text{e-}11 \text{ mbar} \quad \tau_{\text{coin}} = 2 \text{ ns}$$

HE	$\sigma_{\text{capt}} (\text{cm}^2)$	LE	$I_2 (\mu\text{A}_e)$	$\sigma_{\text{ion}} (\text{cm}^2)$	$R_{\text{capt}} (\text{s}^{-1})$	$R_{\text{ion}} (\text{s}^{-1})$	BG ( $\text{s}^{-1}$ )	BG ( $\text{s}^{-1}$ )	rd. coinc.
Ar <sup>18+</sup>	4.5e-18	Ar <sup>4+</sup>	5	8e-16	42	7.4e3	4.8e3	2	7
Ar <sup>18+</sup>	4.5e-18	Ar <sup>8+</sup>	20	1.8e-16	66	2.6e3	4.8e3	0.04	2.5
Ar <sup>18+</sup>	3.5e-18	Ar <sup>12+</sup>	15	4.7e-17	30	400	4.8e3	0.002	0.4
Ar <sup>18+</sup>	1.6e-18	Ar <sup>16+</sup>	0.1	1.5e-16	0.2	0.2	4.8e3	1e-11	1.7e-4
Ar <sup>14+</sup>	1.5e-18	Ar <sup>4+</sup>	5	8e-16	18	9.5e3	2.3e3	2	4.3

# Summary

FISIC is

- an international
  - crossed-beam
  - ion-ion collision
- experiment

FISIC will

- measure absolute electronic cross sections
- benchmark current theories

FISIC has

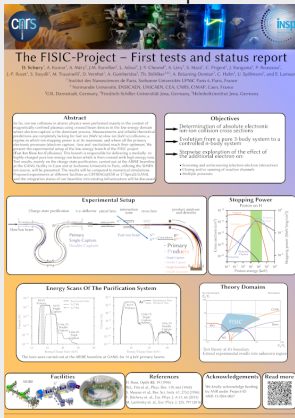
- a working low energy beam line
- a broad acceptance in-line charge state purifier

FISIC needs

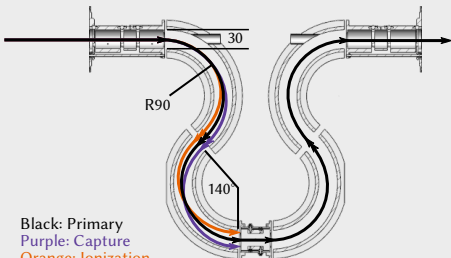
- the high energy beam line integration chamber
- product detectors

# Thank you!

## Come visit our poster!

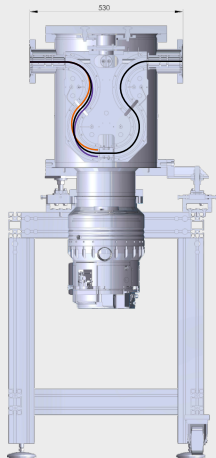


# Omega Purifier

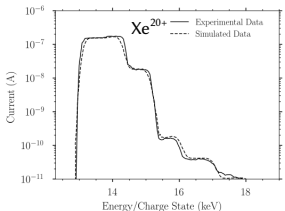
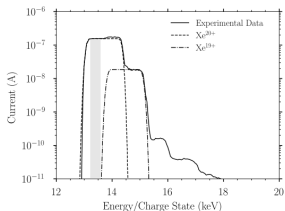
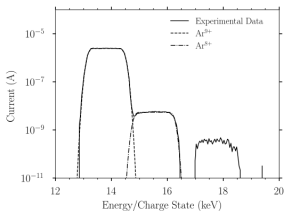
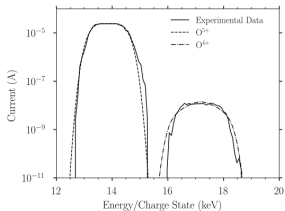


Black: Primary  
Purple: Capture  
Orange: Ionization

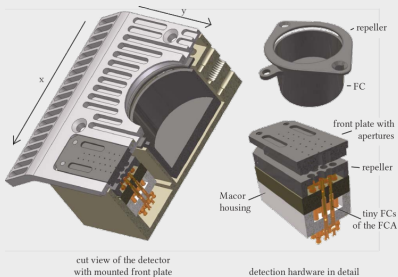
- single lens at entry and exit
- vertical steerer in mirror axis
- focussing in vertical plane
- enclosed Matsuda plates for horizontal focussing
- designed for high emittance beam transport ( $60 \pi$  mm mrad)



# Purifier Scans



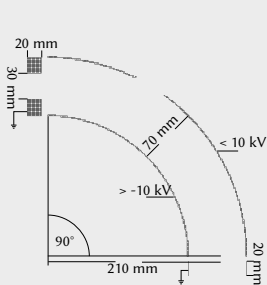
# Faraday Cup



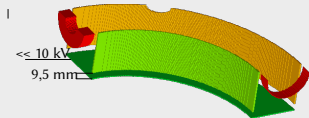
- 58 dpi x 51 dpi resolution<sub>2</sub>
- 200 nA/cm<sup>2</sup> to 20 mA/cm<sup>2</sup>
- max. 40 W
- scan time ~45 s
- 50 pA to 50 μA dynamic range
- durable
- UHV compatible
  
- 44 tFC (four rows)
- scan area 45 mm x 30 mm
- 0.3 mm tFC
- 22.8 mm FC

Panitzsch et al., Direct high-resolution ion beam-profile imaging using a position-sensitive Faraday cup a

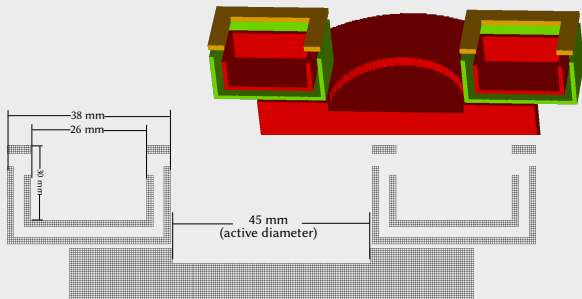
# Product Separation



- Reasonable Separation Power
- Not too big
- No strange angles -> simple
- Few electrodes -> simple
- Few voltages -> simple
- Double-focussing



# Low Energy Detector



- Simple shielded faraday cup with repeller electrode
- Standard Roentdek DLD40 MCP 2D detector
- FC and MCP detector fixed with respect to each other on one manipulator
- Two FCs -> capture or ionisation can be measured without changing anything
- ~125 mm between end of analyser and MCP surface
- Bigger or rectangular MCP (~ 50 to 60 mm) for single AND double reaction products
- Careful tuning may enable DLD40 as well