Particularities in the use of electron-ion coliiders like ELISe

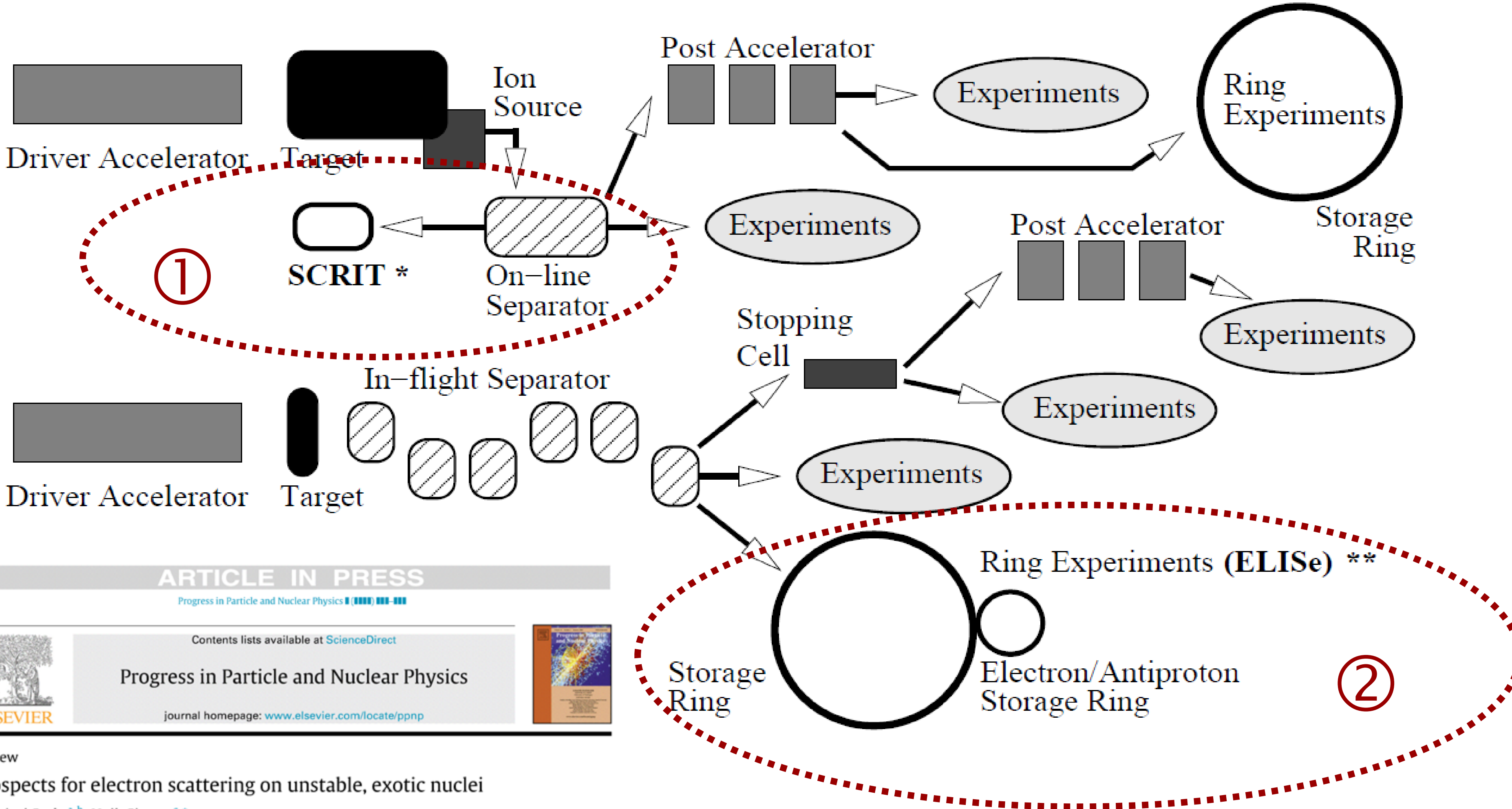
Probing exotic structure of short-lived nuclei by electron scattering

Trento, July 16-20, 2018

HELMHOLTZ GEMEINSCHAFT

H. Simon • GSI Darmstadt

Main use cases SCRIT vs. eA collider



ARTICLE IN PRESS

Progress in Particle and Nuclear Physics ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp

ELSEVIER

Review

Prospects for electron scattering on unstable, exotic nuclei

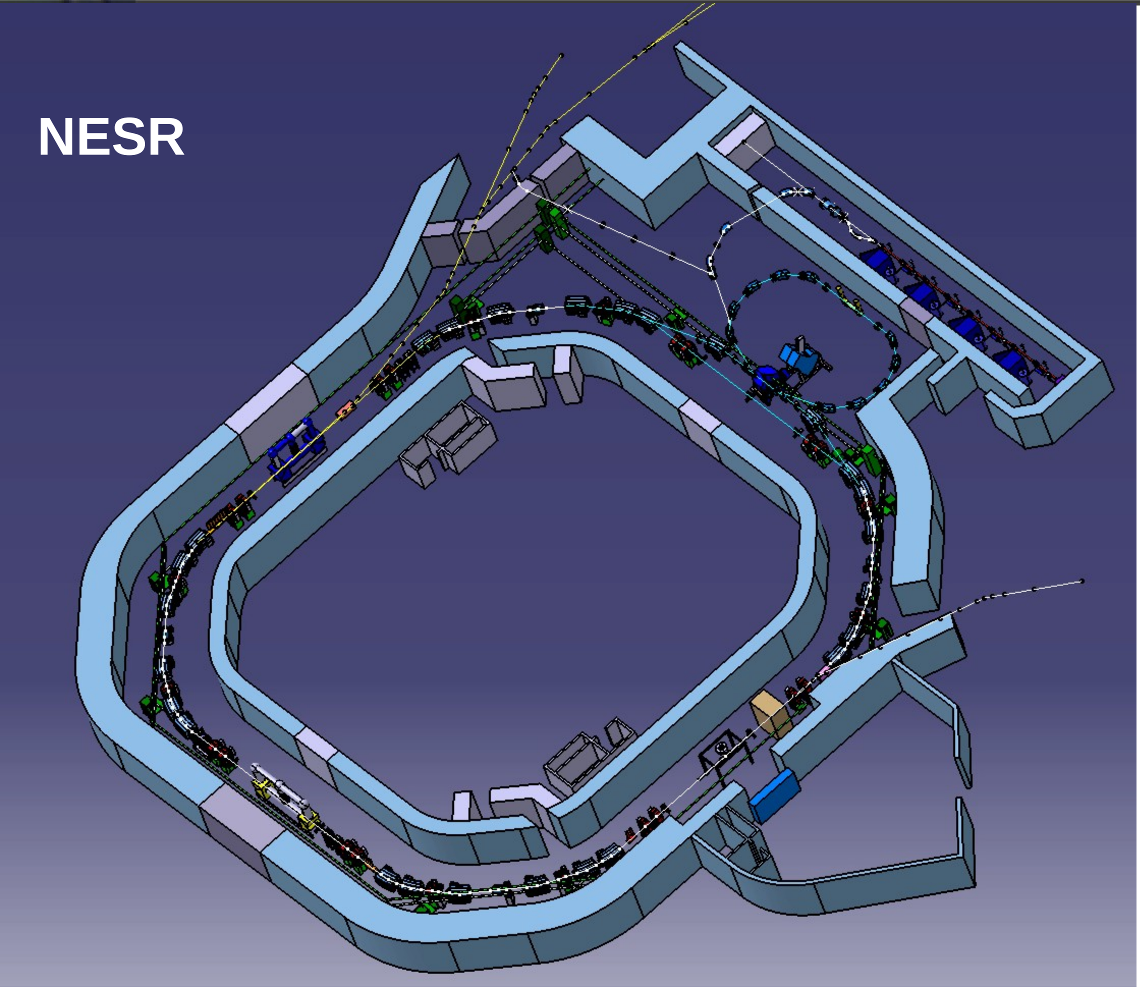
Toshimi Suda [a,b], Haik Simon [c,*]

[a] Research Centre for Electron Photon Science, Tohoku University, 1-2-1 Mikamine, Sendai 982-0826, Japan

[b] RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

[c] GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Realization of an RIB electron collider setup
The ELISe experiment



- 125-500 MeV electrons
- 200-740 MeV/u RIBs

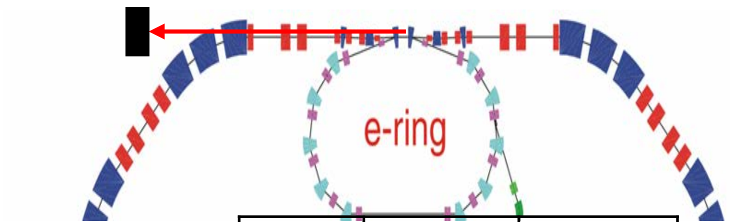
➔ up to 1.6 GeV CM energy

- Original plans K4-K10 Dubna (1992)
Footnote: „We anticipate a possibility to extend in future the K4-K10 complex by installing over the K10 ring a 0.5-1.0 GeV electron storage ring. The very long straight section of the K10 ring will be suitable for arranging electron-ion collisions. This would add a new important dimension to the K4-K10 complex"

AIC option:
- 30 MeV antiprotons

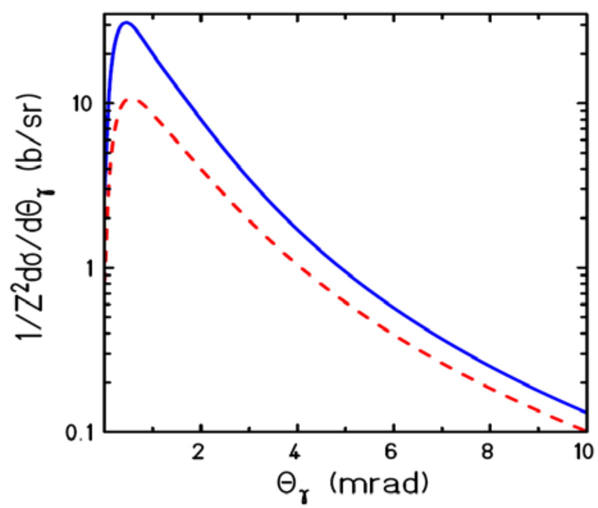
Luminosity Monitor via photons: Concept

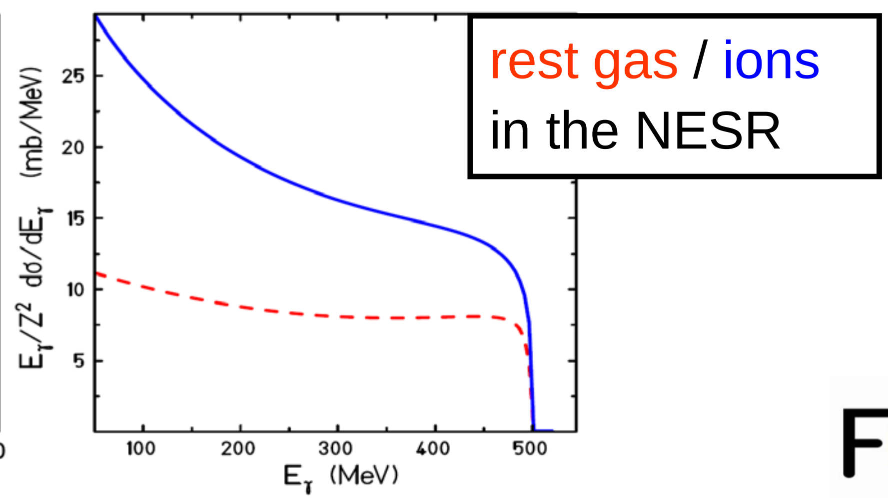
position sensitive
[redacted]-detector



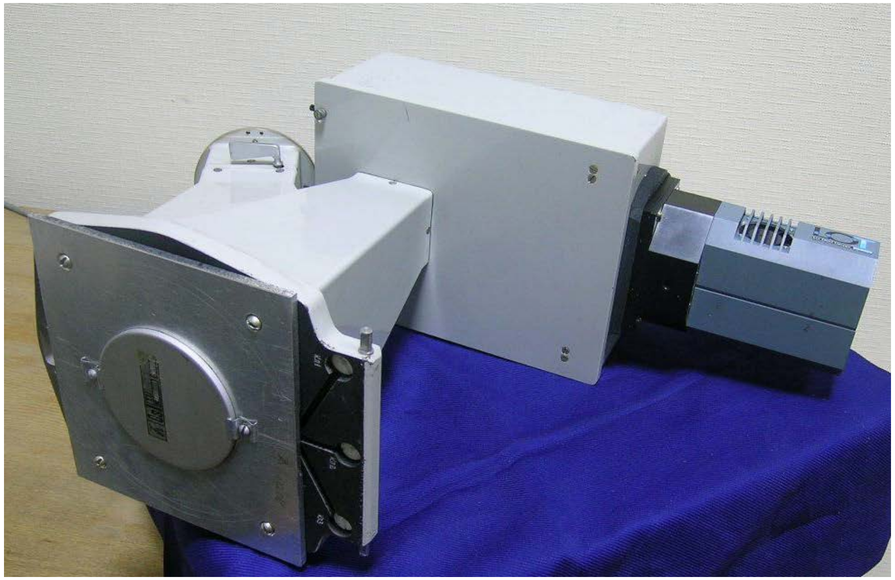
	Ni	Sn	U
σ_{brems} [*barn*] (100-500 MeV)	21	67	227

	Luminosity [$cm^{-2}s^{-1}$]	Effect, [*kHz*]	Background [*kHz*]
$^{238}U^{92+}$	1.0×10^{28}	6800	0.1-20
$^{56}Ni^{28+}$	3.3×10^{28}	2100	Depending on achievable vacuum Conditions <~10^{-9} mbar
$^{69}Ni^{28+}$	2.4×10^{28}	1500	
$^{71}Ni^{28+}$	4.5×10^{26}	29	
$^{104}Sn^{50+}$	9.9×10^{26}	200	
$^{132}Sn^{50+}$	1.8×10^{28}	3800	
$^{133}Sn^{50+}$	4.5×10^{26}	90	



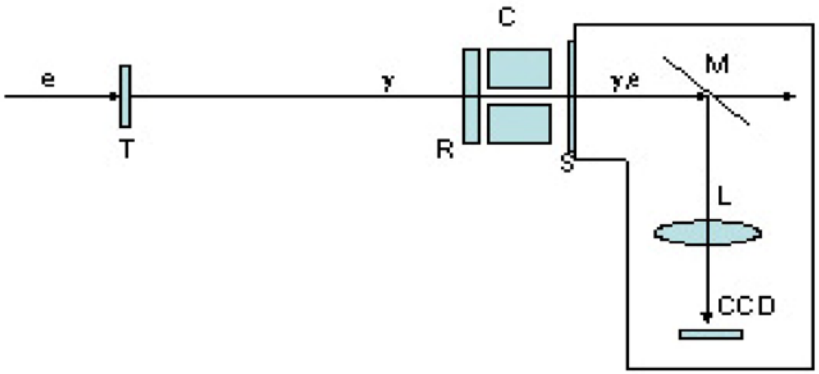


Luminosity monitor: technical realisation/prototypes/simulations



calorimetry
KI Moscow

V. Volkov (GEANT 4 simulations)
Showers created in a stack of 3 × 3 $PbWO_4$ crystals by 300 MeV gammas



gamma imaging:
INR-RAS Moscow

Selected isotopes…

Element	$T_{1/2}$ (s)	τ (s)	N	L (cm^{-2} s^{-1})
^{11}Be	13.8	35.6	8.3×10^{9}	2.4×10^{29}
^{35}Ar	1.75	4.5	5.9×10^{7}	1.7×10^{27}
^{55}Ni	0.21	0.5	2.0×10^{7}	4.0×10^{27}
^{71}Ni	2.56	6.5	3.8×10^{7}	1.1×10^{27}
^{93}Kr	1.29	3.3	6.2×10^{6}	1.8×10^{28}
^{132}Sn	39.7	68.2	6.5×10^{8}	1.9×10^{28}
^{133}Sn	1.4	3.5	6.9×10^{6}	2.0×10^{26}
^{224}Fr	199	59.2	3.0×10^{8}	8.6×10^{27}
^{238}U	10^{17}	60	3.4×10^{8}	1.0×10^{28}

Impact on feasability close to summary!

Obtainable rate at collider different from fixed target

→ Cross section & detection efficiency

Fixed target vs. colliding beams …

- trying to get through the eye of the needle

• Target and scattered off particles can be detected

➔ excitation and deexcitation process is studied

• kinematical focusing

➔ solid angle

➔ Mott cross section enhanced (small angles)

• luminosity for unstable nuclei (no target)

➔ 100µm x 100µm interaction area

vs e.g. dilute ions in a trap

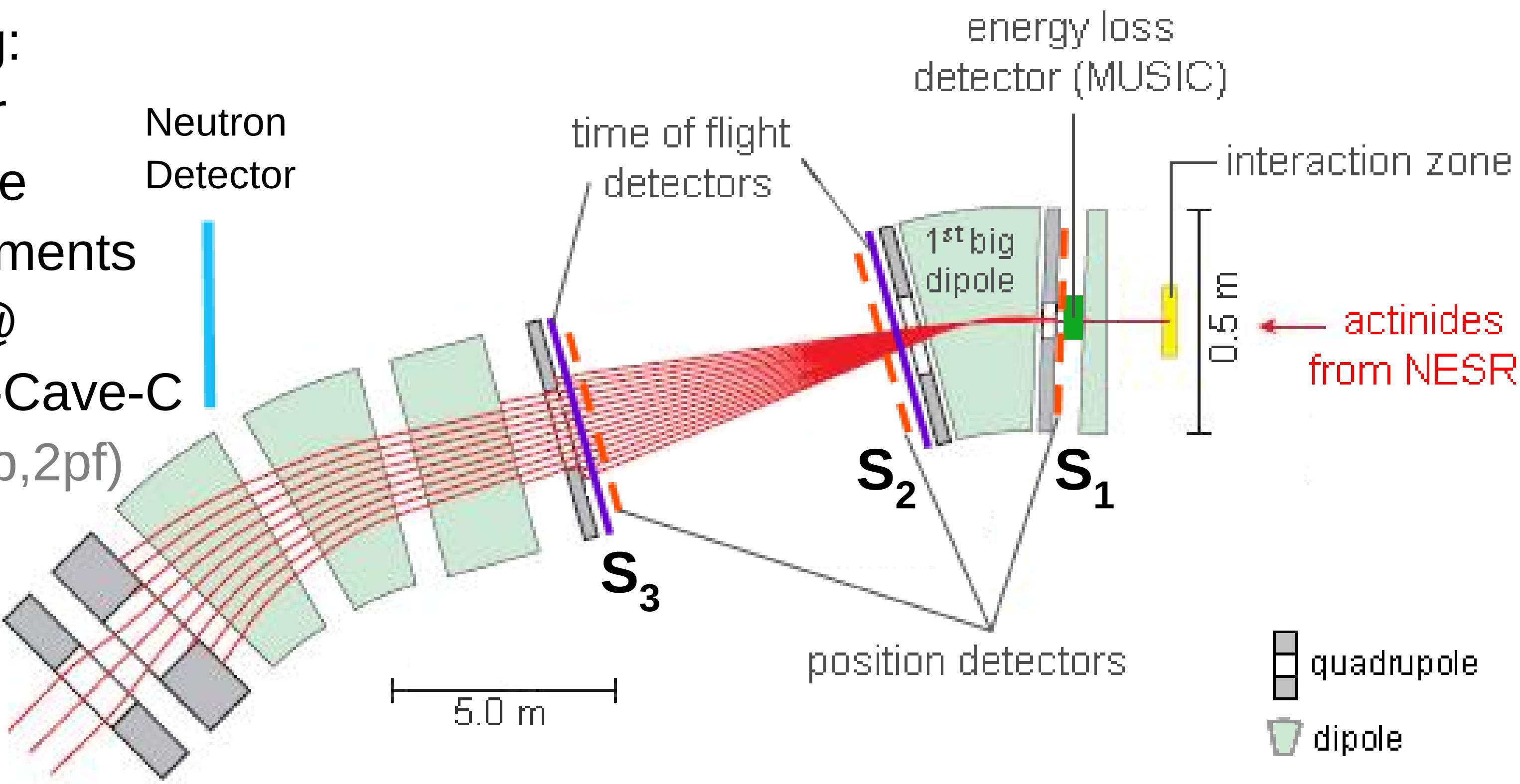
In-Ring spectrometer in the Bypass

CEA-DAM Bruyères-le-Châtel, JINR Dubna, GSI (FELISe → SOFIA)

Ongoing:
Detector prototype developments
SOFIA@
R³B-Cave-C

Neutron Detector

future: (p,2pf)



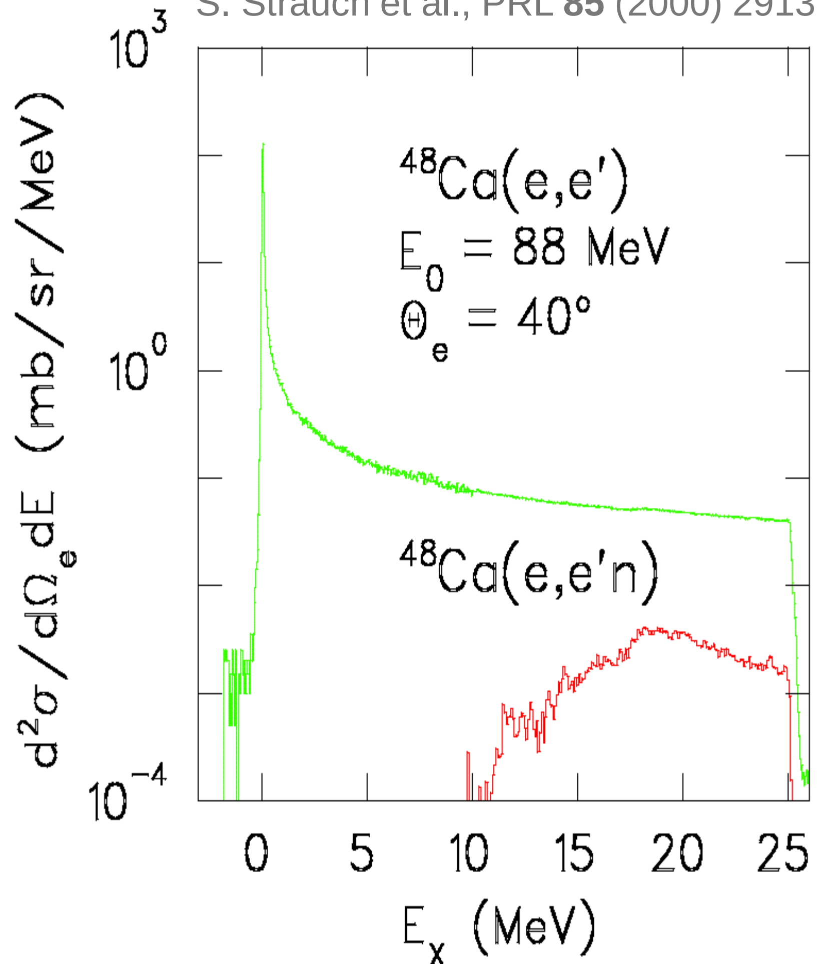
Most demanding physics case: Electrofission studies (FELISe)
-coincident identification of both fission fragments (TKE)
-prefragment excitation energy directly accessible (e,e'f)

GSI FAIR

Advantages: colliding beam kinematics

→ compared to conventional (fixed target) experiments (L_{eff} → $10^{31..32}$ $cm^{-2}s^{-1}$)

S. Strauch et al., PRL **85** (2000) 2913



Fixed target		Collider 1.5GeV
$^{48}Ca(e,e'n)$		$^{48}Ca(e,e'A')$
Ω_n =100msr	**100**	Ω_n ~ 4π
n_{eff} =20 %	**5**	n_{eff} ~ 100 %
$\Theta_{e'}$ = 40 °	**50**	**$\Theta_{e'}$ = 5 °**
	>10^4	
L=10^{31} – 10^{32}	cm^{-2} s^{-1}	**L ~ 10^{27}– 10^{28}**
SCRIT ~10^{28}/ETIC ~10^{30}		**ELISe ~10^{28}**

comparable

→ Large effective lumi. through kinematics

Kinematics: trade luminosity vs. resolution

$\beta = p_A / E_A, \quad \delta = \sqrt{(1-\beta)/(1+\beta)}$, = 0.3 @ 740 AMeV (e:500MeV)

➔ Electron scatt. @1.64 GeV

Fixed target	Collider
Conventional kinematics ($\beta = 0$)	Counter-propagating beams ($\beta > 0$)
Scattered electron momentum	
$p_{e'} = \dfrac{p_e - E^*}{1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}}$	$p_{e'} = \dfrac{p_e - \delta E^*}{1 + 2\frac{p_e - p_A}{M}\,\delta\sin^2\frac{\theta}{2}}$
Momentum transfer	
$q^2 = \dfrac{4p_e^2\sin^2\frac{\theta}{2}}{1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}}$	$q^2 = \dfrac{4p_e^2\sin^2\frac{\theta}{2}}{1 + 2\delta\frac{p_e - p_A}{M}\sin^2\frac{\theta}{2}}$
Resolution (momentum dependence)	
$\Delta E^* \approx -\left(1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}\right)\Delta p_{e'}$	$\Delta E^* \approx -\left(\frac{1}{\delta} + 2\frac{p_e - p_A}{M}\sin^2\frac{\theta}{2}\right)\Delta p_{e'}$
Resolution (angular dependence)	
$\Delta E^* \approx -\frac{p_e p_{e'}}{M}\sin\theta\Delta\theta$	$\Delta E^* \approx -\frac{(p_e - p_A)p_{e'}}{M}\sin\theta\Delta\theta$

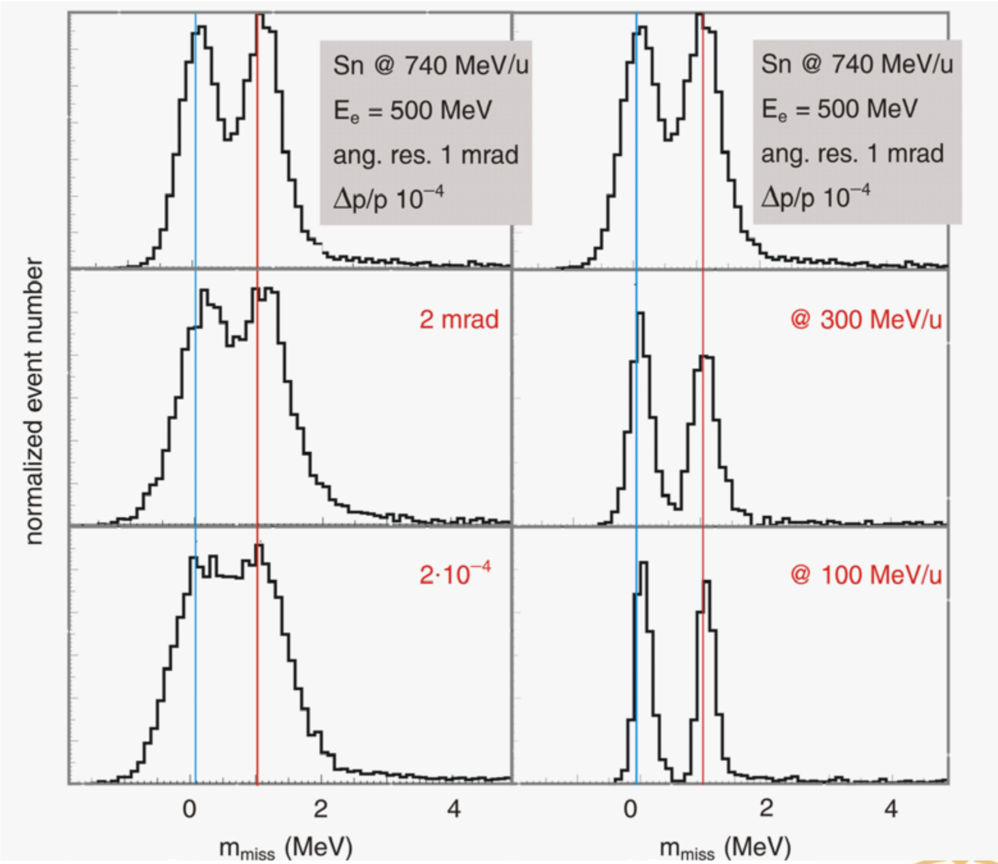
← larger mom. transf. at given angle

← worse resolution

Where’s the challenge ?

Monte Carlo Simulation: ΔE* = 1 MeV

Cola++, Simul++ (H. Merkel, Univ. Mainz)

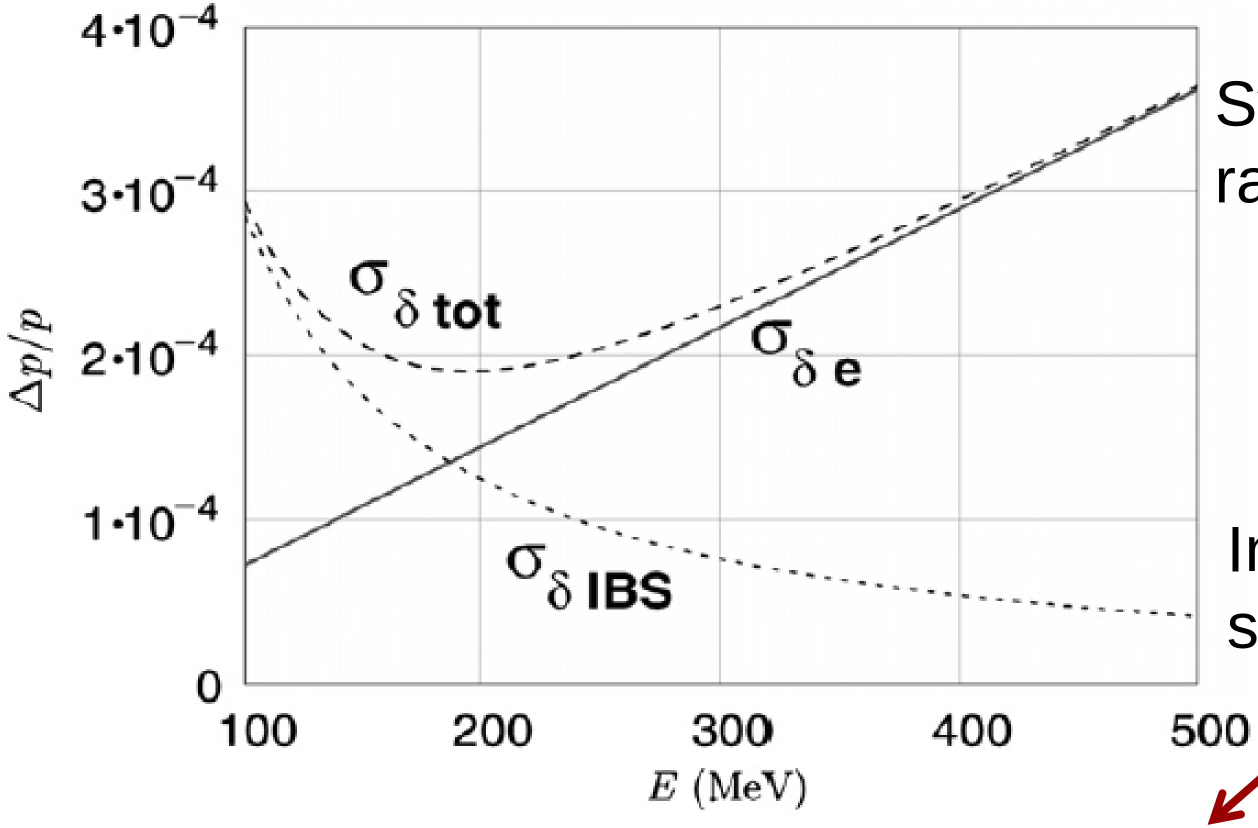


Pure kinematics calculus:

- colliding beam kinematics
- angular and energy resolution coupled
- achievable resolution can be improved by getting the “target” to “rest”

  ➔ reduced luminosity

Electron beam constraints



Synchrotron radiation

Intra-beam scattering

➔Trade resolution vs. Luminosity
(see also Petr Shatunov's talk)

Possible realization of the ELISe experiment at the ESR (study at different beam energies)

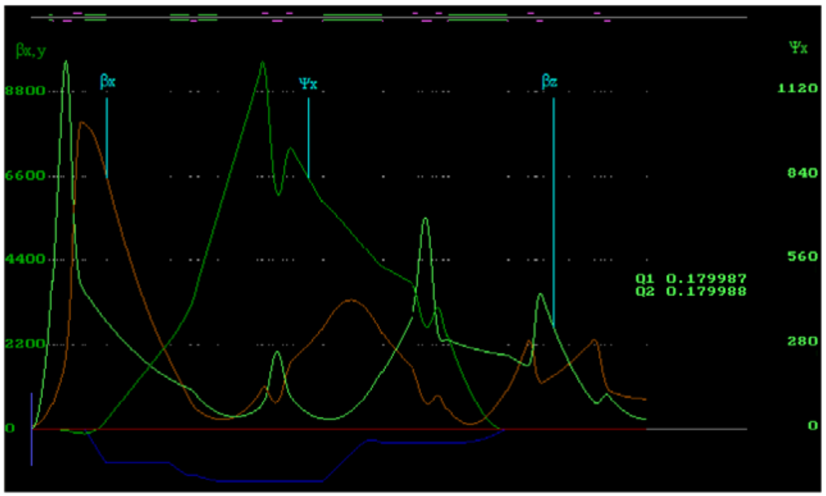
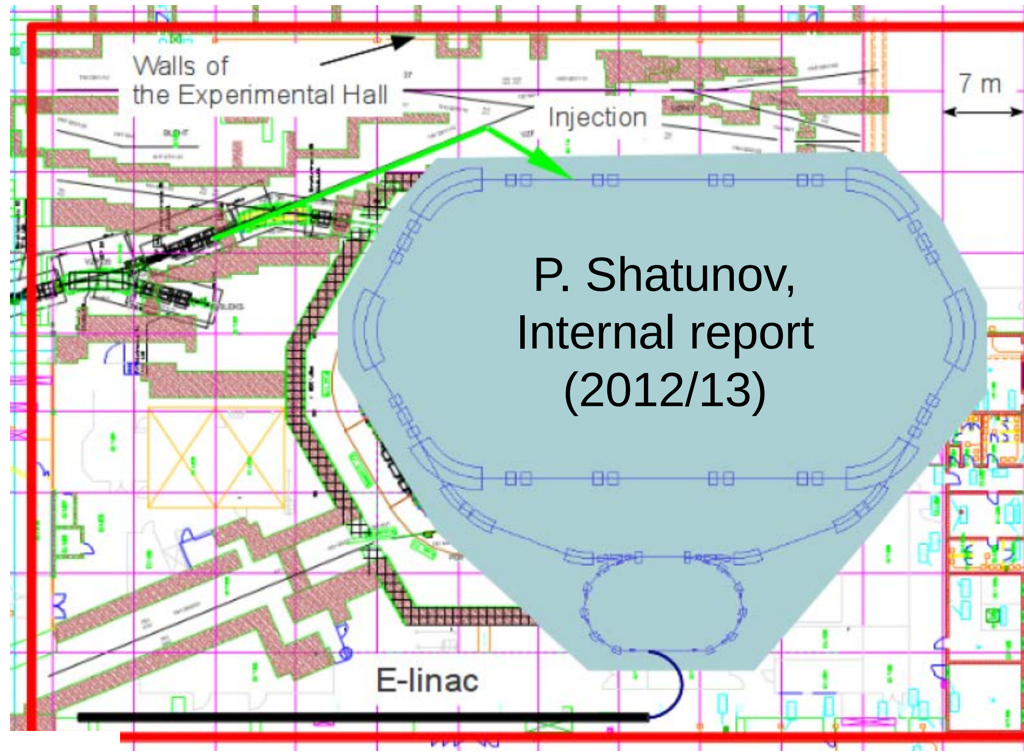
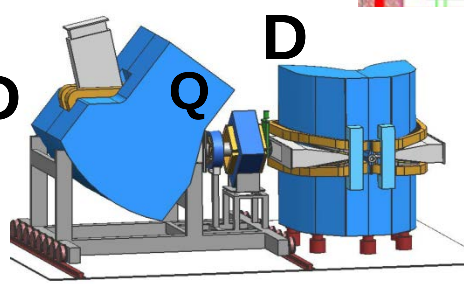
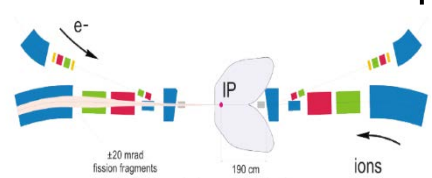


Figure 9. Beta (β, cm) and dispersion (Ψ, cm) functions of stretched ESR (1 half) in the collider mode.



GPA Berg et al.,
NIM **A640** (2011) 123
NIM **A659** (2011) 198





ELISe Collaboration
NIM **A637** (2011) 60

Main consequences:

- Lower ion energies (e.g. 340 AMeV vs. 740 AMeV)
  - less maximum luminosity (tune shift ~ factor 3…4)
- High resolution (stochastic and electron cooling)
- Favourably injection from SuperFRS via CR into ESR:
  bad injection efficiency for non pre-cooled beams

➔ viable programme with ~10^6 less particles only for the most exotic species at the outskirts of the nuclear chart (flat top for isotopes close to stability)

Expected Luminosities (NESR)
- and related physics programme

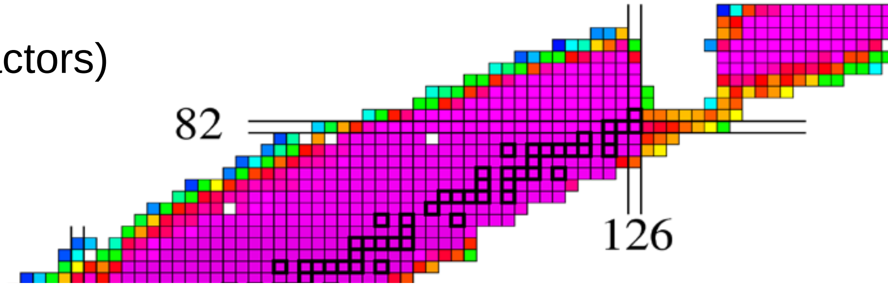
- $10^{29} cm^{-2} s^{-1}$ (black)
- $10^{28} cm^{-2} s^{-1}$ (magenta)
- $10^{27} cm^{-2} s^{-1}$ (red)
- $10^{26} cm^{-2} s^{-1}$ (yellow)
- $10^{25} cm^{-2} s^{-1}$ (green)
- $10^{24} cm^{-2} s^{-1}$ (cyan)
- $10^{23} cm^{-2} s^{-1}$ (light blue)
- $10^{22} cm^{-2} s^{-1}$ (blue)

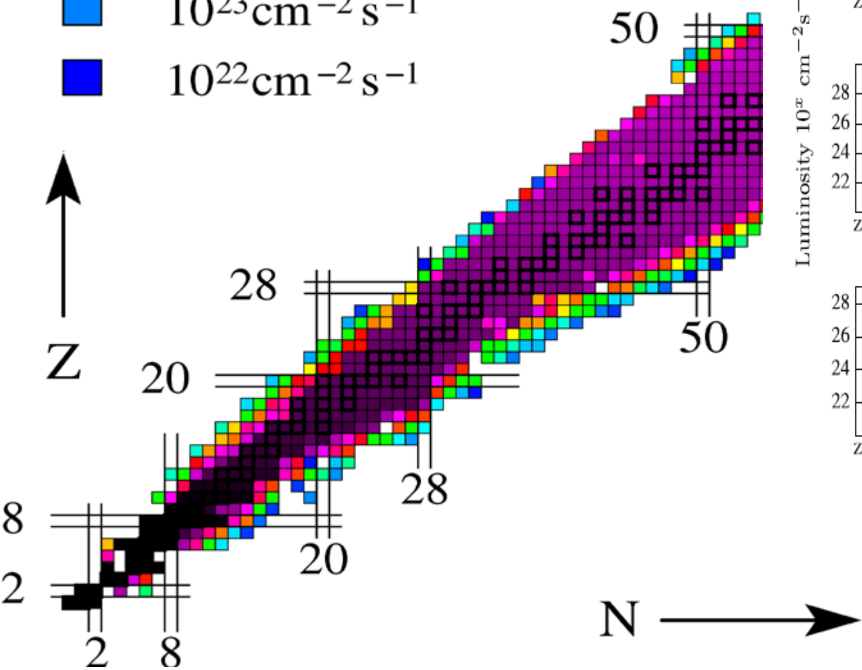
Quasielastic (spectroscopic factors)

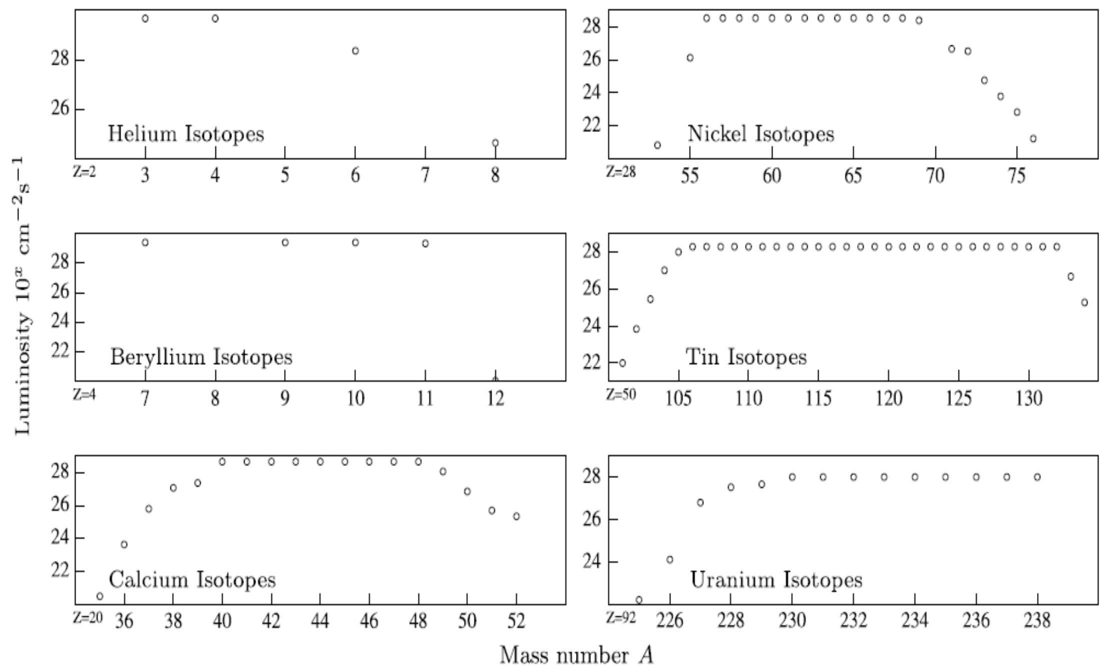
Inelastic (e.g. GR studies)

charge distributions

charge radii







Full simulation of production, transport and storage

Physics programme via rate estimates

Table 2
Estimate for the required luminosities for different studies in colliding beam kinematics. It is assumed that the maximum running time shall not exceed four weeks.

Reaction	Deduced quantity	Target nuclei	Luminosity $\mathcal{L}$ $cm^{-2}\,s^{-1}$
Elastic scattering at small q	r.m.s. charge radii	Light Medium	10^{24}
First minimum in elastic form-factor	Density distribution with 2 parameters	Light Medium Heavy	10^{28} 10^{26} 10^{24}
Second minimum in elastic form-factor	Density distribution with 3 parameters	Medium Heavy	10^{29} 10^{26}
Giant resonances	Position, width, strength, decays	Medium Heavy	10^{28} 10^{28}
Quasi-elastic scattering	Spectroscopic factors, spectral function, momentum distributions	Light	10^{29}

Summary

- Electron(Antiproton)-RIB Collider is feasible - collider mode provides optimal use for RIBs. Large gain factors are expected (via kinematics), these would enable especially also inelastic scattering studies (detection).

➔ Conceptual design for all major components (at NESR) done

➔ Options for running at the existing ESR studied (i.e. exp's at lower energies)

Trade achievable rates versus luminosity

- Unique experiment for FAIR (and other facilities with storage rings)

→ DERICA

http://www.gsi.de/elise/

GSI

FAIR

Other ideas …

ELSEVIER Nuclear Instruments and Methods in Physics Research A 516 (2004) 228–236 Section A
www.elsevier.com/locate/nima

e.g. New SUBARU/Spring-8

High-energy photon beam production with laser-Compton backscattering

K. Aoki[a], K. Hosono[a,*], T. Hadame[a], H. Munenaga[a], K. Kinoshita[a], M. Toda[a], S. Amano[b], S. Miyamoto[b], T. Mochizuki[b], M. Aoki[c], D. Li[c]

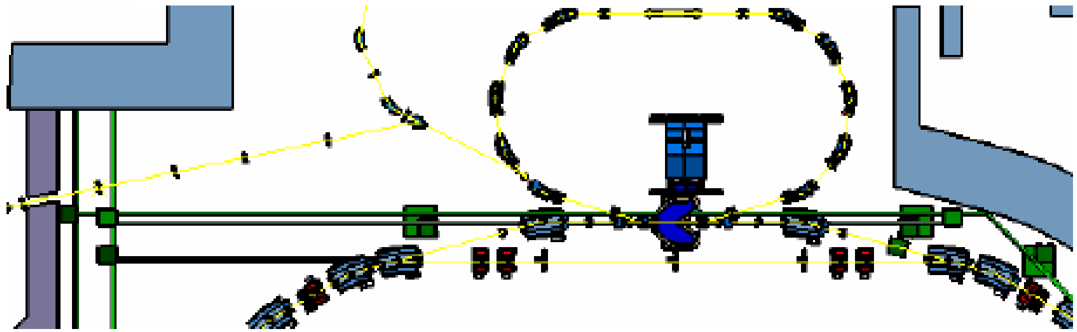
[a] Graduate School of Engineering, Himeji Institute of Technology, 2167 Shosha Himeji, Himeji, Hyogo 671-2201, Japan
[b] LASTI, Himeji Institute of Technology, Kamigori-Kouto, Hyogo 678-1205, Japan
[c] Institute for Laser Technology, Honmachi, Osaka 550-0004, Japan

Received 25 June 2003; received in revised form 12 August 2003; accepted 26 August 2003

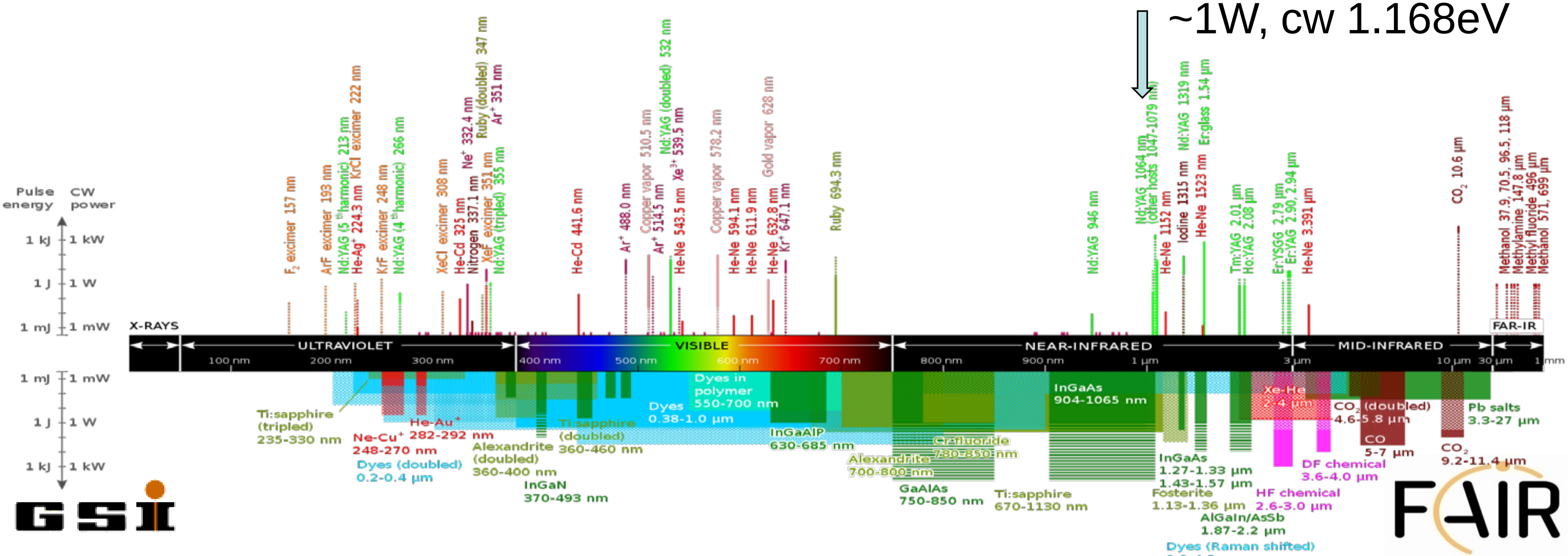
- Laser systems

➔ Compton backscattering

$$E_{max} = 4\,\gamma^2\,E_{LASER}$$

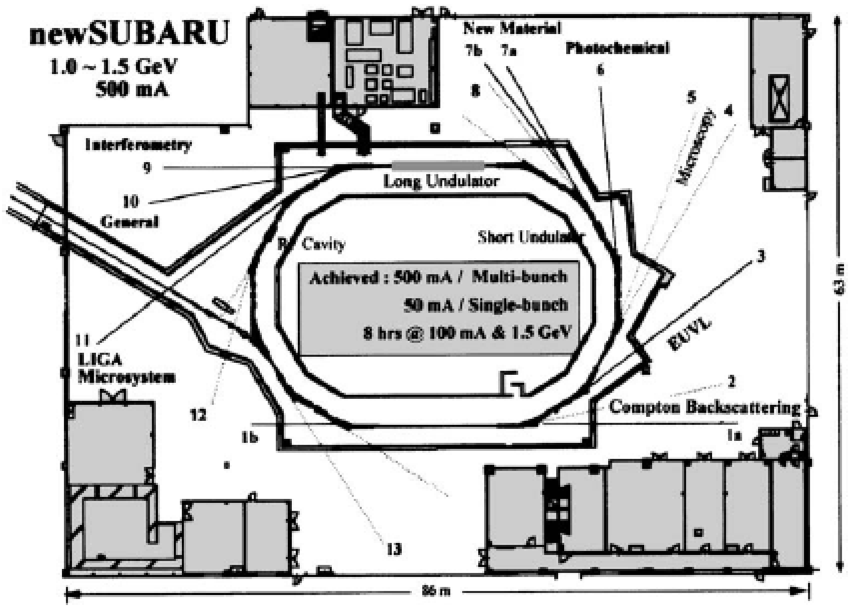


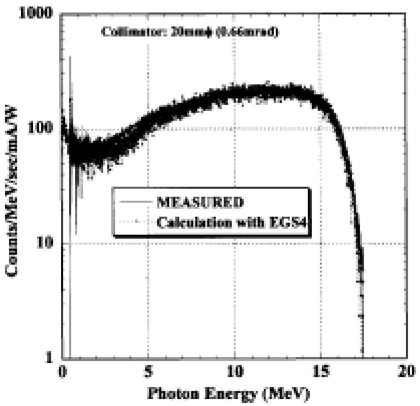
~1W, cw 1.168eV

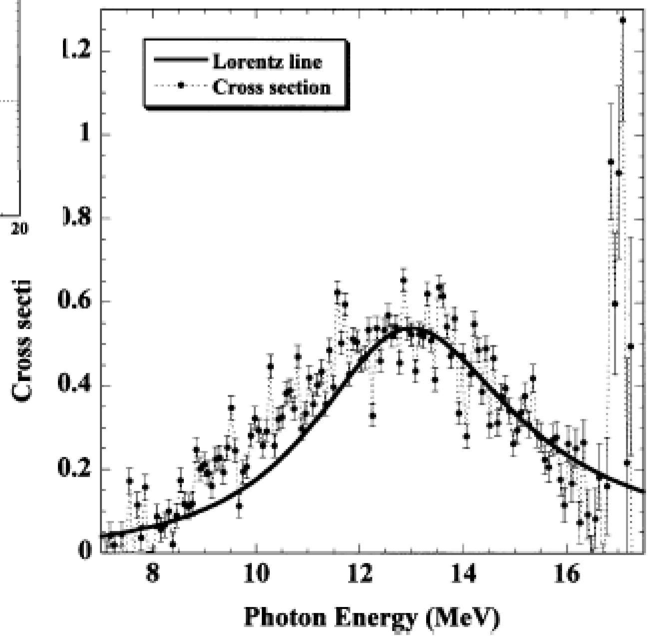


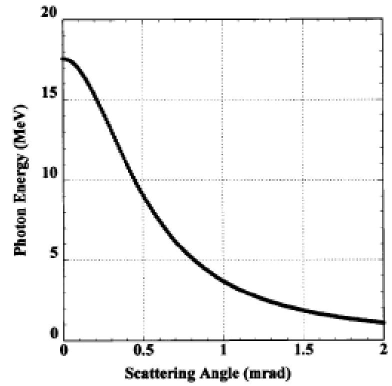
Direct comparison
➔ looks promising

- beam current (425 mA @ 500MeV)
- laser intensity (~1 W cw / 1-6 eV)
- overlap/angular spread straight sec. **?**
- shown: 10mA/1GeV on 0.5 W/1.168eV Nd:YVO_4









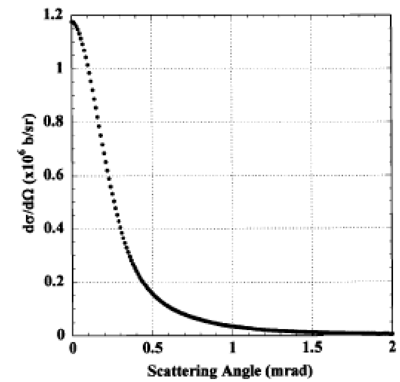
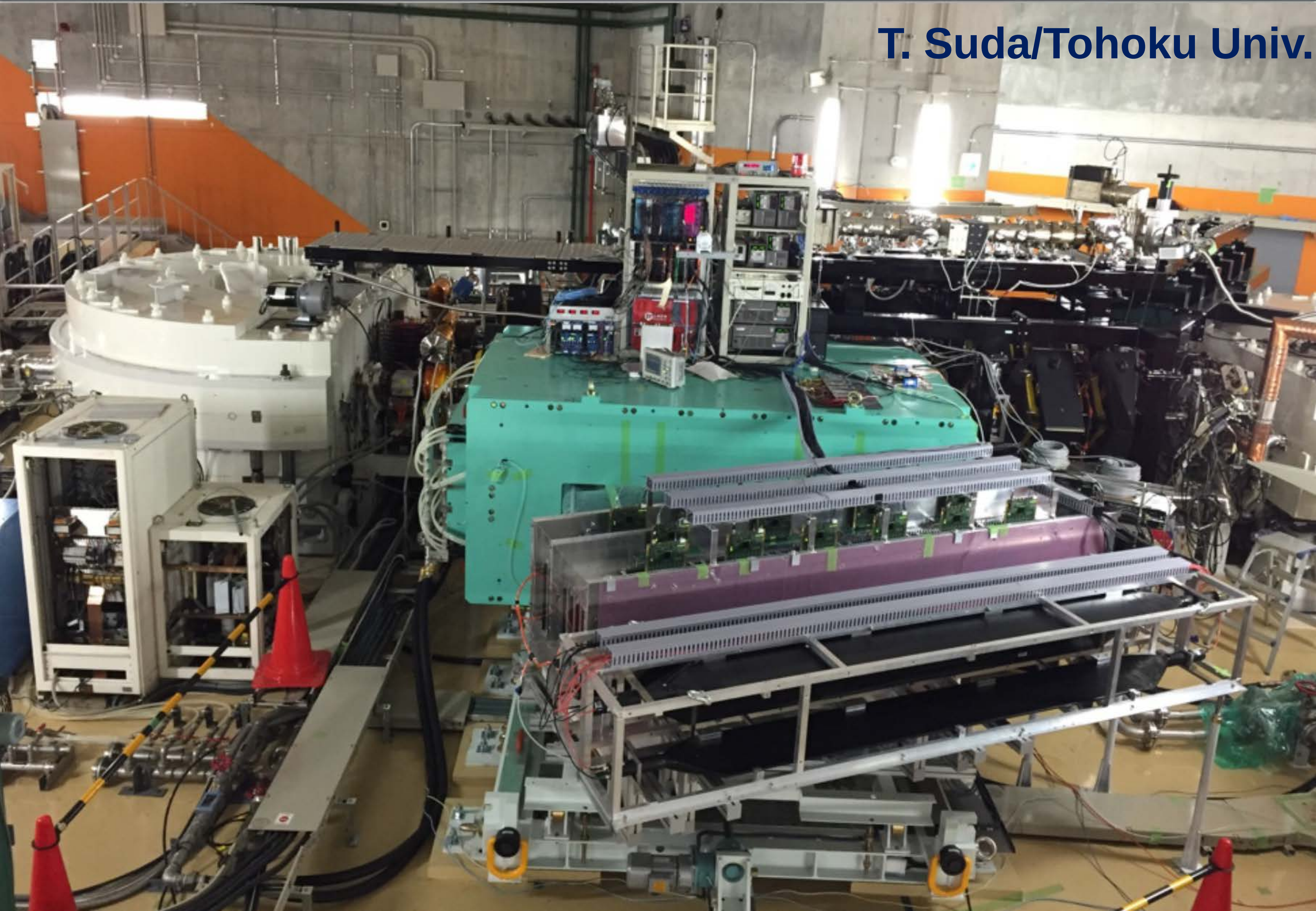


Photo-nuclear reaction
E1 (GDR) ^{197}Au

GSI

FAIR

SCRIT facility as of today



T. Suda/Tohoku Univ.

^{132}Xe(e,e')

First electron scattering data for (stable) Xenon nuclei.

~10^{7} ions on the electron beam

国立研究開発法人理化学研究所　仁科加速器研究センター
第242回 RIBF核物理セミナー
RIKEN Nishina Center for Accelerator Based Science
The 242nd RIBF Nuclear Physics Seminar

First result of the SCRIT electron scattering facility

Prof. Kyo Tsukada
(Research Center For Electron Photon Science,
Tohoku University)

We constructed the SCRIT electron scattering facility at RIBF in order to realize electron scattering off unstable nuclei. Electron scattering provides the most powerful and reliable information about the structure of atomic nuclei as demonstrated for stable nuclei in the latter half of the 20th century. Meanwhile electron scattering with unstable nuclei has not been realized yet since it is difficult to prepare these nuclei as the target material due to rare and short-lived features. We have invented new target forming technique named Self-Confining Radio-Isotope Ion Target (SCRIT), in which nuclei of interest are three-dimensionally trapped as a target along the electron beam axis. The luminosity required for elastic electron scattering (10^27 [1/cm^2/s]) was achieved with only 10^8 target ions.

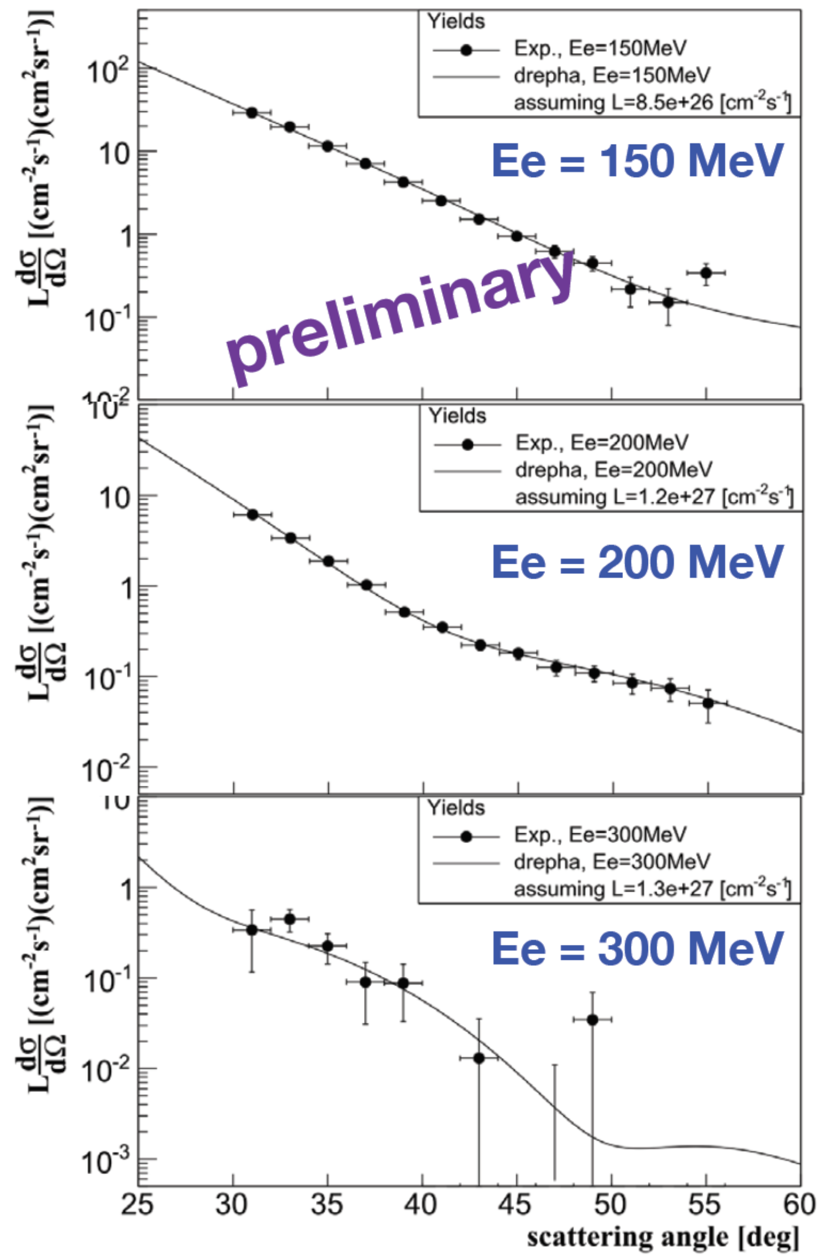
In this seminar, I will report the first result of electron scattering from 132Xe at the SCRIT electron scattering facility and some future prospects.

＊The talk will be given in English language.

Jul.11th(Tue.)2017 13:30~
RIBF Hall (rm.201), RIBF bldg., RIKEN

Contact: Nuclear Physics Seminar Organizing Committee
npsoc@ribf.riken.jp
http://ribf.riken.jp/~seminar/

Kyo Tsukada



Further Systems

« Retour

SPhN

Séminaires du SPhN

Service de Physique Nucléaire

Electron-radioactive ion collisions

Atelier ESNT

du 25/04/2016 au 27/04/2016
Bat 703, p 135 salle visio-conférence, CEA Saclay, Orme des Merisiers

On behalf of the "Espace de Structure et de réactions Nucléaires Théorique" (ESNT), the workshop entitled:
"Electron-radioactive ion collisions: theoretical and experimental challenges"
will be held in April 25-27th at CEA-Saclay, Orme-les-Merisiers site.
The goals of the project are:
1. To review the past achievements with electron scattering on stable nuclei
2. To discuss observables, and state-of-the-art theoretical methods to estimate them
3. To stimulate reflections on new observables that can be measured using electrons as a probe
4. To present the SCRIT machine and its recent results, and the ELISe project
5. To discuss challenges for the ETIC project.

For details about the updated program, see the ESNT Web site http://esnt.cea.fr >> Ateliers 2016
For further information, please contact the local organizer of the project: V. Somà (SPhN).

http://esnt.cea.fr/Phocea/Page/index.php?id=58
Contact : Valerie LAPOUX

ETIC (Electron-Trapped Ion Collider)

- Working group started at CEA/IRFU within GANIL2025 discussions on a possible electron-ion collider started at CEA/IRFU
- SCRIT concept matches well GANIL settings (continuous injection / low energy)
- ETIC goal: gain a **factor > 100 in luminosity** w.r.t. SCRIT
  - ➘ Greatly expand accessible types of reactions and reach in N/Z
  - ➘ Open up exciting areas of potential physics research

L~ $10^{30}cm^{-2}s^{-1}$

Antoine Chancé

ER-LINAC

➔15x15 µm²

Electron beam spot

System design: Collider

-TDR prepared

The Electron-Ion Scattering experiment ELISe at the International Facility for Antiproton and Ion Research (FAIR) - a conceptual design study

A.N. Antonov, M.K. Gaidarov, M.V. Ivanov, D.N. Kadrev

INRNE-BAS Sofia - Bulgaria

M. Aïche, G. Barreau, S. Czajkowski, B. Jurado

Centre d'Etudes Nucléaires Bordeaux-Gradingnan (CENBG) - France

G. Belier, A. Chatillon, T. Granier, J. Taieb

CEA Bruyères-le-Châtel - France

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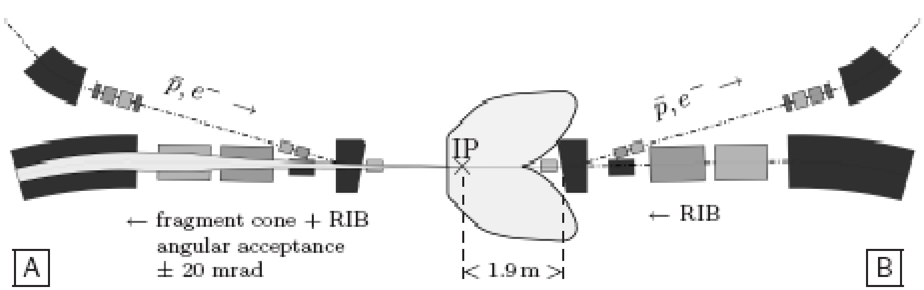
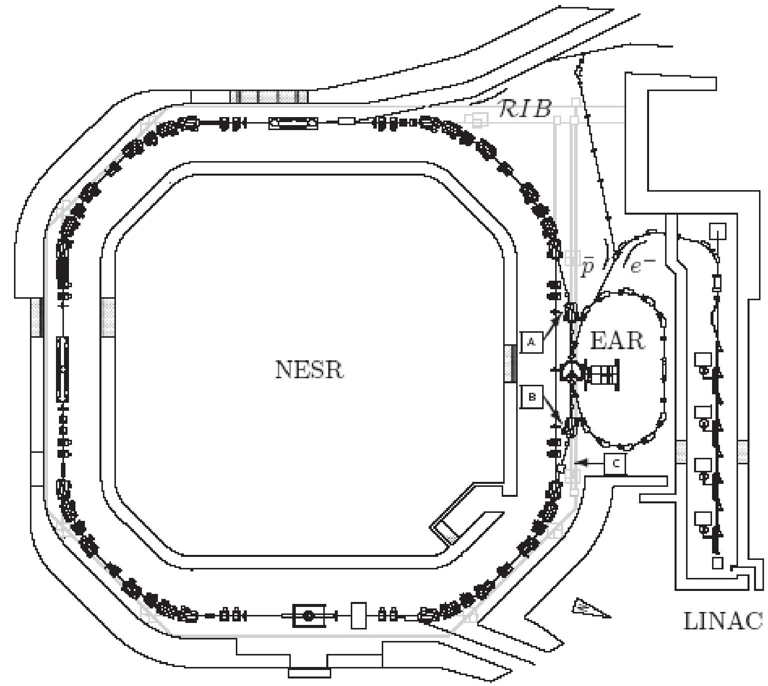


Figure 6: Interaction zone with the interaction point IP in the bypass section of the NESR.



ELISe collaboration,
NIM **A637** (2011) 60

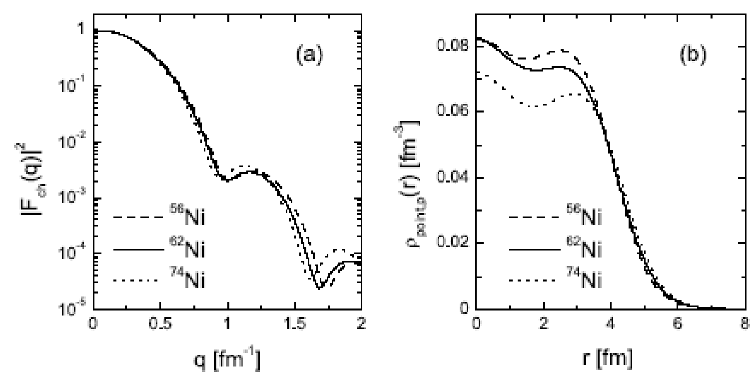
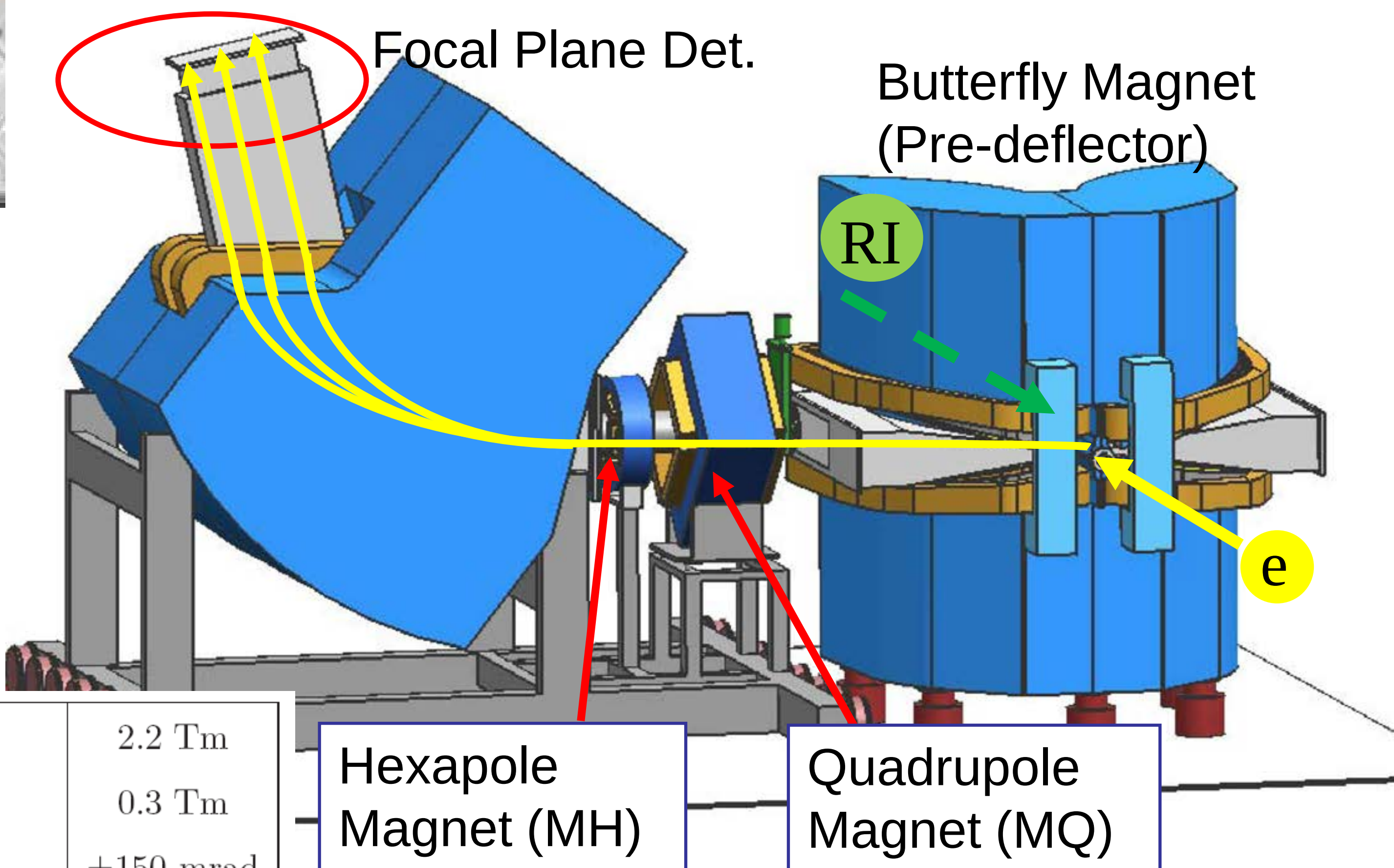


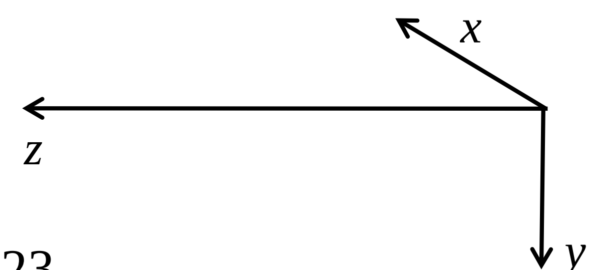
Figure 1: Charge form factors (panel (a)) calculated in DWBA and HF+BCS proton densities (panel (b)) for the unstable doubly-magic ^{56}Ni (dashed line), stable ^{62}Ni (full line) and unstable ^{74}Ni (dotted line) isotopes [7].

Design of a suitable magn. high resolution spectrometer

GPA Berg et al.



Maximum rigidity $B\rho$	2.2 Tm
Minimum rigidity $B\rho$	0.3 Tm
Angle acceptance, azimuthal	±150 mrad
Angle acceptance, polar at 11.4°	±24 mrad
Angle acceptance, polar at 22.7°	±70 mrad
Energy acceptance	± 5 %
Resolving Power E/ΔE	$\approx 10^4$
Angle resolution	1 mrad
Kinematic compression factor	0.3 - 0.6



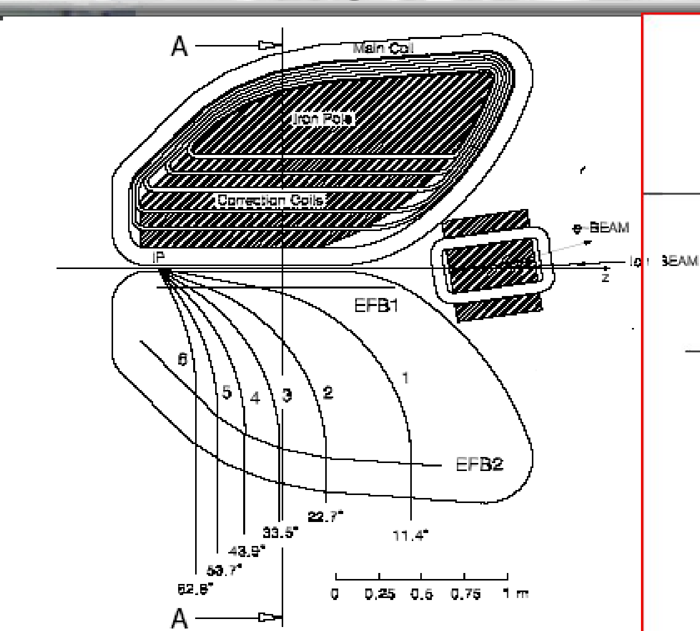
GPA Berg et al.,
NIM **A640** (2011) 123

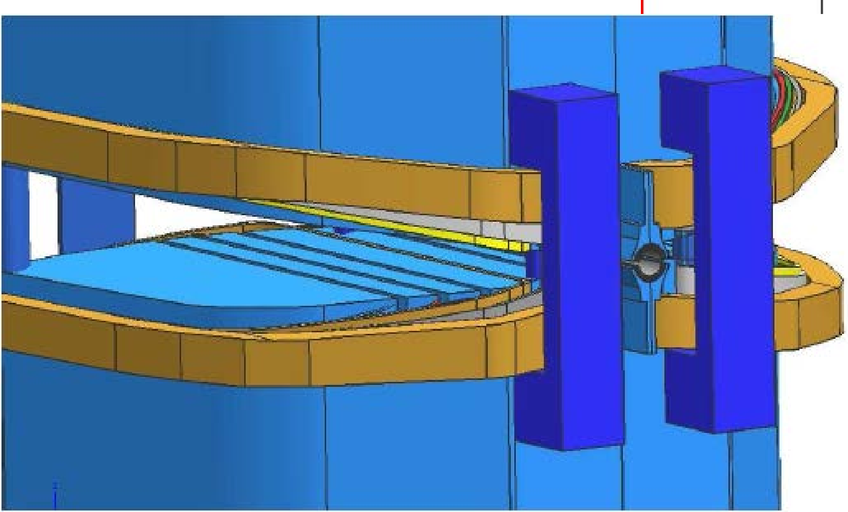
FAIR

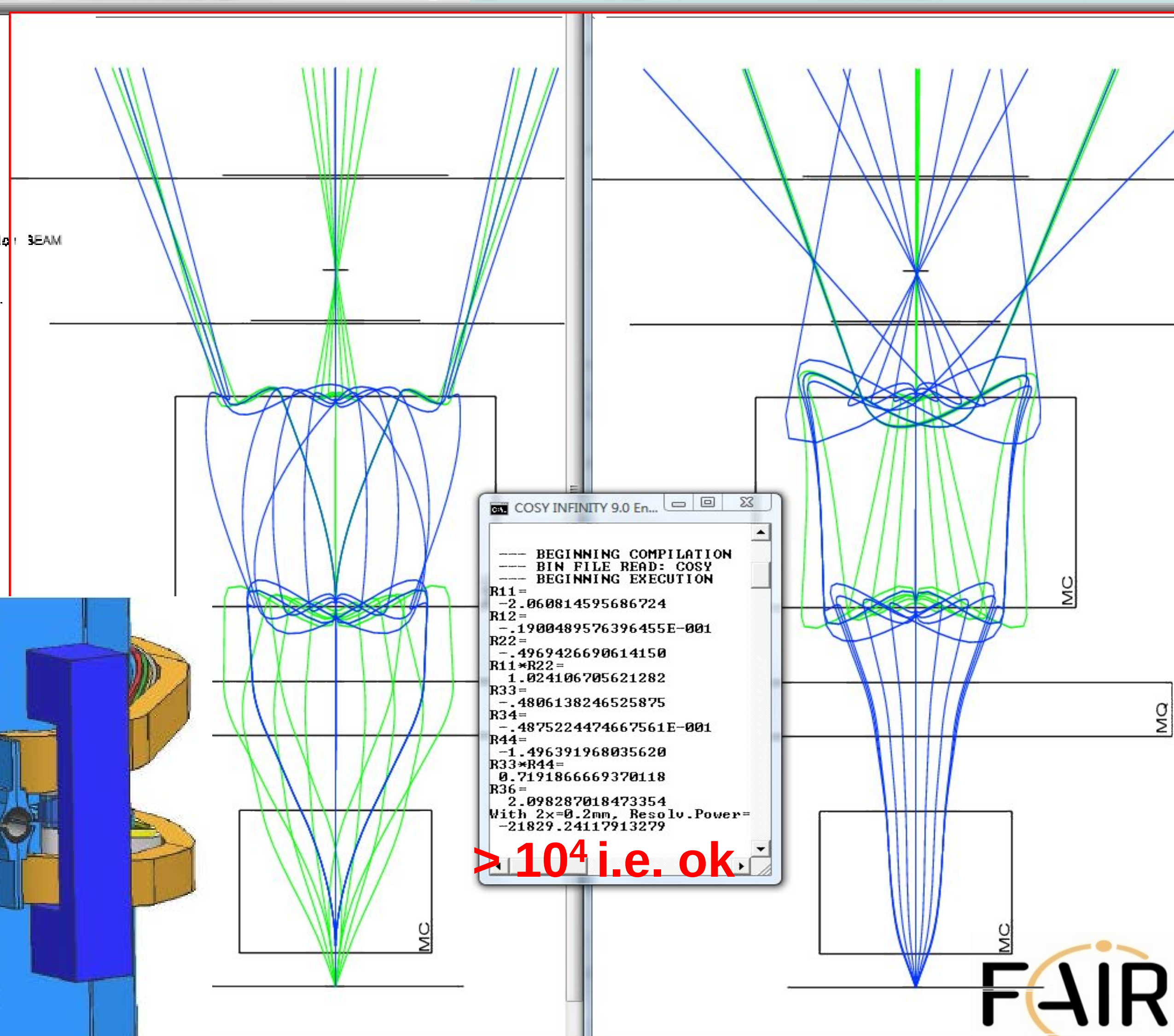
Resolution

GPA Berg et al. → T. Adachi et al.

Θ_{Lab}: 10-60°
q: 20-600 MeV/c
e energies: 125-500 MeV



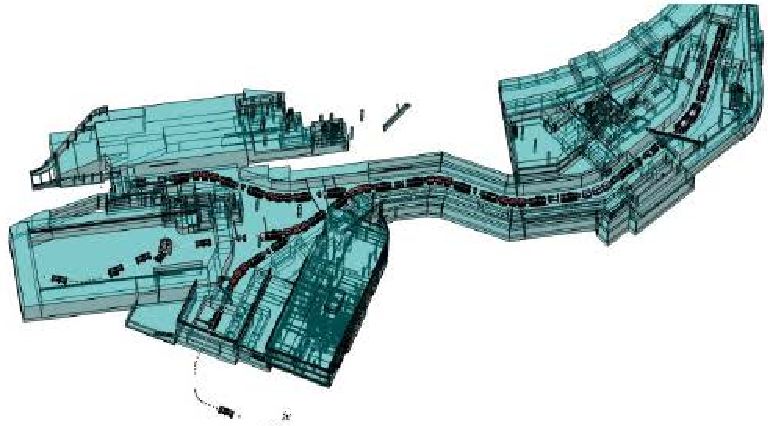


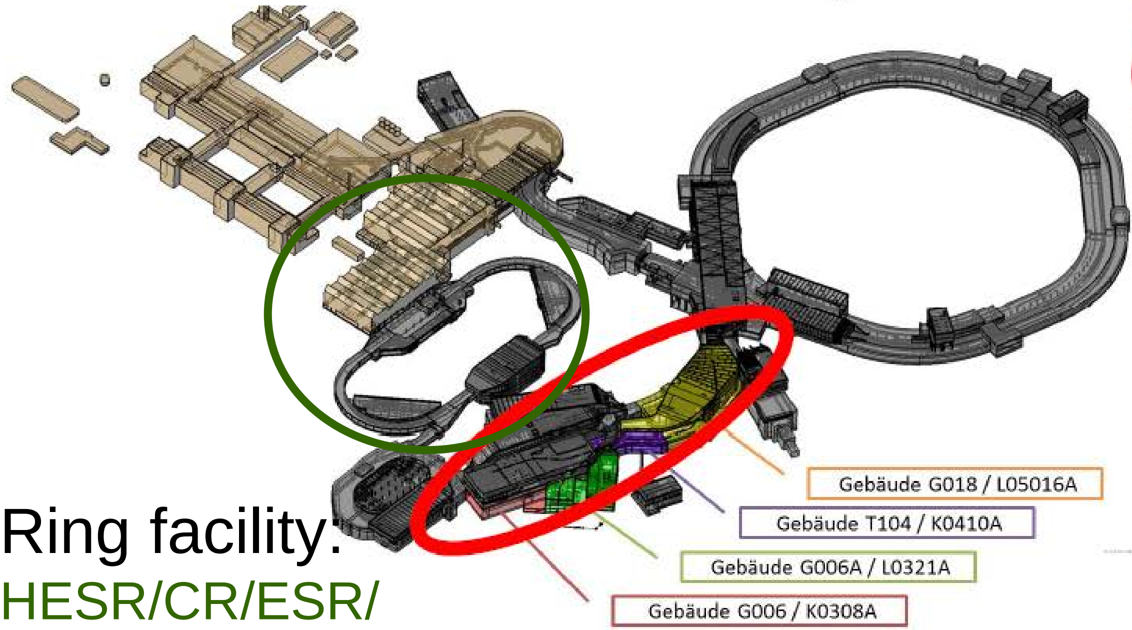


> 10^4 i.e. ok

FAIR

Current status with respect to the MSV - NESR is delayed





Ring facility:
HESR/CR/ESR/
Cryring complex

The ELISe collaboration

BINP Novosibirsk - Russia Koop, I.A., Skrinsky, A.N., Korostelev, M.S., Parkhomchuk, V.V., Shatilov, D.N., Shiyankov, S.V., Valishev, A.A., Shatunov, Y.M., Pavlov, V.M., Otboev, A.V., Nesterenko, I.N., Logatchov, P.V.

CEA Bruyeres le Chatel - France Chatillon, A., Belier, B., Granier, T. , Taieb, J.

CEA Saclay/ IRFU - France Doré, D., Letourneau, A., Ridikas, D. , Dupont, E. , Berthoumieux, E., Panebianco, S.

CEN Bordeaux-Gradingnan - France Czajkowski, S., Jurado, B., Aïche, M., Barreau, G.

CSIC Madrid - Spain Sarriguren, P., Ramirez, C. F. , Borge, M.J.G., Garrido, E., Alvarez, R., Moya de Guera, E.

Chalmers University of Technology – Sweden Nyman, G., Johansson, H., Heinz, A., Jonson, B., Nilsson, T.

Complutense University of Madrid - Spain Udias-Moinelo, J., Fraile Prieto, L.M., Herraiz, J.L., Vignote, J.R.

DAEES Kyushu University - Japan Kadrev, D.N.

Daresbury Laboratory - United Kingdom Lemmon, R.

FZ Rossendorf - Germany Junghans, A.

GSI Darmstadt - Germany Münzenberg, G., Nolden, F., Schmidt, K.-H., Simon, H., Weick, H., Steck, M. , Beller, P.†, Kelic, A., Geissel, H., Emling, H., Egelhof, P., Boretzky, K., Becker, F., Aumann, T., Kester, Litvinov, Y., O. , Franzke, B., Kurz, N., Dolinskii, A.

Granada University – Spain Amaro Soriano, J.E. : Lallena Rojo, A.M.

INR Moscow - Russia Nedorezov, V. , Mushkarenkov, A.N., Lisin, V.P., Polonski, A.L., Rudnev, N.V., Turinge, A.A.

INRNE-BAS Sofia - Bulgaria Antonov, A.N. , Gaidarov, M., K. Ivanov, M.V.

IPN Lyon - France Schmitt, C.

IPPE Obninsk - Russia Kamerdzhiev, S.P.

JINR Dubna - Russia Sereda, Y., Klygin, S., Grigorenko, L., Sidorchuk, S.I., Krupko, S.A., Gorshkov, A.V., Rodin, A.M., Fomichev, A.S., Golovkov, M., Artukh, A., Seleznev, I.A., Meshkov, I.N., Syresin, E.M., Ershov, S.N., Vorontsov, A.N. , Teterev, Y.

Johannes Gutenberg University Mainz - Germany Merkel, H., Müller, U., Distler, M.O.

Justus-Liebig University Giessen - Germany Lenske, H.

KVI Groningen - The Netherlands Wörtche, H., Kalantar, N., Berg, G.

Lund University – Sweden Avdeichikov, Vladimir, Rudolph, D.

Sendai University - Japan Suda, T.

RRC Kurchatov Institute Moscow – Russia Volkov, V.A., Chulkov, L.V., Korsheninikov, A.A., Danilin, B., Kuzmin, E.

Rohde University – South Africa Karatakaglidis, S.

SSC RF Obninsk - Russia Litvinova, E.V.

Seville University - Spain Caballero, J.A.

TU Darmstadt - Germany Richter, A., Schrieder, G., Enders, J., Pietralla, N.

University of Arizona – USA Bertulani, C.

University of Basel - Switzerland Krusche, B., Hencken, K., Jourdan, J., Rohe, D., Trautmann, D., Rauscher, T.

Universität Köln – Germany - Zilges, A.

Universities of Liverpool/ Manchester/Surrey/York - United Kingdom
Chartier, M., Cullen, Stevenson, P., Johnson, R., Catford, W., Al-Khalili, J., Barton, C., Jenkins, D.

Yamagata University – Japan Kato, S.

135 Collaborators / 36 Institutes / 12 countries (2013)

Other ideas …

ELSEVIER Nuclear Instruments and Methods in Physics Research A 516 (2004) 228–236 Section A
www.elsevier.com/locate/nima

e.g. New SUBARU/Spring-8

High-energy photon beam production with laser-Compton backscattering

K. Aoki[a], K. Hosono[a,*], T. Hadame[a], H. Munenaga[a], K. Kinoshita[a], M. Toda[a], S. Amano[b], S. Miyamoto[b], T. Mochizuki[b], M. Aoki[c], D. Li[c]

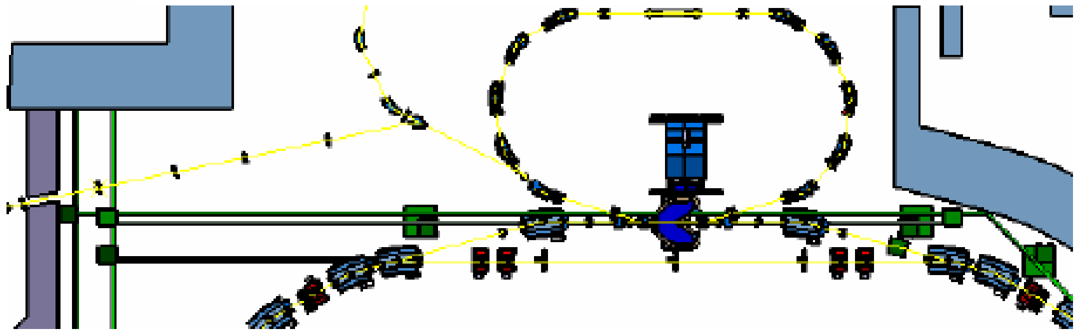
[a] Graduate School of Engineering, Himeji Institute of Technology, 2167 Shosha Himeji, Himeji, Hyogo 671-2201, Japan
[b] LASTI, Himeji Institute of Technology, Kamigori-Kouto, Hyogo 678-1205, Japan
[c] Institute for Laser Technology, Honmachi, Osaka 550-0004, Japan

Received 25 June 2003; received in revised form 12 August 2003; accepted 26 August 2003

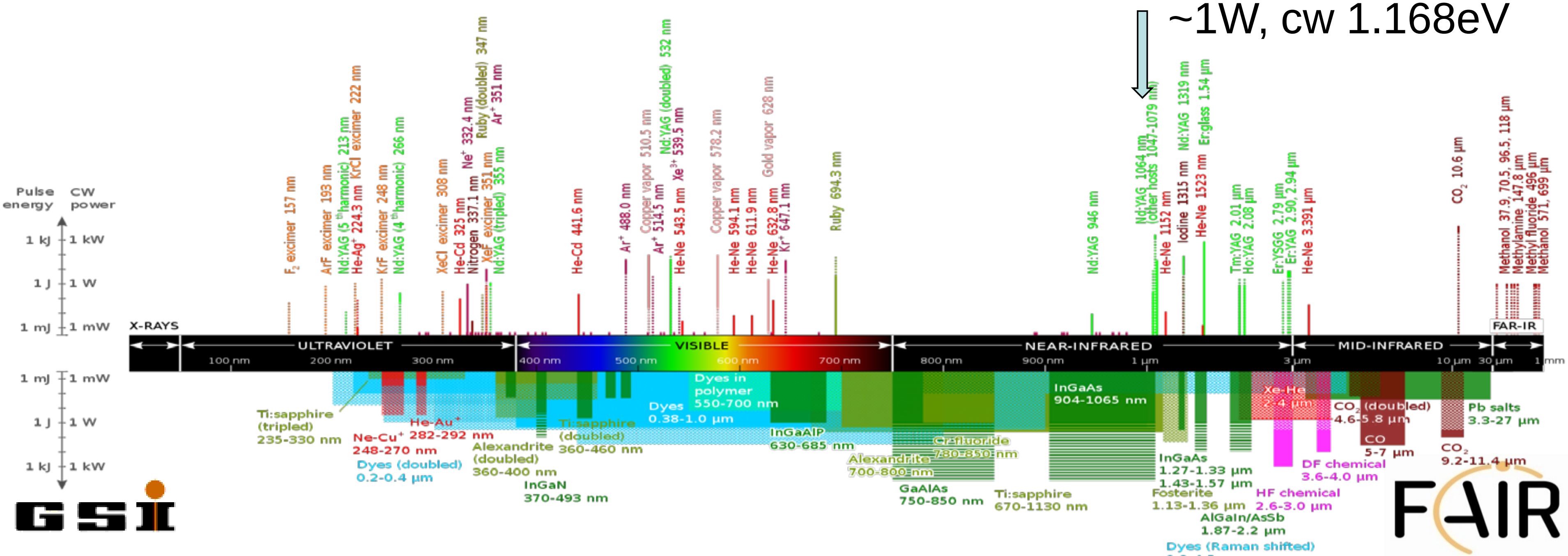
- Laser systems

➔ Compton backscattering

$$E_{max} = 4\,\gamma^2\,E_{LASER}$$



~1W, cw 1.168eV

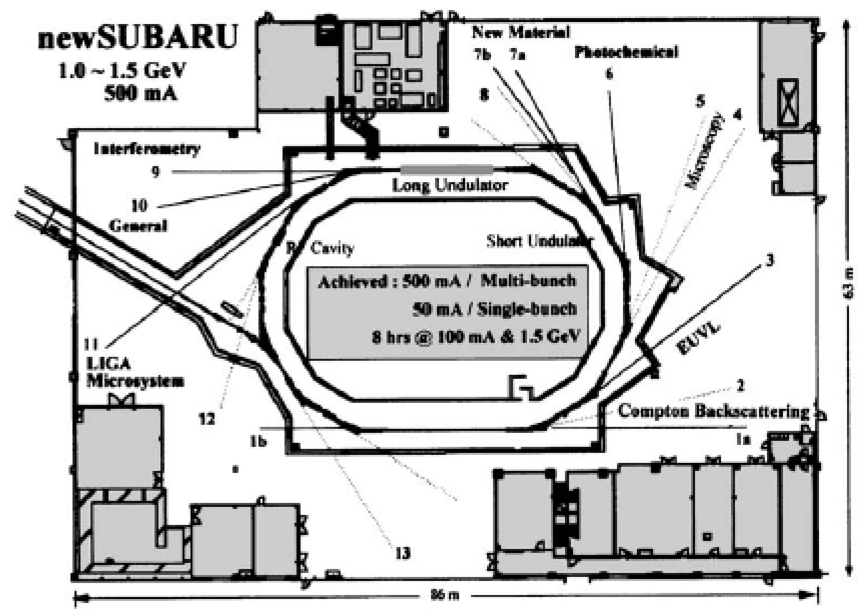


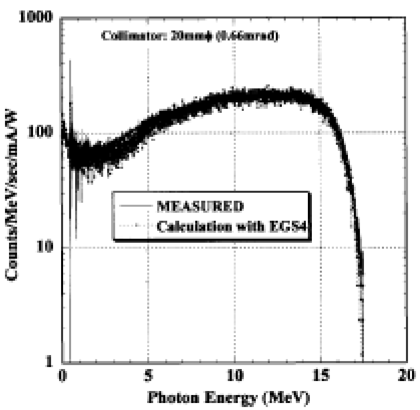
GSI

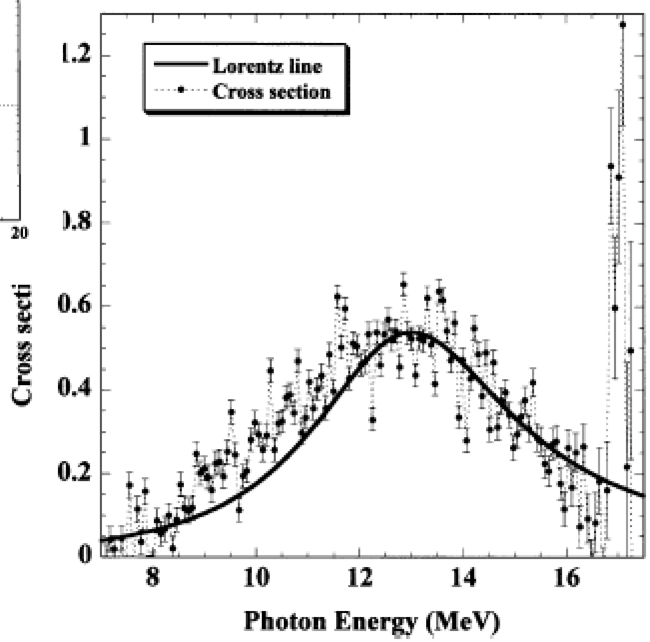
FAIR

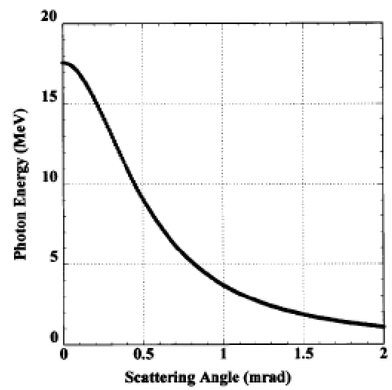
Direct comparison
➔ looks promising

- beam current (425 mA @ 500MeV)
- laser intensity (~1 W cw / 1-6 eV)
- overlap/angular spread straight sec. **?**
- shown: 10mA/1GeV on 0.5 W/1.168eV Nd:YVO_4









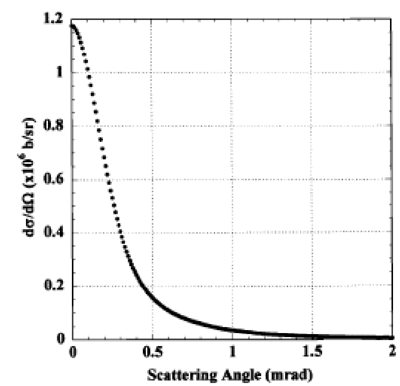


Photo-nuclear reaction

E1 (GDR) ^{197}Au

Electron scattering off RIBs
-a few good reasons

1. Clean pointlike electromagnetic probe
   - no nuclear background
     (as in conventional scattering experiments)

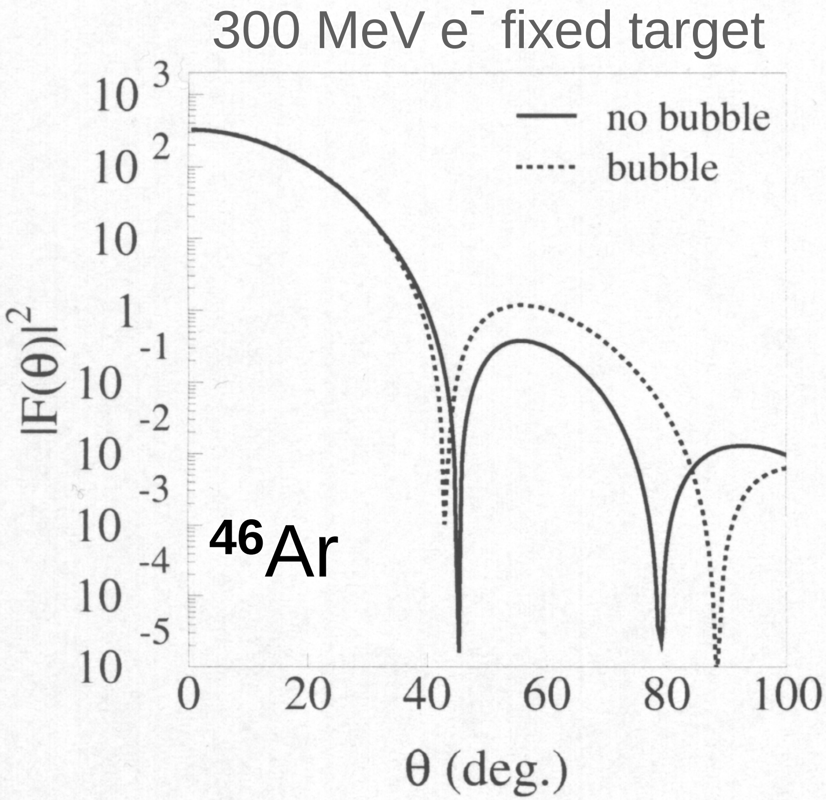
2. Sensitivity to charge distributions
   - higher moments of charge distributions (density ↔ wf.)
   - absolute charge radii (ab initio calculations)

   → Deformation vs. Clustering for (very) proton-neutron asymmetric nuclei
   (facilitated access compared to conventional methods)

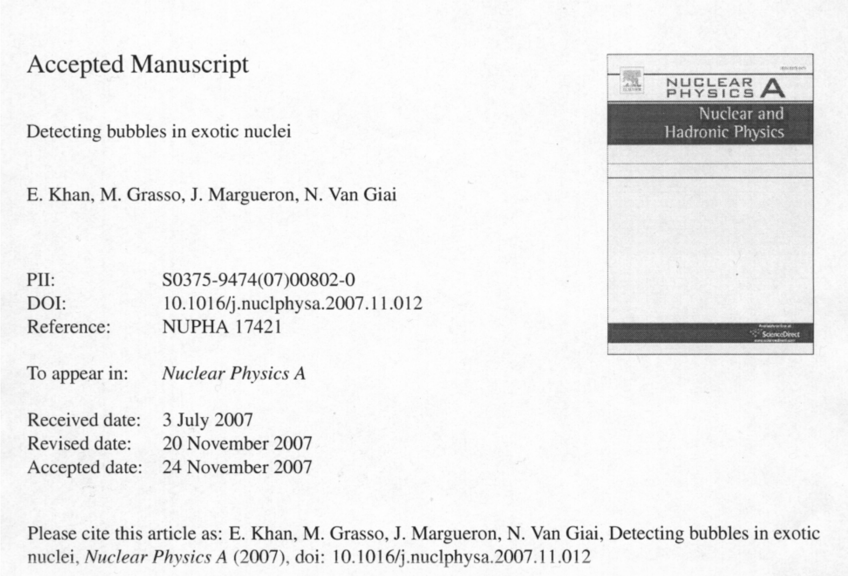
3. Transition form factors
   - additional information to plain spectroscopy

Elastic Scattering

change in interior…



Ar: inversion ($2s_{1/2}$, $1d_{3/2}$)



Accepted Manuscript

Detecting bubbles in exotic nuclei

E. Khan, M. Grasso, J. Margueron, N. Van Giai

PII: S0375-9474(07)00802-0
DOI: 10.1016/j.nuclphysa.2007.11.012
Reference: NUPHA 17421

To appear in: *Nuclear Physics A*

Received date: 3 July 2007
Revised date: 20 November 2007
Accepted date: 24 November 2007

Please cite this article as: E. Khan, M. Grasso, J. Margueron, N. Van Giai, Detecting bubbles in exotic nuclei, *Nuclear Physics A* (2007), doi: 10.1016/j.nuclphysa.2007.11.012

Nucl. Phys. A800(2008)37
Phys. Rev. C79(2009)034318
[nucl-th] 1311.4412 (2013)

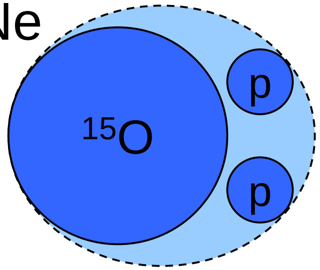
$L=2.7 \times 10^{28}$ cm^{-2} s^{-1}

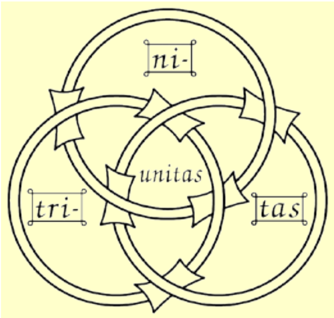
➔Absolute measurement
➔Charge distributions

… vs. valence or surface structure.

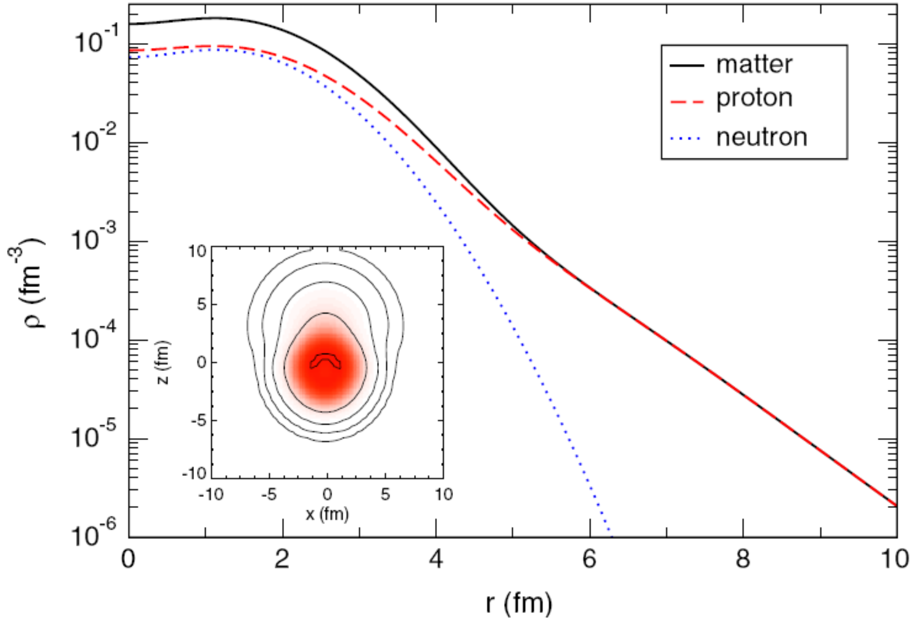
"^{17}Ne is a proton-dripline nucleus,
with strong indications of having a 2p – halo"

Zhukov & Thompson, PRC 52 (1995) 3505





*W. Geithner, T.Neff et al, PRL **101** 252502 (2008)*



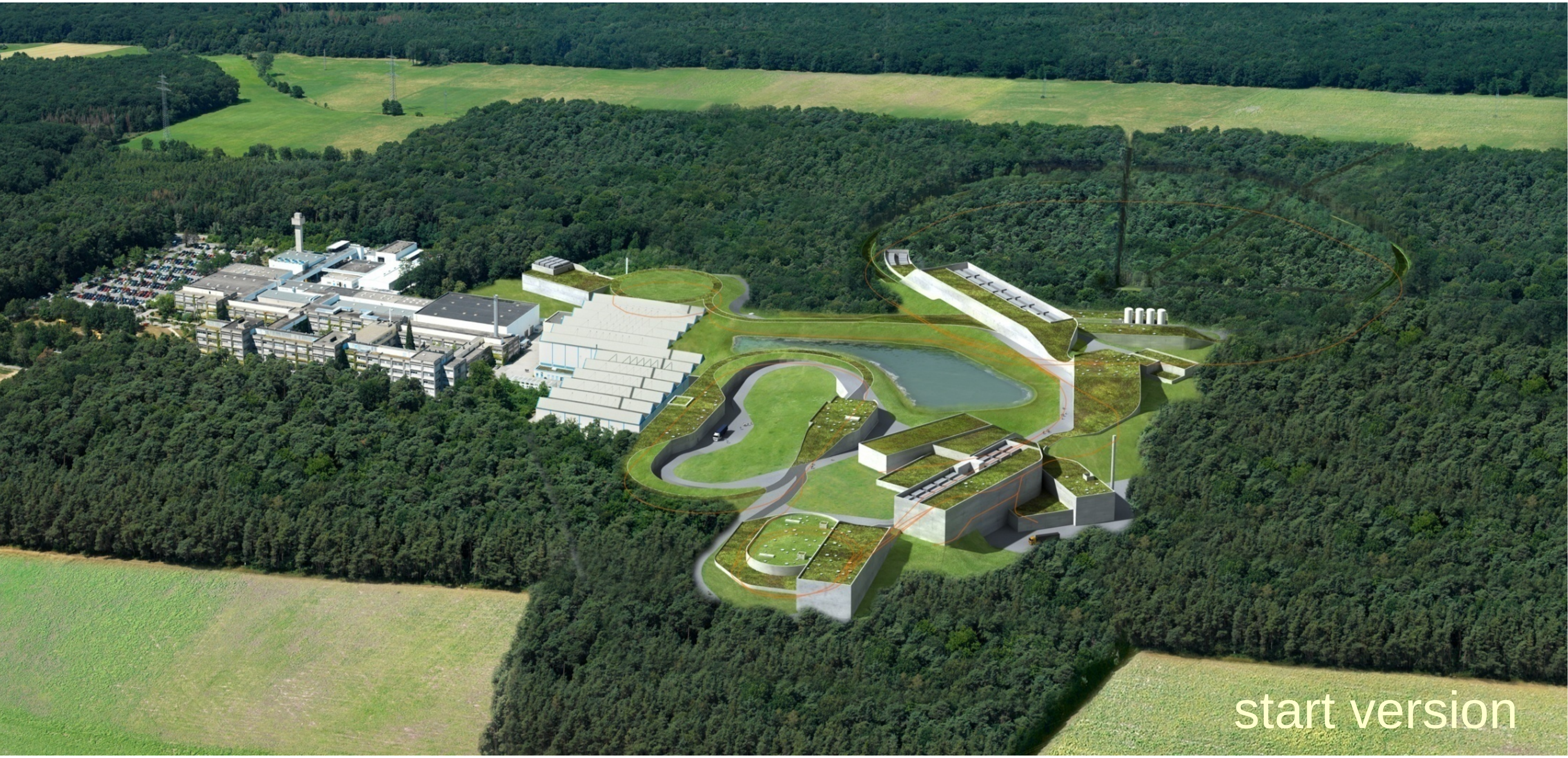
- S_{2p} = 943 keV, S_p = 1479 keV
- $T_{1/2}$ = 109.2 ms (β^+ to ^{17}F)
- Groundstate J^π=1/2$^-$; no bound exc. States

~50% Probability
outside classical forbidden region

- Indirect measurements not always conclusive

Novel Opportunities @ FAIR, RIKEN, FRIB,TRIUMF, GANIL, ...

Ground breaking 20170704



Intensity increase 3-4 orders of magnitude !

NESR is postponed ...

still …

GSI · Planckstraße 1 · 64291 Darmstadt · Deutschland

GSI Helmholtzzentrum für Schwerionen GmbH
Dr. Haik Simon
Kernreaktionen
Planckstraße 1
64291 Darmstadt

FAIR

FAIR
Facility for Antiproton and Ion Research

FAIR Bereichsleitung
Scientific Director FAIR (des.)
Prof. Boris Sharkov

FAIR Project Office
Dr. Simone Richter
Administrative Director FAIR *(des.)*

Telefon +49 6159 71-1555
Fax +49 6159 71-3916
Mobil +49 174 3281417

s.richter@gsi.de

February 26, 2010

Geschäftsführung:
Professor Dr. Dr. h.c. Horst Stöcker
Christiane Neumann
Dr. Hartmut Eickhoff

Vorsitzende des Aufsichtsrates:
Dr. Beatrix Vierkorn-Rudolph
Stellvertreter:
Ministerialdirigent Dr. Rolf Bernhardt

Sitz: Darmstadt
Amtsgericht Darmstadt HRB 1528

VAT-ID: DE 111 671 917
Landesbank Hessen/Thüringen
BLZ 500 500 00 - Konto 50 01865 004
IBAN DE56 5005 0000 5001 8650 04
BIC HELA DE FF

Dear Dr. Simon,

We hereby reconfirm your designation as Machine Coordinator for the following FAIR-Accelerator/Accelerator-related Experiment-Infrastructure:

ER

In spite of the fact that the accelerator/accelerator-related experiment-infrastructure ER is not part of the FAIR Modularized Start Version, the FAIR Management would like to keep all machine coordinators in charge.

We want to keep you fully informed about the next planning steps, so when any of the modules 4 – 6 can be realized, the planning can continue.

Kind regards,

Prof. Boris Sharkov — Dr. Simone Richter — Dr. Dieter Krämer

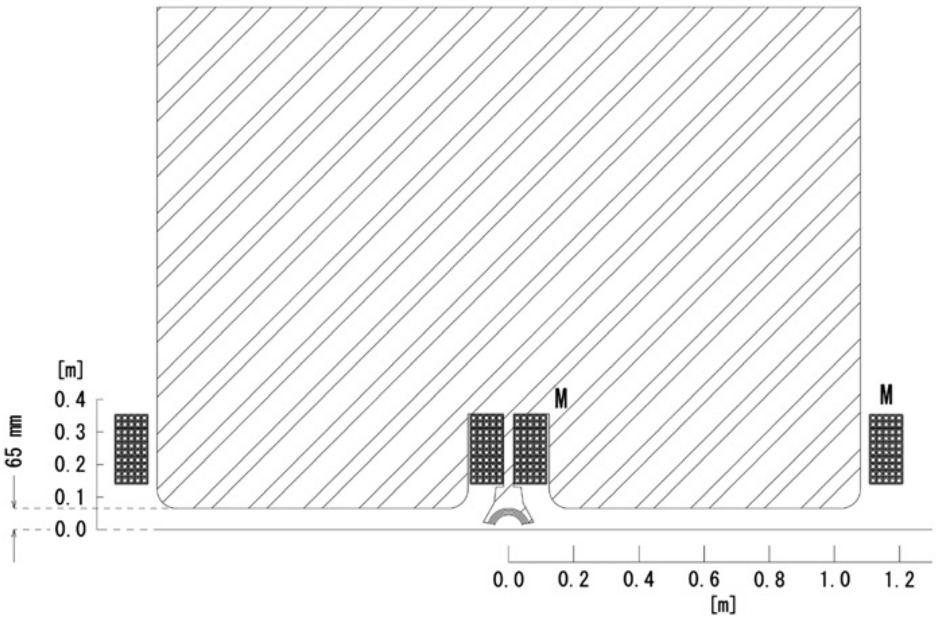
Prof. Zbigniew Majka

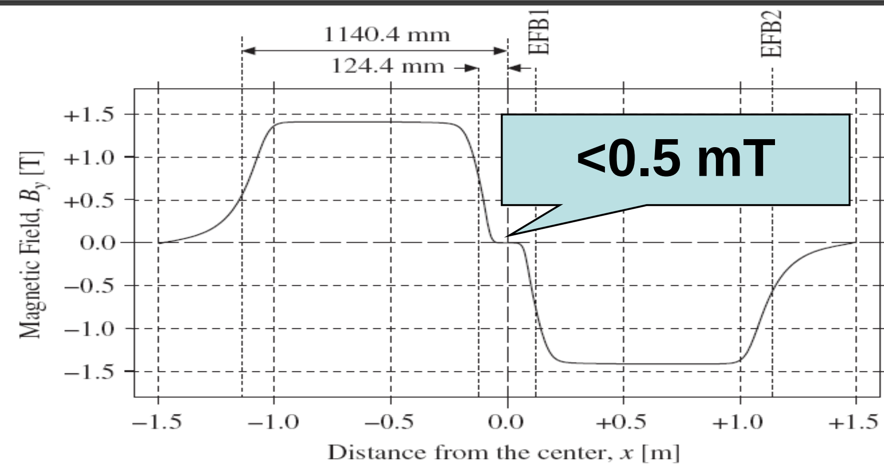
cc: Dr. Thomas Aumann, Prof. Dr. Karlheinz Langanke

HELMHOLTZ GEMEINSCHAFT

Further improvements …

T. Adachi, GPA Berg, et al.



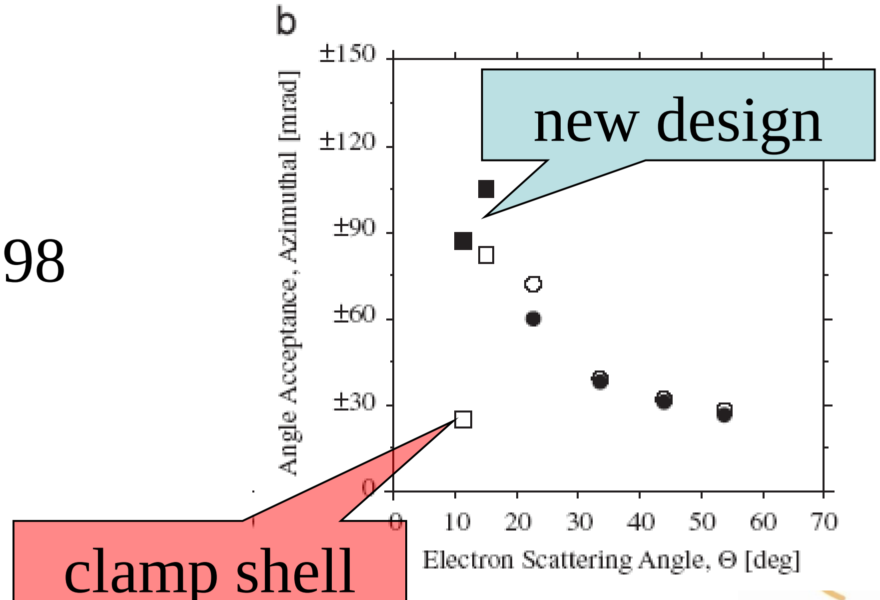


T. Adachi et al.,

Nucl. Inst. Meth. **A659** (2011) 198

doi:10.1016/j.nima.2011.06.081

➔no correction coils needed

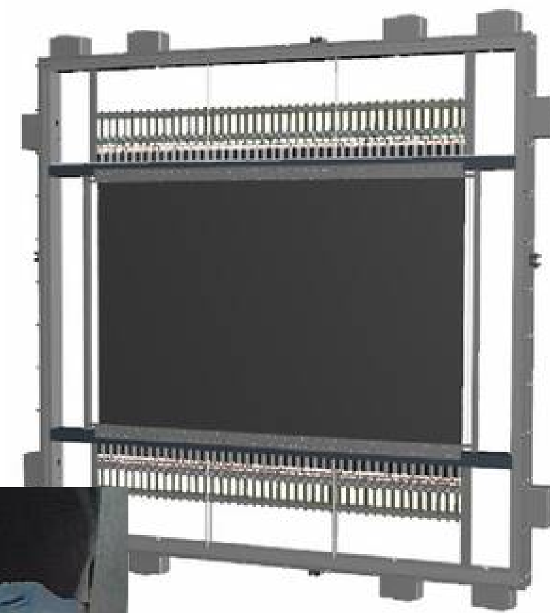


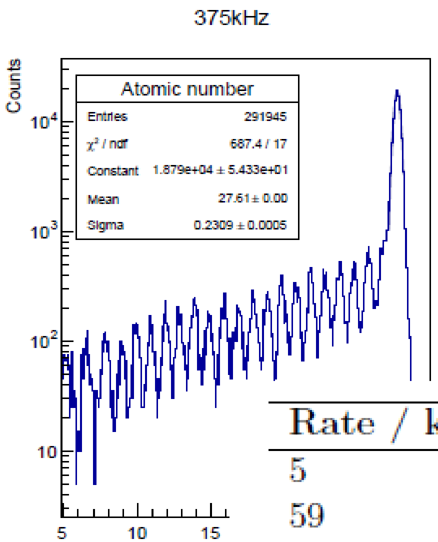
E.g.
R³B Time-of-flight detector prototyping

Performance goals:

- Time resolution σ_t/t = 2E-4
  (⇔ σ_t =20 ps for 20 m flight path at 1 *A*GeV)
- Energy resolution σ_E /E = 1%
- High-counting rate capabilities (~1 MHz)
- Large dynamic range (up to Pb-U).
- FPGA based TDC readout (ΔE via ToT Techniques)

Detector layout





Excellent time and energy resolution at high rates

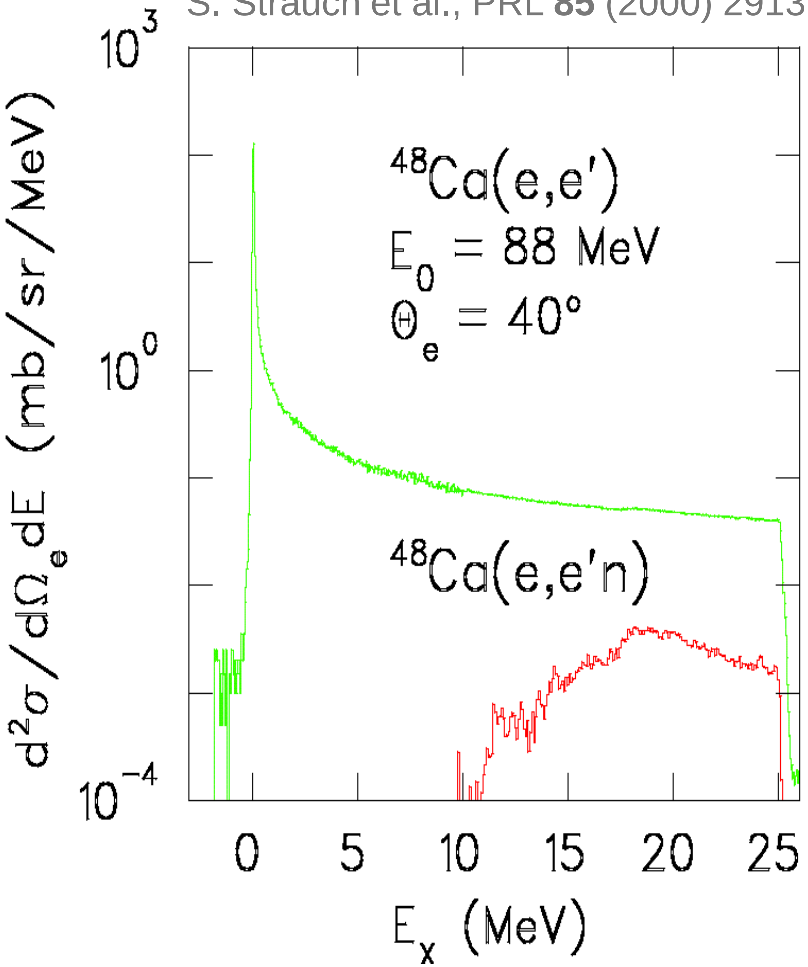
Rate / kHz	σ_t / ps	σ_t^{det} / ps
5	41	14
59	41	14
375	45	16
1000	64	23

Prototype studies @ Cave-C 08/2014 10/2014

Inelastic Scattering @ forward angles

→compared to conventional (fixed target) experiments

S. Strauch et al., PRL **85** (2000) 2913



Fixed target		Collider 1.5GeV
^{48}Ca(e,e'n)		^{48}Ca(e,e'A')
Ω_n =100msr	**100**	Ω_n ~ 4π
n_{eff} =20 %	**5**	n_{eff} ~ 100 %
$\Theta_{e'}$ = 40 °	**50**	**$\Theta_{e'}$ = 5 °**
	$\geq 10^4$	
L=10^{31} - 10^{32}	cm^{-2} s^{-1}	**L ~ 10^{27}**

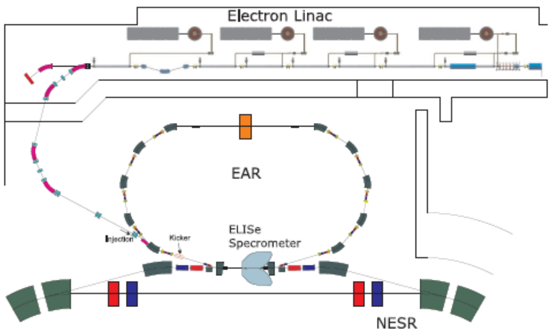
GSI

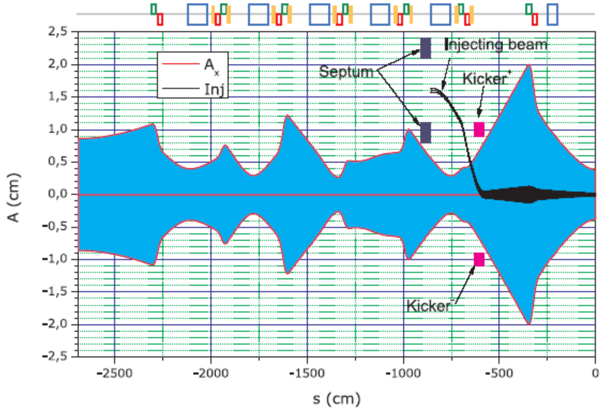
➔ Large gain through kinematics

Associated LINAC and injection scheme

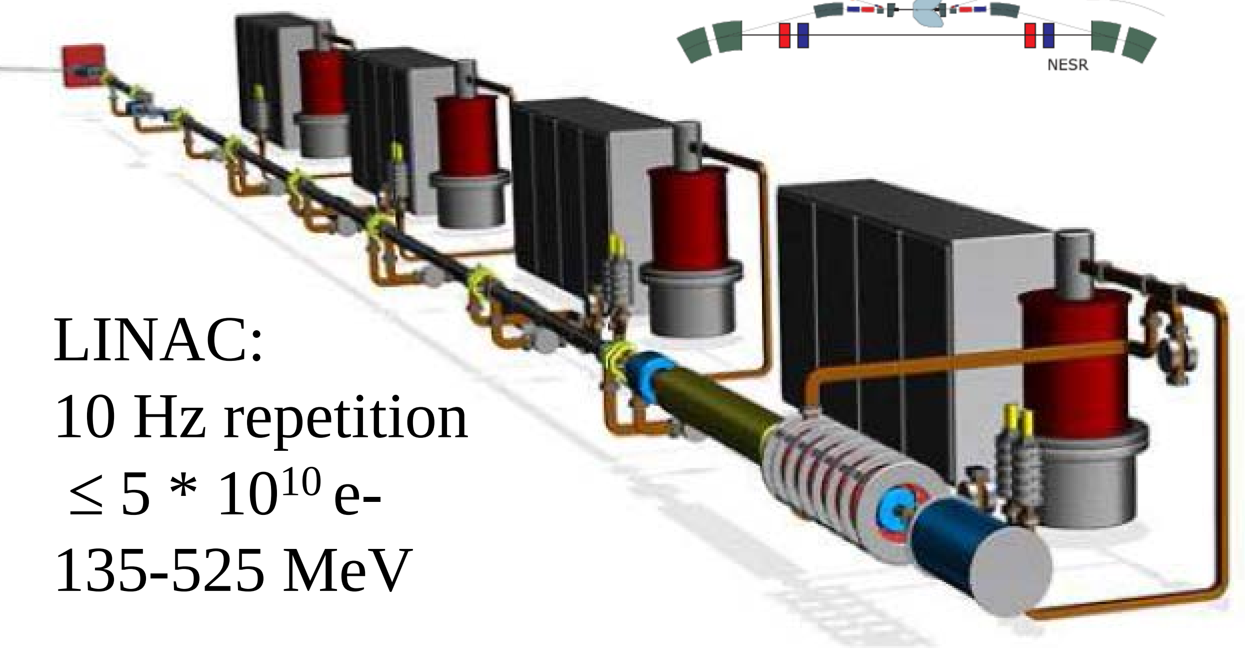
P. V. Logachev, D. Shwartz, P. Shatunov, I. Koop BINP/Novosibirsk

INTAS open call 2005 -2007/ FRRC 2009-

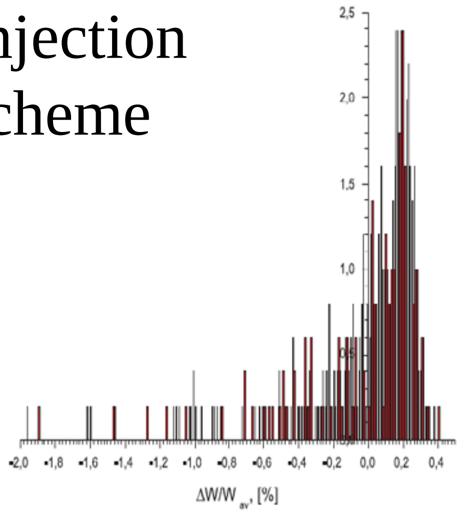




Injection scheme



LINAC:
10 Hz repetition
$\leq 5 * 10^{10}$ e-
135-525 MeV



Paper in preparation

& Interaction region design

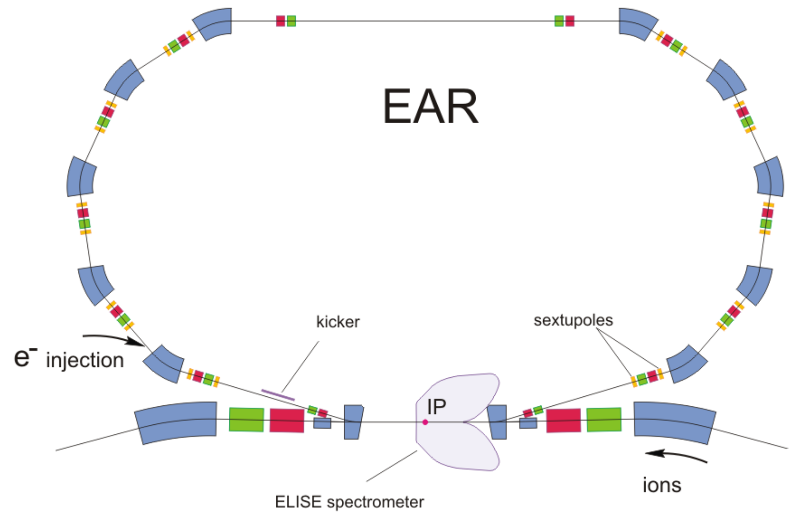
Design of the associated interaction zone

D. Shwartz, P. Shatunov, I. Koop BINP/Novosibirsk

INTAS open call 2005 -2007/ FRRC 2009-

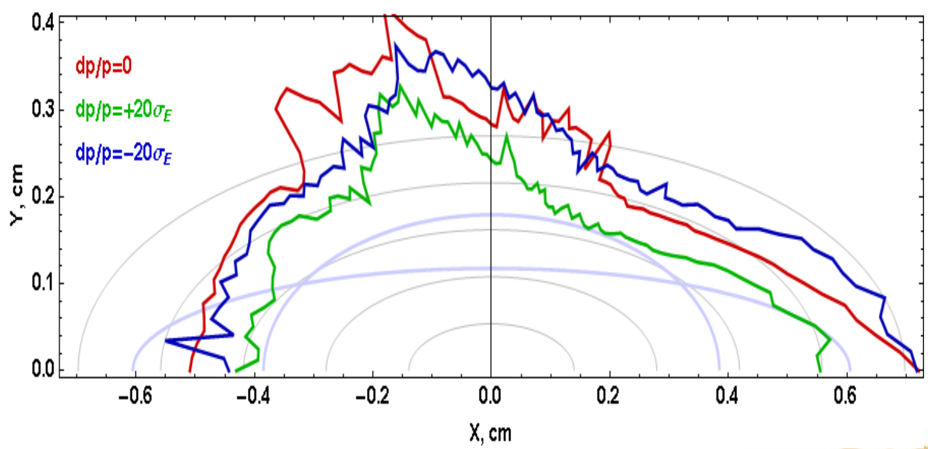
Overlap of the two beams
150µm × 60µm

Emittances 50 µm·mrad



+- 1.5% momentum acceptance and dynamic apperture

Accepted cone
+- 20 mrad for fission fragments …



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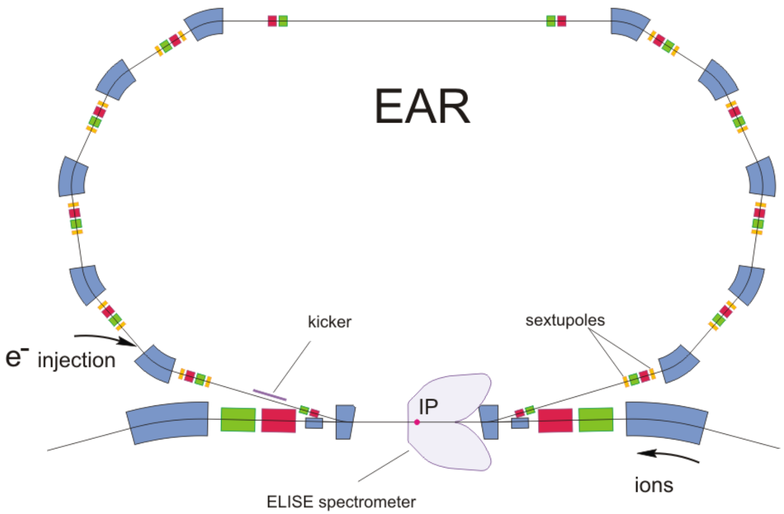
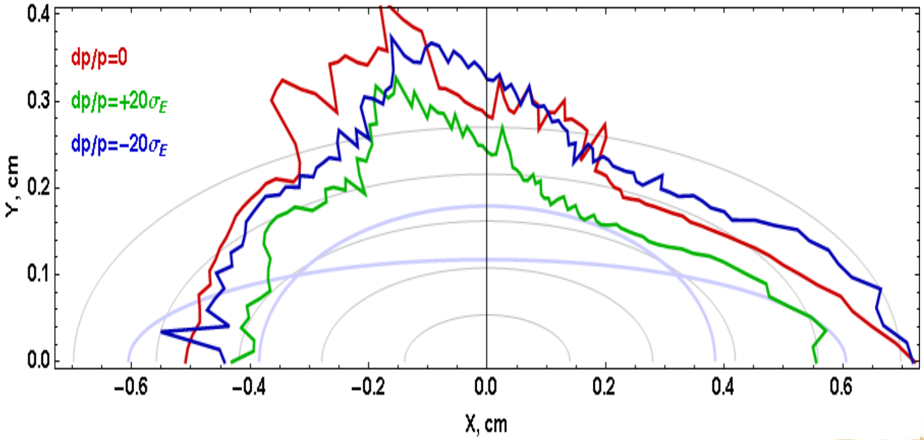
FAIR

Design of the associated interaction zone

D. Shwartz, P. Shatunov, I. Koop BINP INTAS open call 2005 / FRRC

- Overlap of the two beams 150µm × 60µm
- Emittances 50 µm·mrad
- +- 1.5% momentum acceptance and dynamic apperture
- Accepted cone +- 20 mrad for fission fragments …





Example:ToF set-up

➔ prototype SOFIA@R³B-CaveC

J. Taieb et al., CEA Bruyères-le-Châtel

- Most demanding part : 35ps FWHM needed

  S. Nishimura et al., Nucl. Inst. Meth. A510 (2003)377

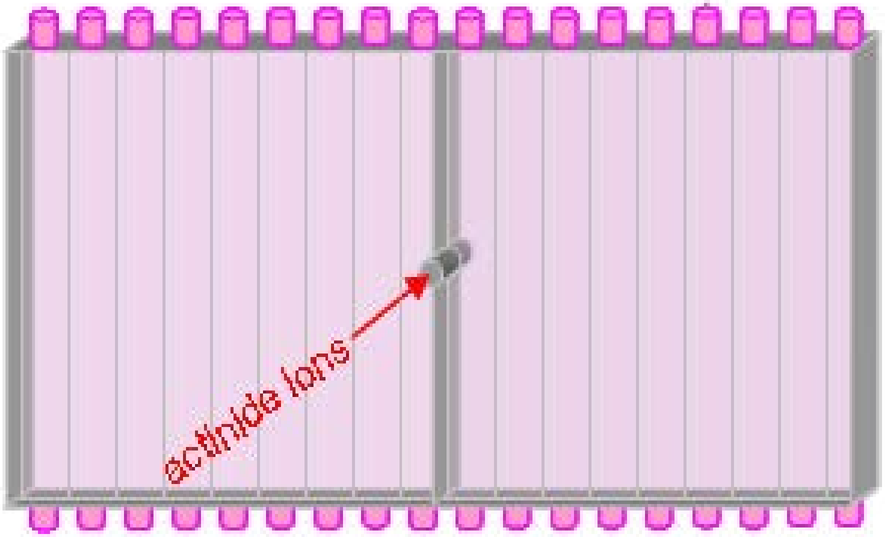
- Very fast plastic stripes

  (Eljen Technology: EJ-323 0.25% quenched 43ps rise time)

  - T_2 : 30 x 150 x 0.5 mm^3 (2 x   5 paddles)
  - T_3 : 30 x 300 x 0.5 mm^3 (2 x 10 paddles)

- Fast PMT (H6533)

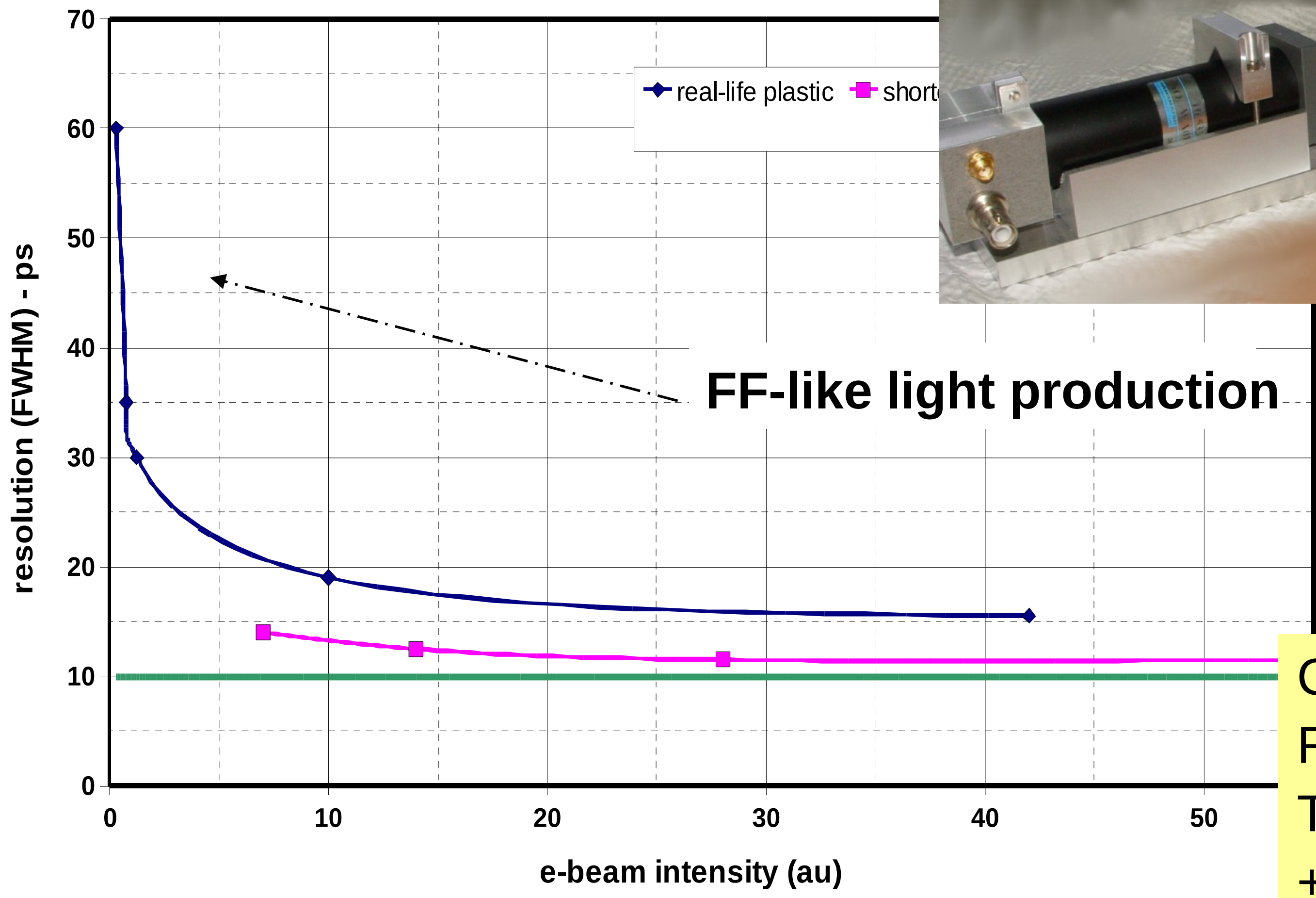
- No light guide/grease

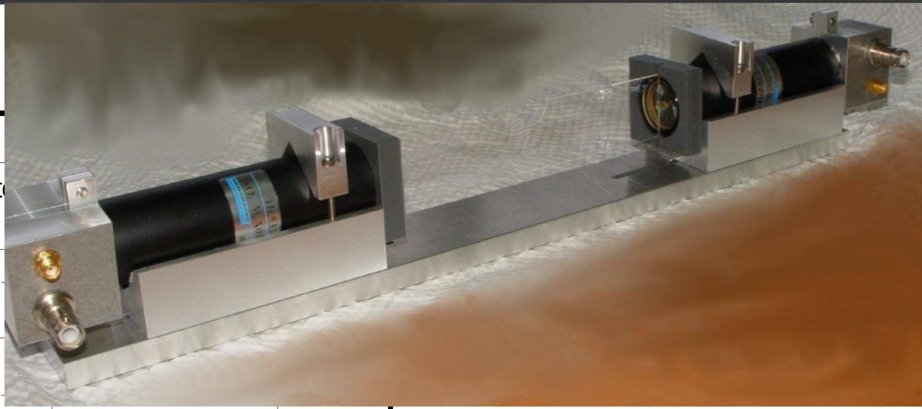


GSI

First test: ToF resolution

J. Taieb et al., CEA Bruyères-le-Châtel





Compatible

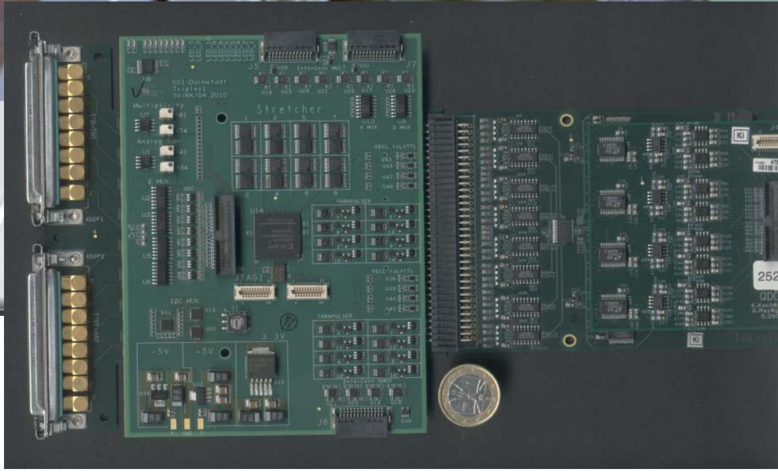
Readout electronics:

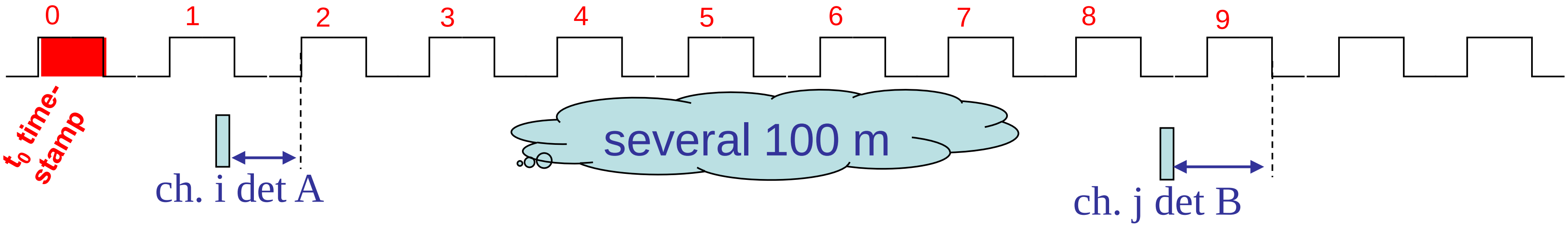
TACQUILA

+ BuTiS/White Rabbit TDS

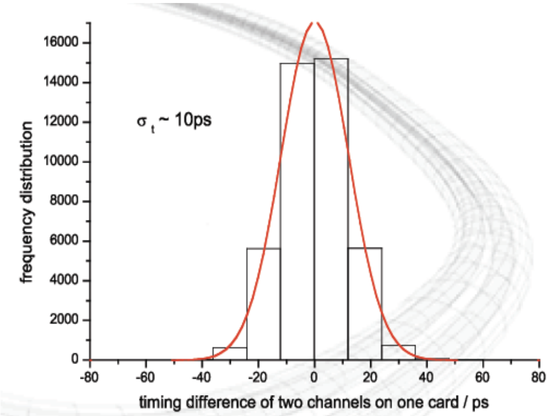
Precision timing (<50ps) vs. Campus Clock

J. Hoffmann, K. Koch, N. Kurz, W. Ott
P. Moritz, C. Caesar, H.S.



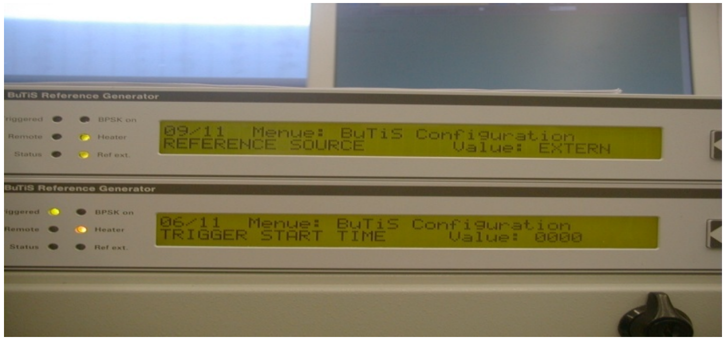


- synchronized precision oscillators 17ps R.M.S (abs.100ps/km, <1ps jitter)



Tacquila system (ASIC FhG/GSI)

New systems (ASIC dev. GSI FPGA based TDC)

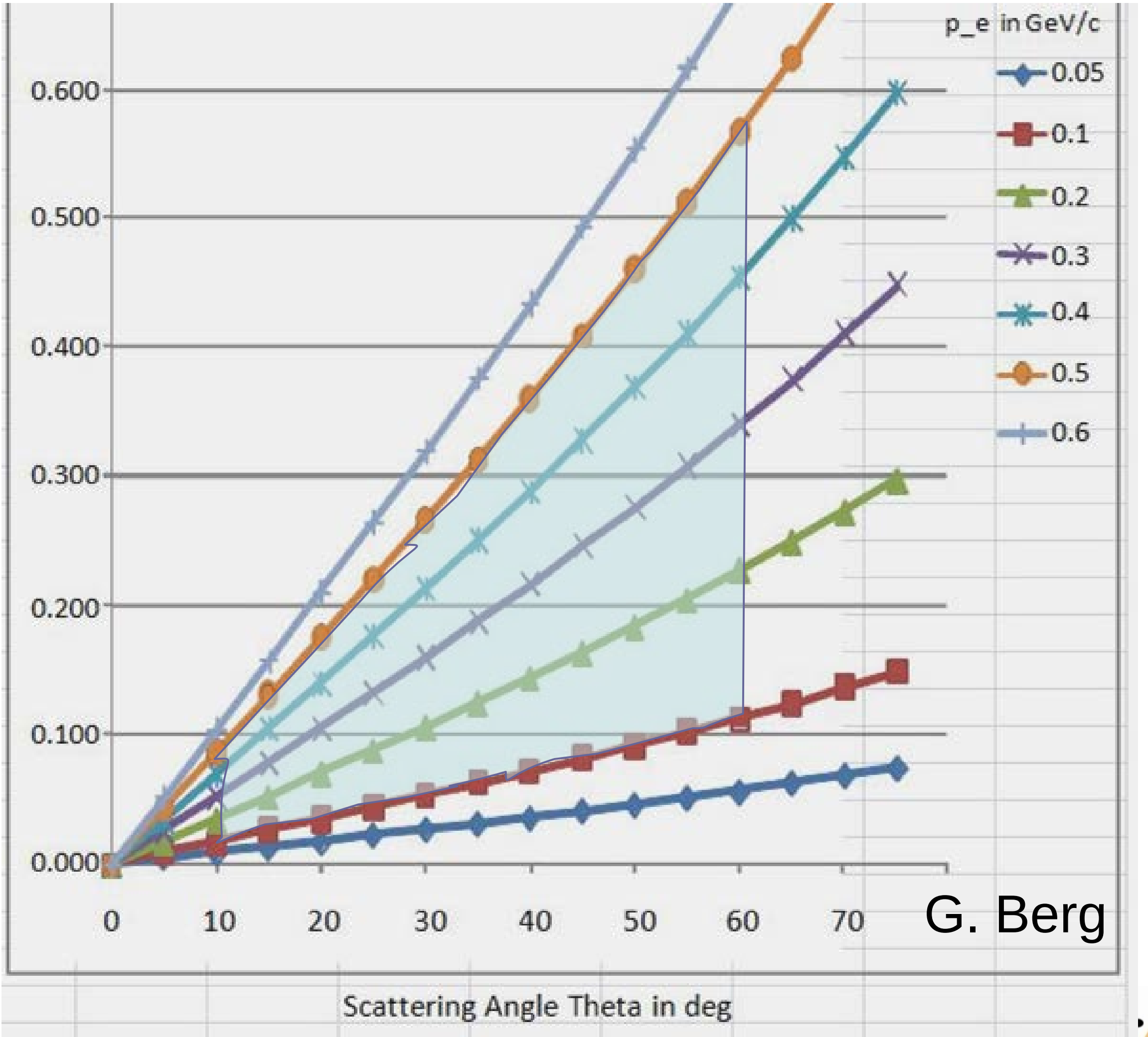


… you can measure ToF over long distances !

FAIR

Kinematic Range

Momentum Transfer:
q: 20 to 600 MeV/c



Quasielastic scattering

→ 2nd generation experiment

- Not hampered by nuclear reaction mechanism; like (d,^{3}He) or (p,2p)

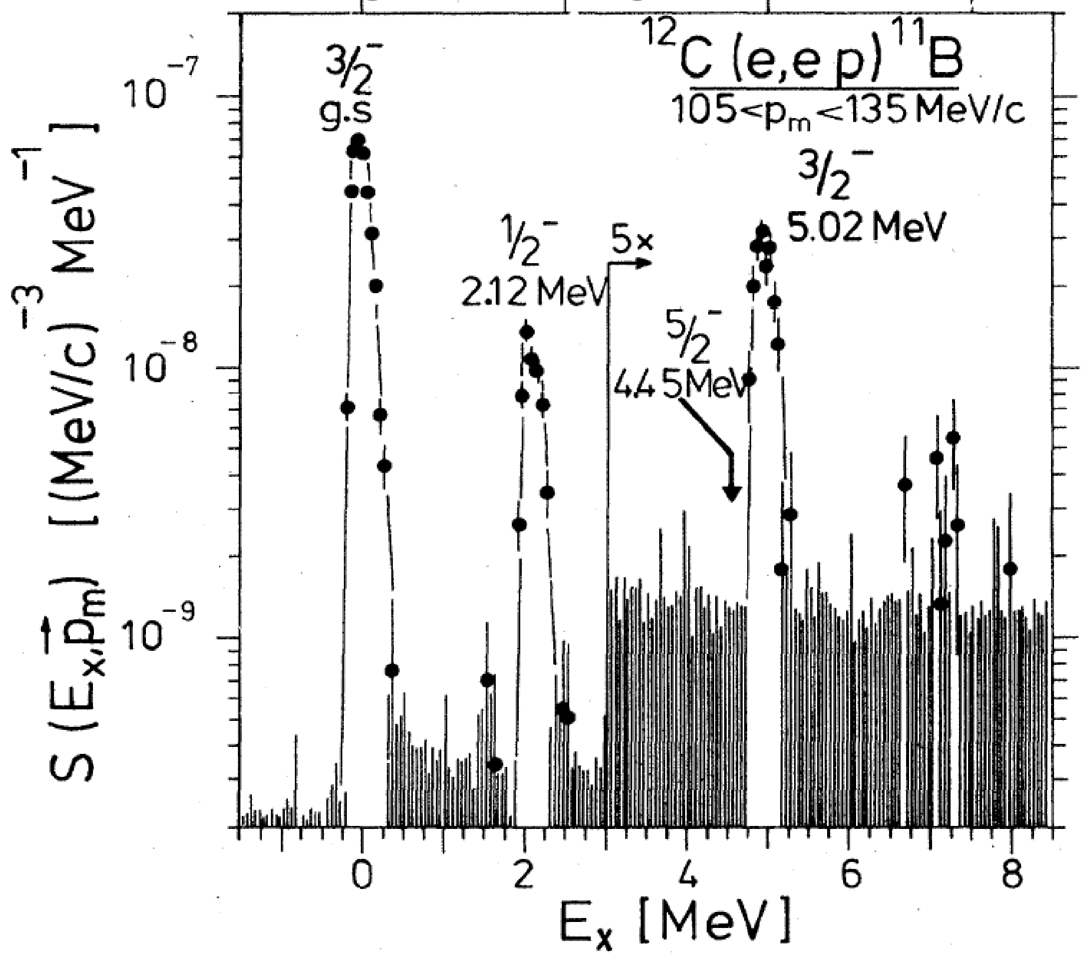
➔ spectroscopic factors / spectral functions

- Spectrometer resolution requirements moderate

- cross sections small (μb)

- Rates: 0.1-10/s ($10^{28..29}$cm^{-2}s^{-1})
  3 days 25-2500 kEv.

15mg/cm² C target / res. 300keV



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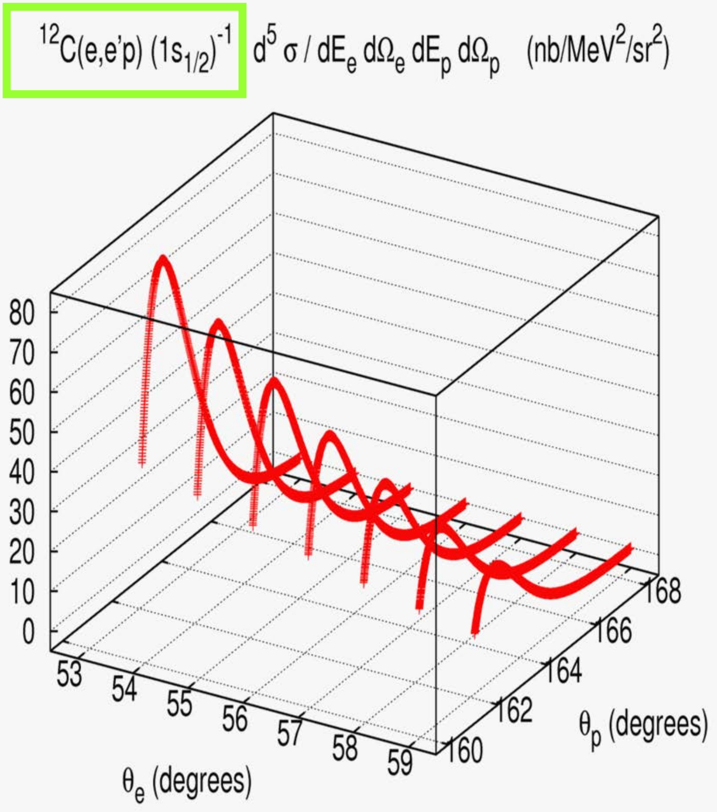
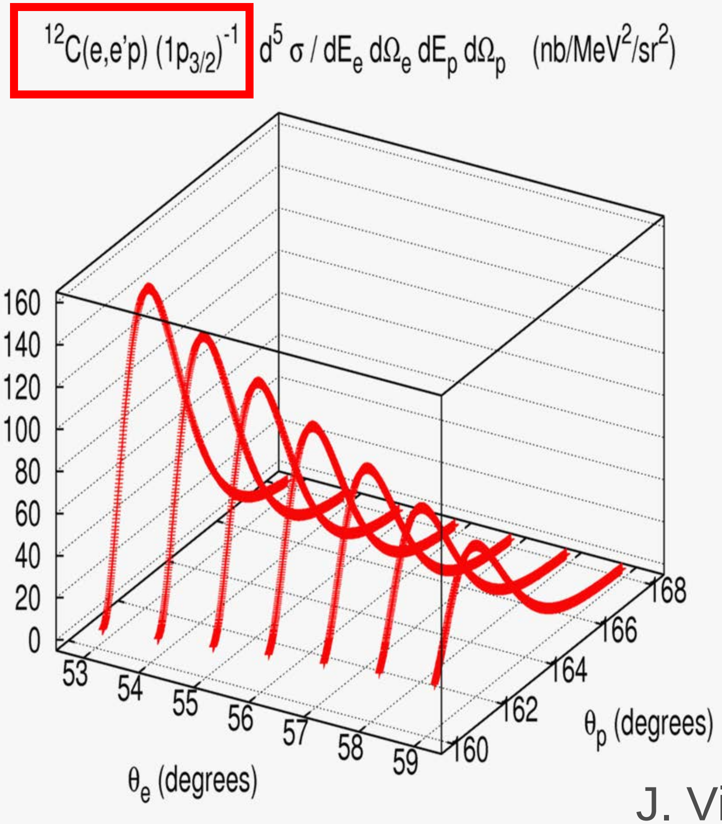
Cross section





J. Vignote

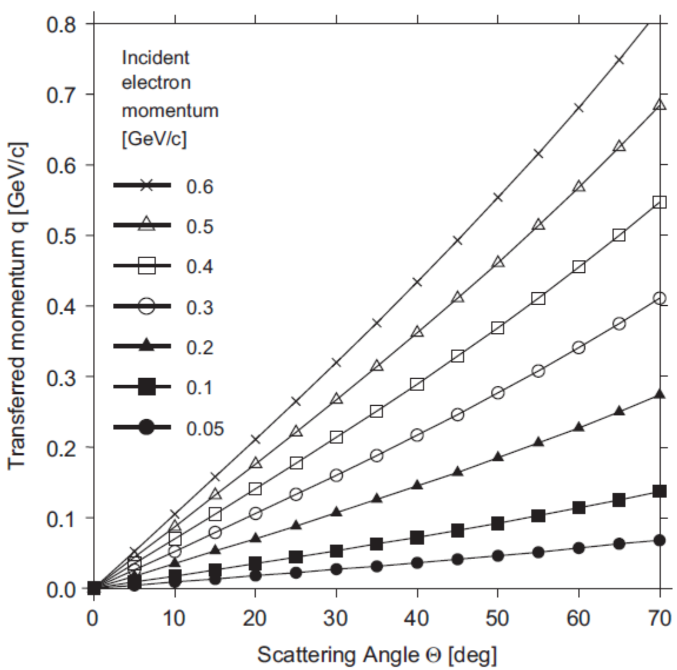
➔ proton detection [160,164]°

Kinematics

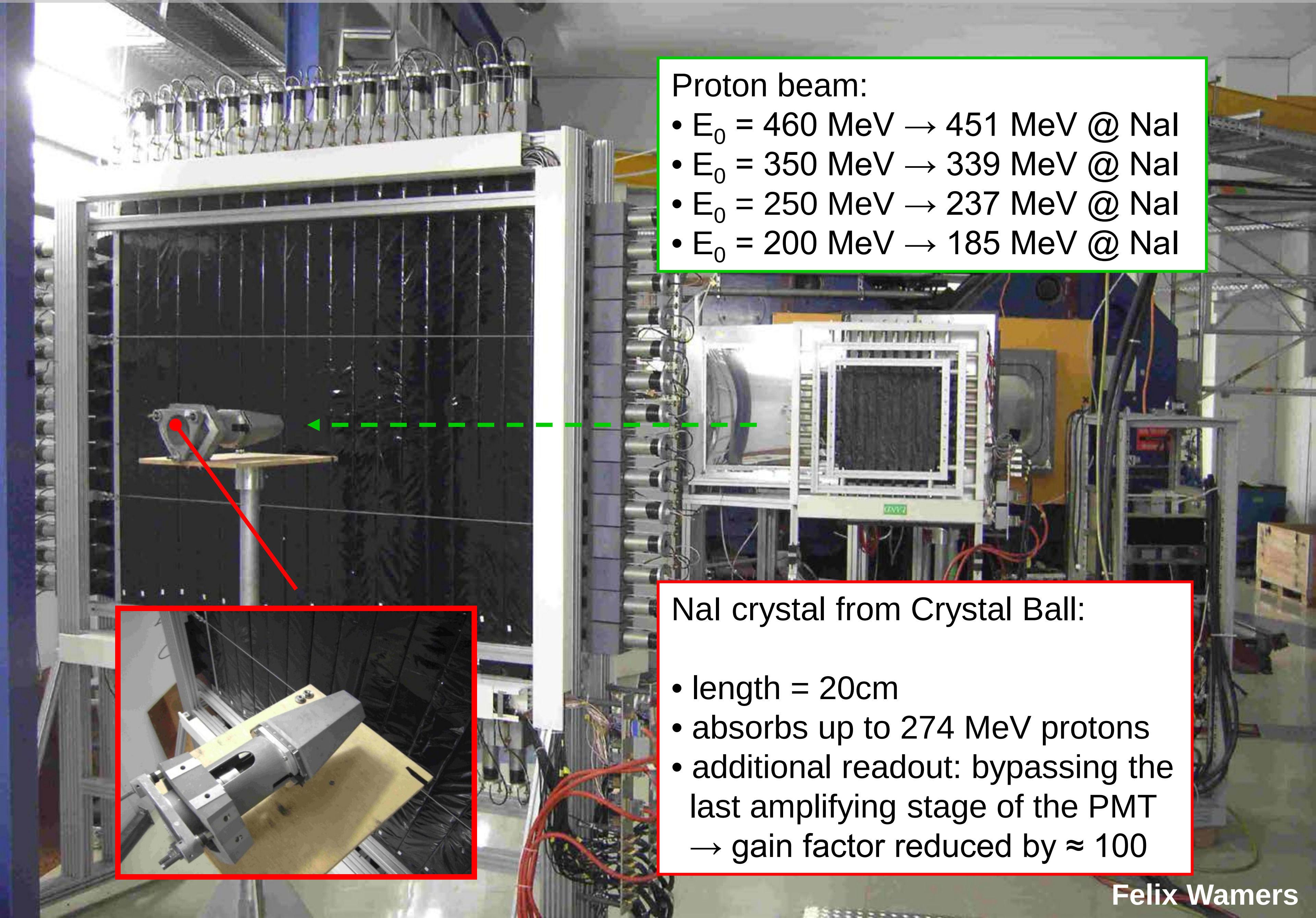
$\beta = p_A / E_A, \quad \delta = \sqrt{(1-\beta)/(1+\beta)}$ = 0.3 @ 740 AMeV/500MeV

➔ Electron scatt. @1.64 GeV

Fixed target	Collider
Conventional kinematics ($\beta = 0$)	Counter-propagating beams ($\beta > 0$)
Scattered electron momentum	
$p_{e'} = \dfrac{p_e - E^*}{1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}}$	$p_{e'} = \dfrac{p_e - \delta E^*}{1 + 2\frac{p_e - p_A}{M}\delta\sin^2\frac{\theta}{2}}$
Momentum transfer	
$q^2 = \dfrac{4p_e^2\sin^2\frac{\theta}{2}}{1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}}$	$q^2 = \dfrac{4p_e^2\sin^2\frac{\theta}{2}}{1 + 2\delta\frac{p_e - p_A}{M}\sin^2\frac{\theta}{2}}$
Resolution (momentum dependence)	
$\Delta E^* \approx -\left(1 + 2\frac{p_e}{M}\sin^2\frac{\theta}{2}\right)\Delta p_{e'}$	$\Delta E^* \approx -\left(\frac{1}{\delta} + 2\frac{p_e - p_A}{M}\sin^2\frac{\theta}{2}\right)\Delta p_{e'}$
Resolution (angular dependence)	
$\Delta E^* \approx -\frac{p_e p_{e'}}{M}\sin\theta\Delta\theta$	$\Delta E^* \approx -\frac{(p_e - p_A)p_{e'}}{M}\sin\theta\Delta\theta$



R³B: Energy of a proton beam measured with a NaI crystal



Proton beam:

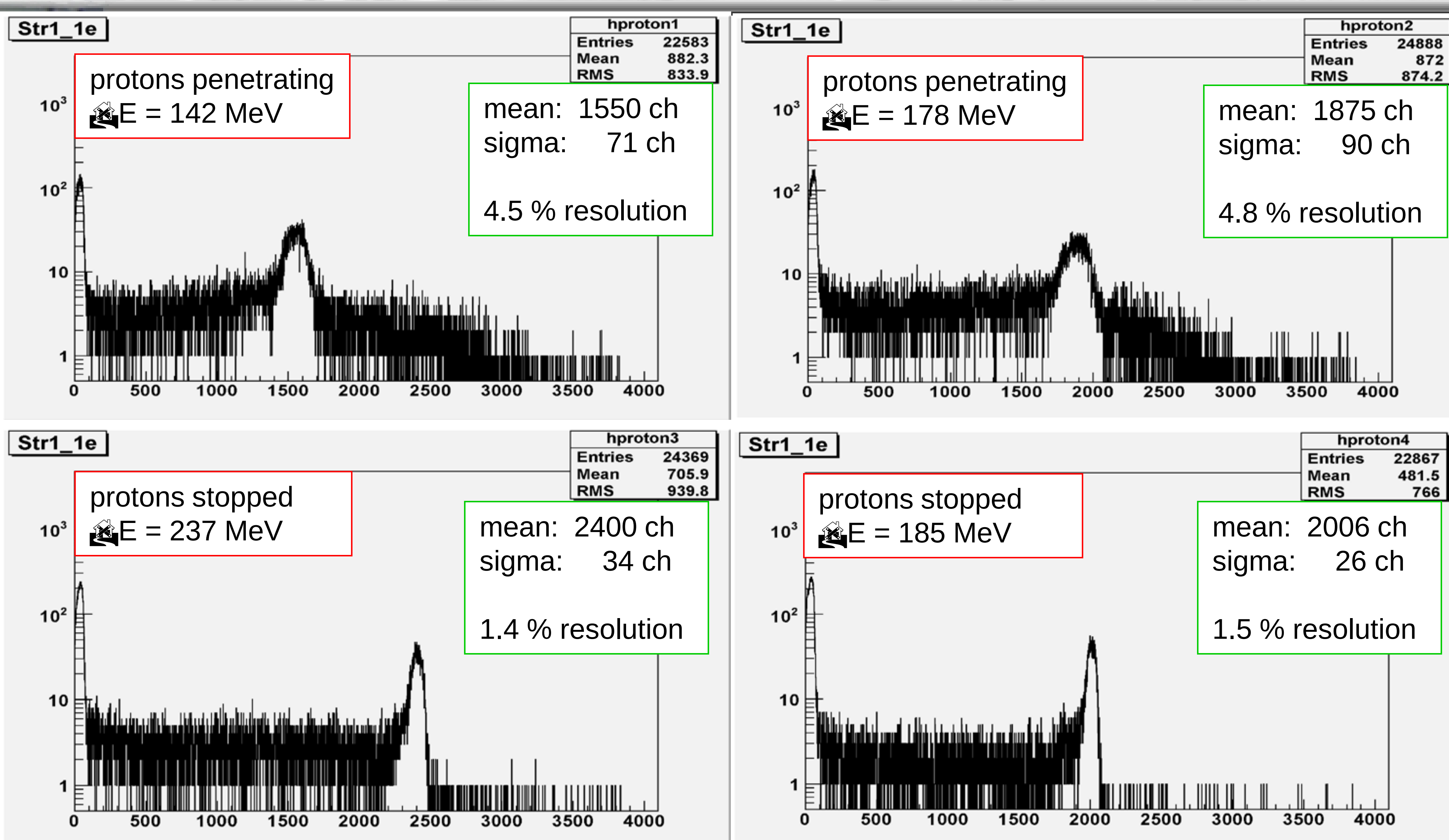
- E_0 = 460 MeV → 451 MeV @ NaI
- E_0 = 350 MeV → 339 MeV @ NaI
- E_0 = 250 MeV → 237 MeV @ NaI
- E_0 = 200 MeV → 185 MeV @ NaI

NaI crystal from Crystal Ball:

- length = 20cm
- absorbs up to 274 MeV protons
- additional readout: bypassing the last amplifying stage of the PMT → gain factor reduced by ≈ 100

Felix Wamers

Raw spectra of protons in NaI crystal



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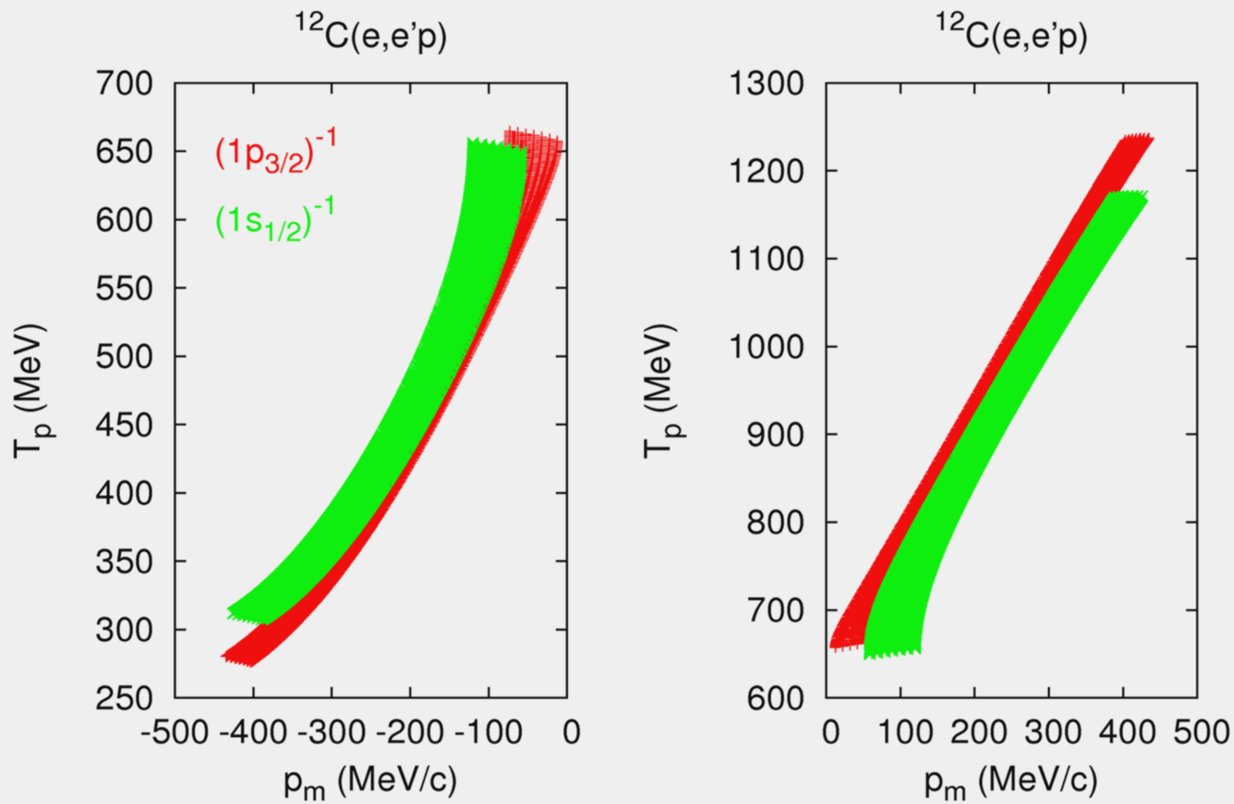
Resolution concerns ...

- negative p_m: 1:1 correlation T_p resolution corresponds to achievable E_m resolution.
- positive p_m: T_p resolution can be about twice worse



GSI

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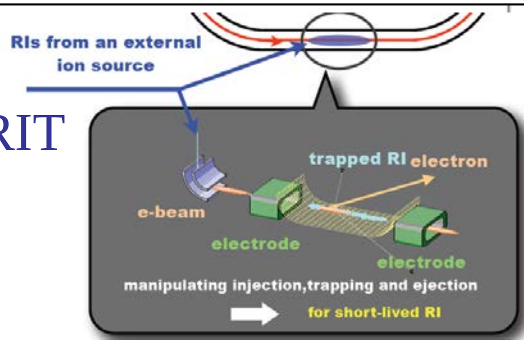
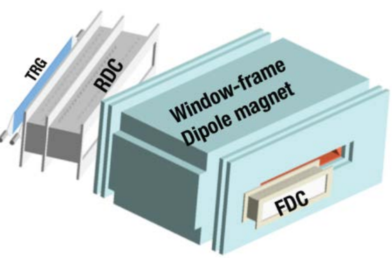
Electron energy : 150 - 700 MeV
stored current : 300 mA (as of today)
beam life time : 2 hours

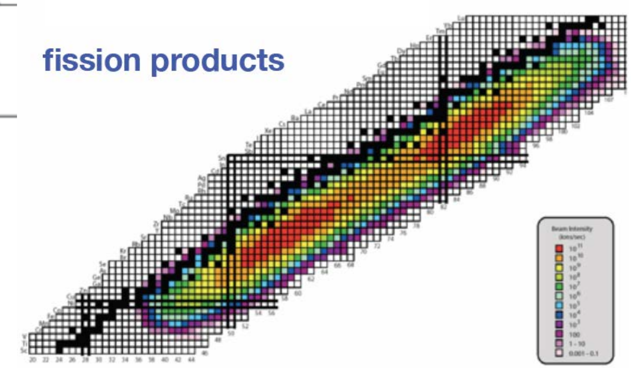
RTM : Race Track Microtron
injector + ISOL driver
150MeV/0.5 mA peak/2 μs pulse

Self Confining RI Target / SCRIT



$\Delta p/p \sim 10^{-3}$
$d\Omega \sim 100 msr$



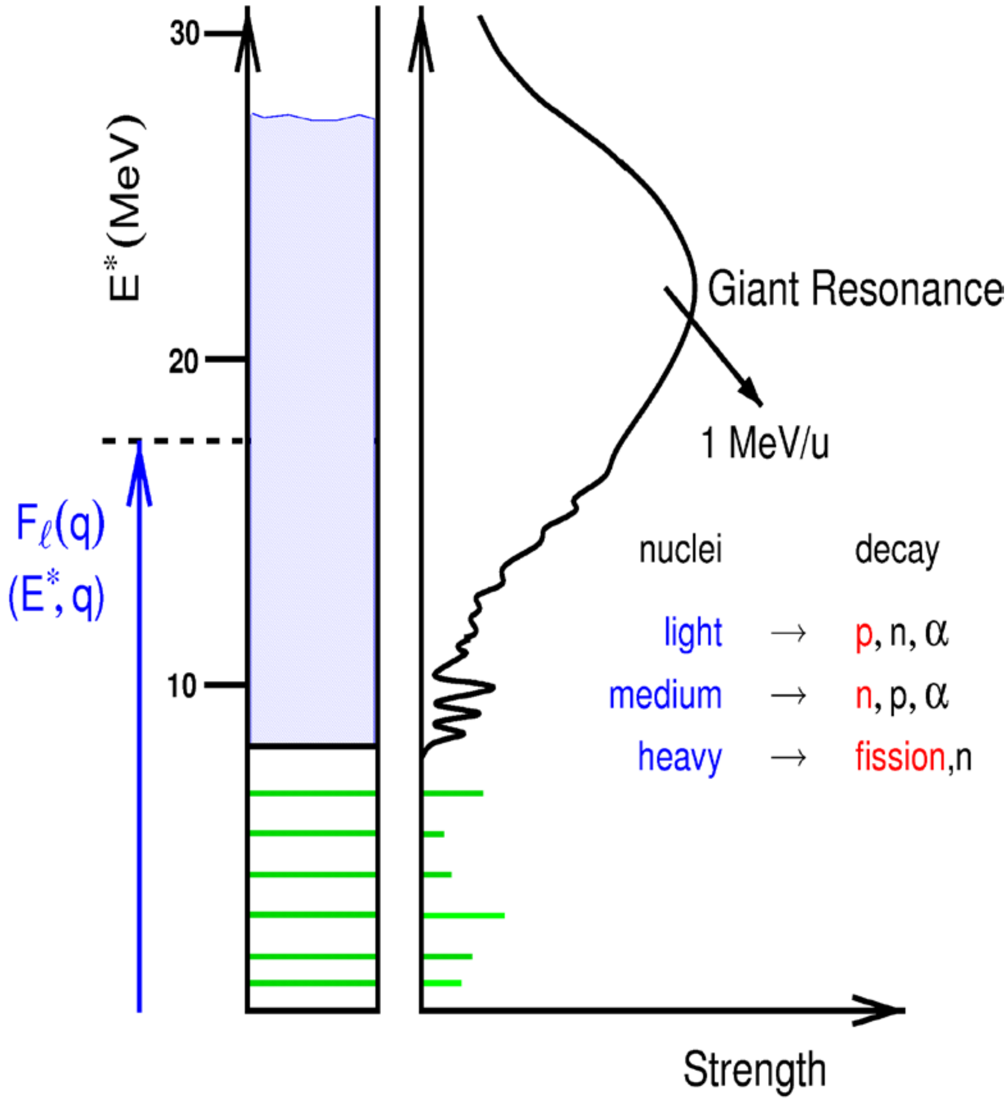


10^{26}	10^{27}	10^{28}	10^{29}	10^{30}	10^{31}	10^{32}

(/cm²/s)

elastic scattering · as of today · inelastic scattering · Giant Resonance · quasi-elastic (e,e'p) · magnetic scattering

Inelastic scattering in the eA collider



- Excitation energy is measured directly
  (below and above particle tresh.)
- momentum transfer ➔ multipolarity of transition can be determined
- final state identification with very high efficiency
  (e,e'X) ➔ (e,e' A') ➔
  suppression of elastic radiative tail (no background)

➔Full measurement with purely electromagnetic probe
(no nuclear background as in Coulomb excitation)