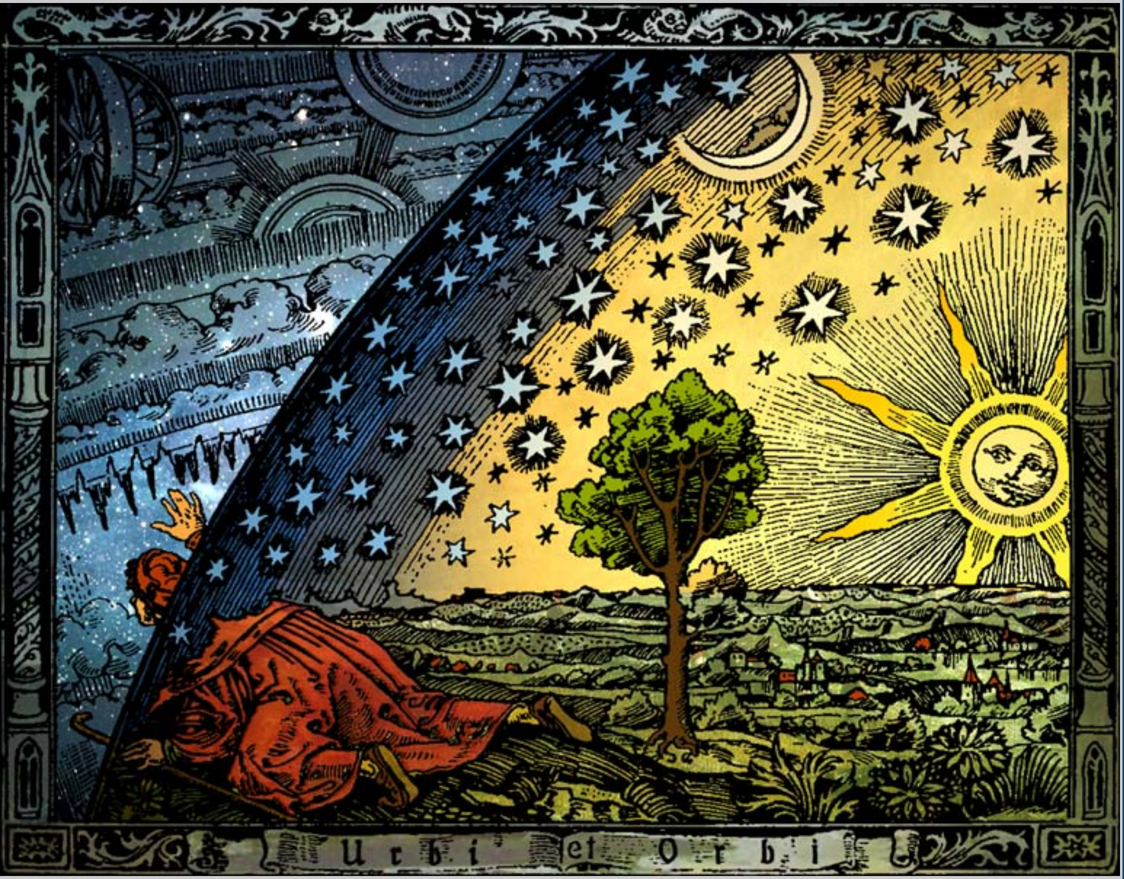
Status of the ELISE Project
-- electron scattering off RIBs



H. Simon • GSI Darmstadt

53. International Winter Meeting on **Nuclear Physics**
Jan 26th – 30th, 2015
Bormio, Italy

Electron scattering off RIBs -a few good reasons

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

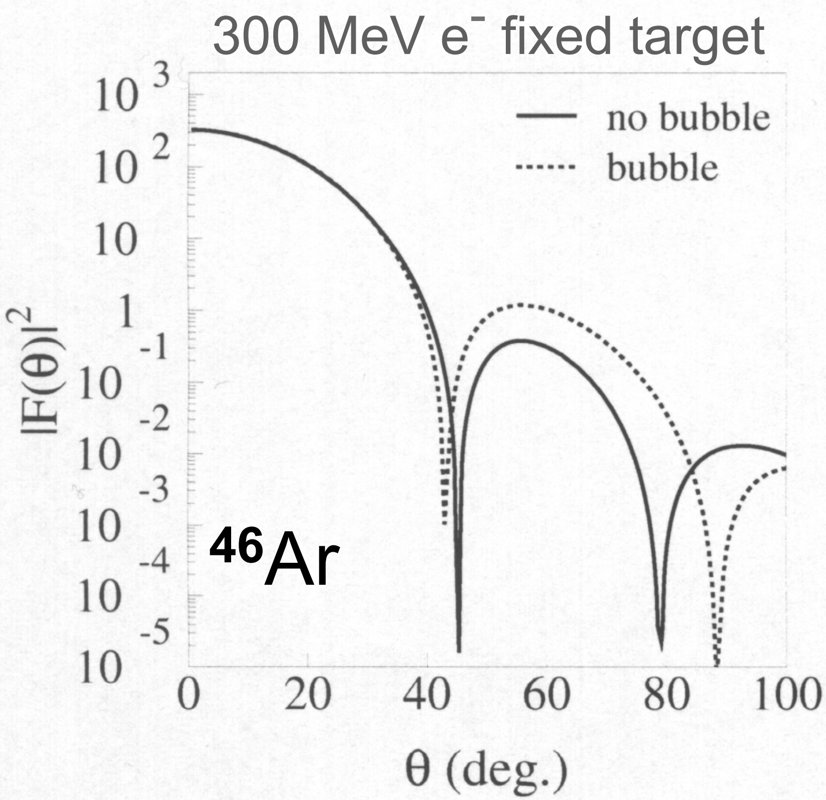
2. Sensitivity to charge distributions
   - higher moments of charge distributions (density ↔ wf.)
   - absolute charge radii (ab initio calculations)

   → Deformation vs. Clustering for (very) proton-neutron asymmetric nuclei
     (not accessible in conventional methods)

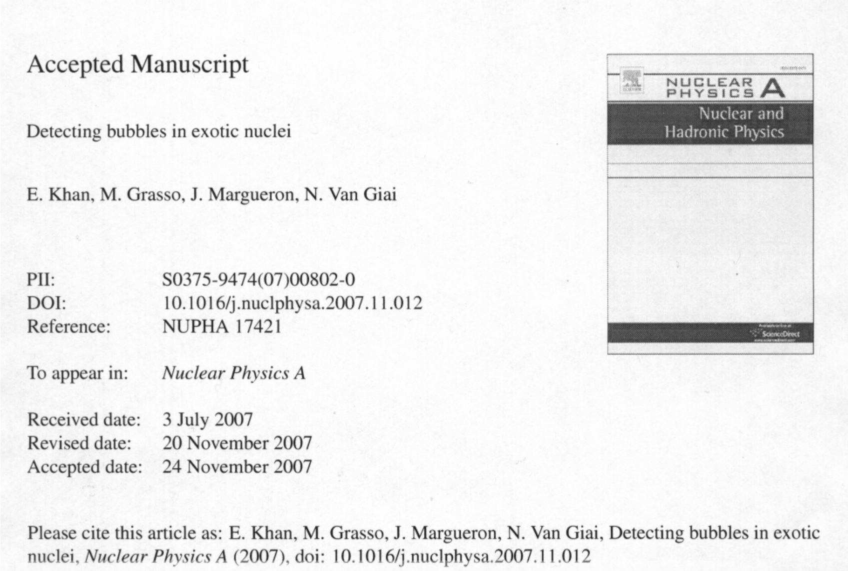
3. Transition form factors
   - additional information to plain spectroscopy

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
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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)

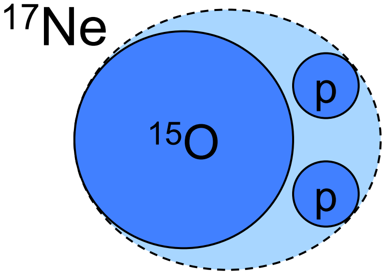
$L = 2.7 \times 10^{28}$ cm^{-2} s^{-1}

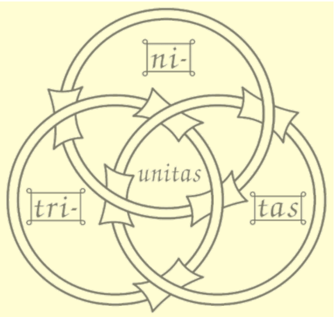
→ Absolute measurement
→ Charge distributions

… vs. valence or surface structure.

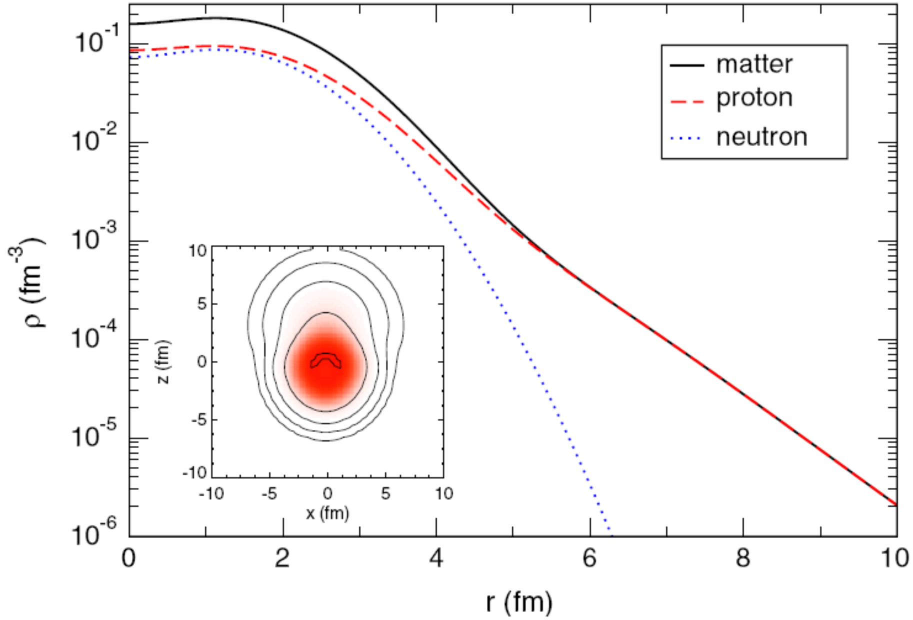
"^{17}Ne is a proton-dripline nucleus,
with strong indications of having a 2p – halo"

*Zhukov & Thompson, PR**C** 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 $J^{\pi}=1/2^-$; no bound exc. States

~50% Probability
outside classical forbidden region

- Indirect measurements not always conclusive

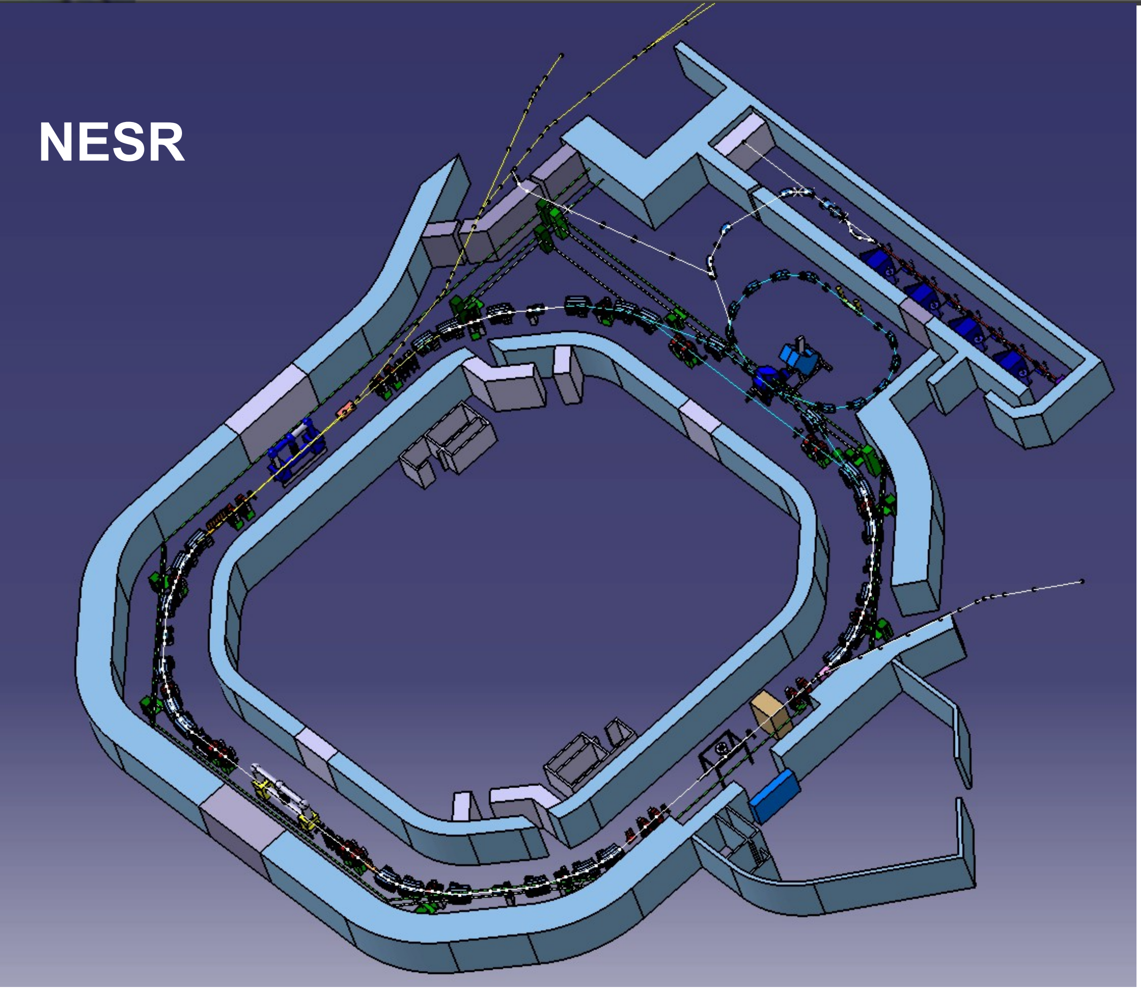
Novel Opportunities @ FAIR

Intensity increase 3-4 orders of magnitude !

Realization of an RIB electron collider setup

The ELISe experiment

Haik Simon • GSI / Darmstadt



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

➔ up to 1.5 GeV CM energy

- spectrometer setup at the interaction zone & detector system in ring arcs

- Part of the core facility

http://www.gsi.de/fair/reports/btr.html

AIC option:

- 30 MeV antiprotons

- detector system in ring arcs
- schottky probes

Competing Project: SCRIT (@RIBF with own ISOL)
- proposal 2005 (!) → RIB 2014

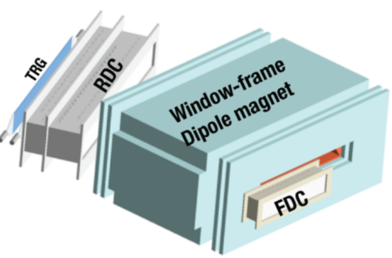
Courtesy T. Suda / Sendai

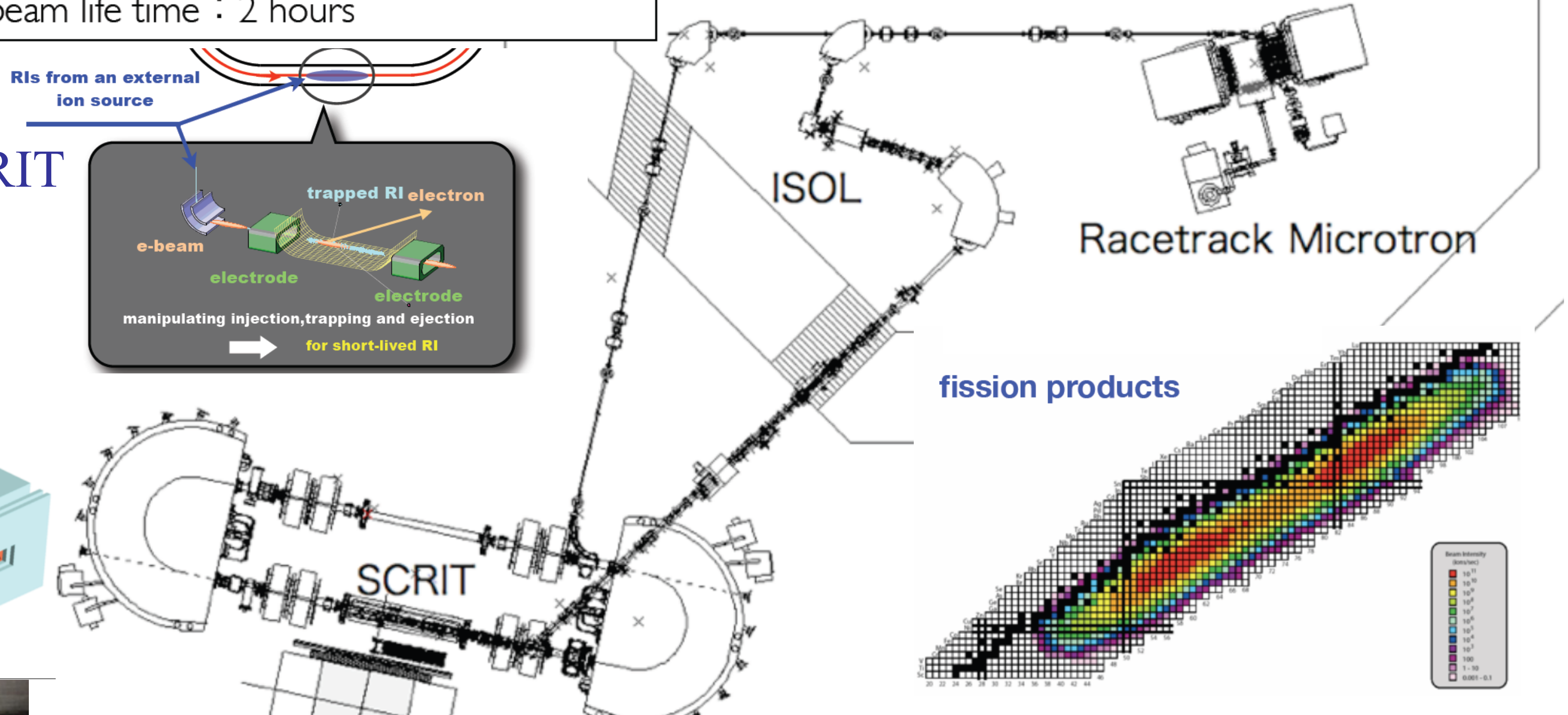
Electron energy : 150 - 700 MeV
stored current : 300 mA (as of today)
beam life time : 2 hours

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





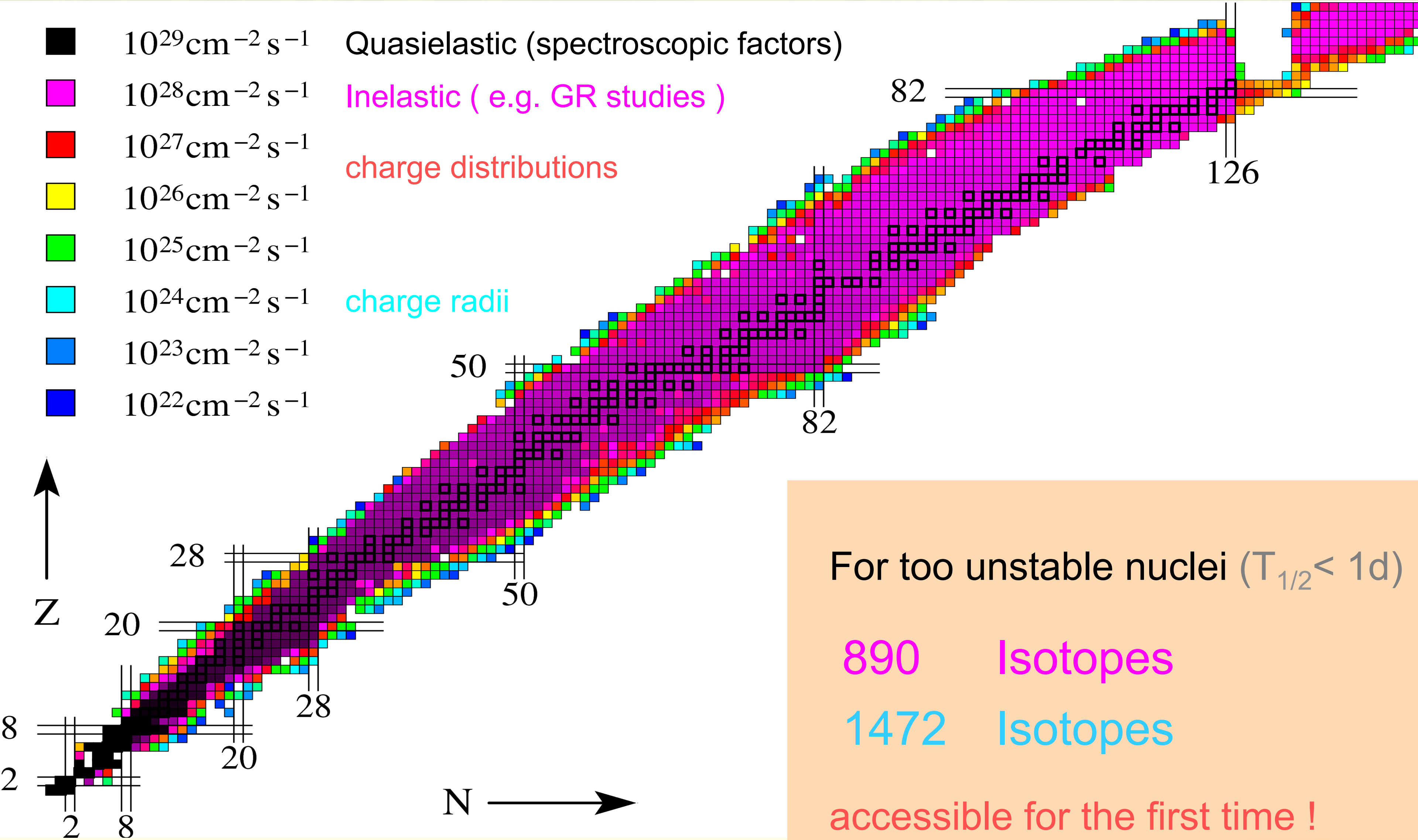
10^{26}	10^{27}	10^{28}	10^{29}	10^{30}	10^{31}	10^{32}

(/cm²/s)

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

Expected Luminosities (NESR)

➔ Full simulation of production, transport and storage



For too unstable nuclei ($T_{1/2}$< 1d)

890 Isotopes

1472 Isotopes

accessible for the first time !

Why should one try to collide 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

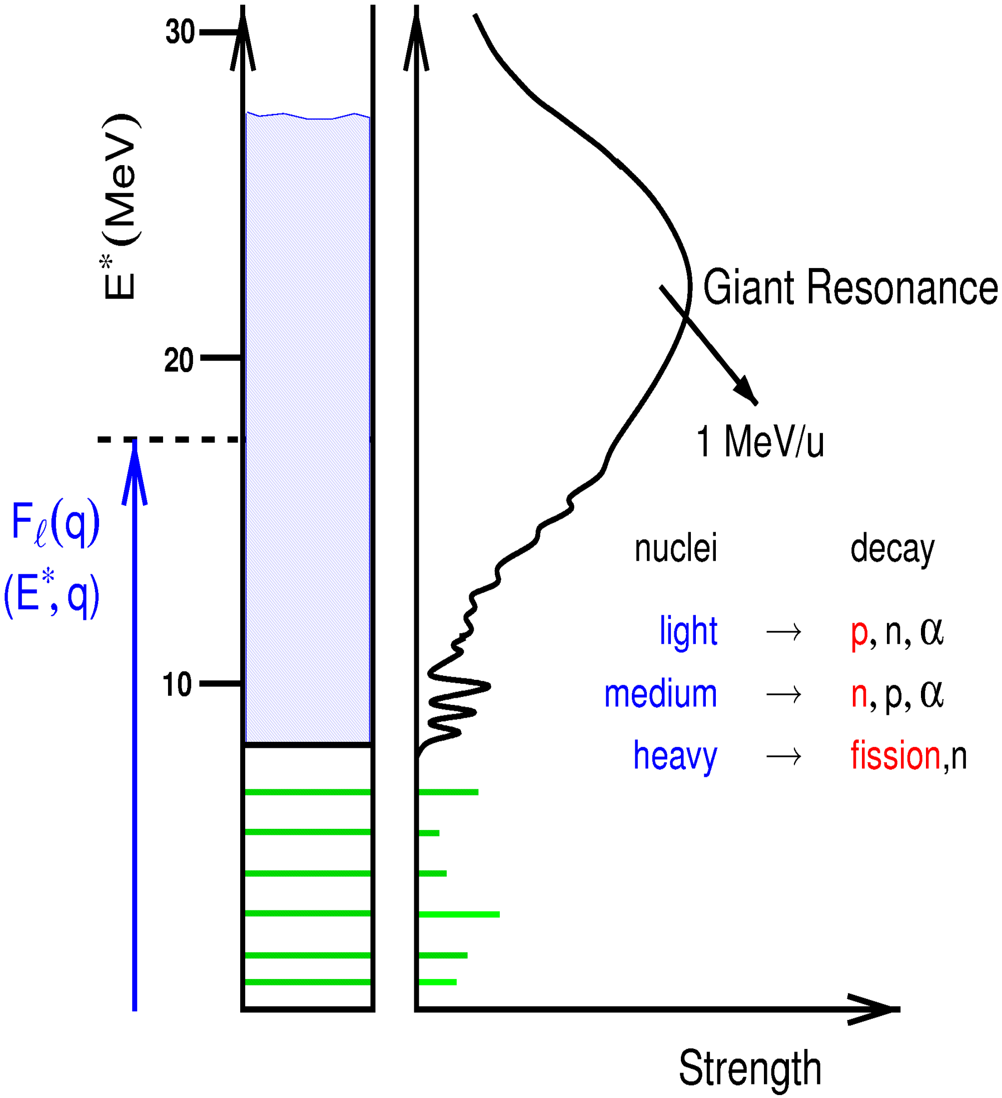
➔ Mott cross section enhanced (small angles)

- luminosity for unstable nuclei (no target)

➔ 100μm x 100μm interaction area

vs e.g. dilute ions in a trap

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)

System design:
- preparation for TDRs

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

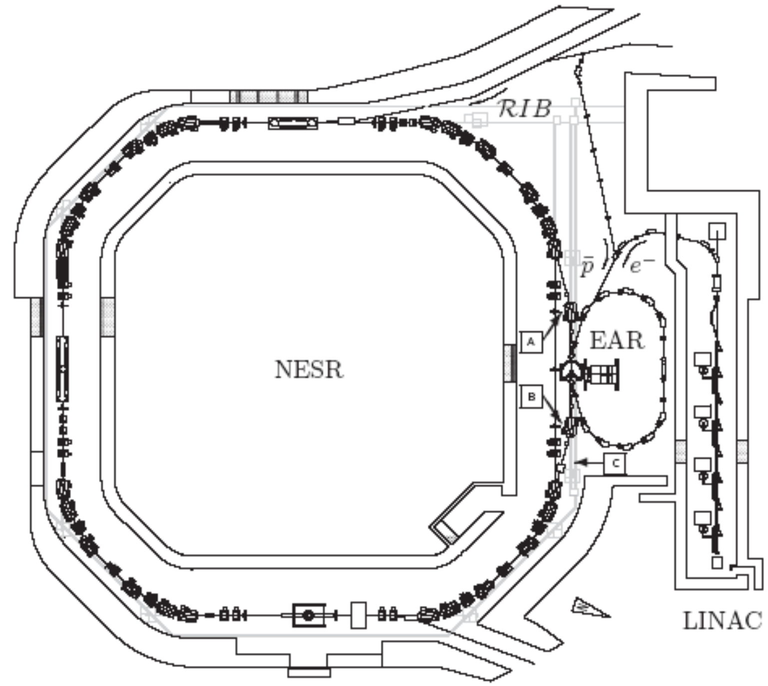
M. Aïche, G. Barreau, S. Czajkowski, B. Jurado

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

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

CEA Bruyères-le-Châtel - France

...



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

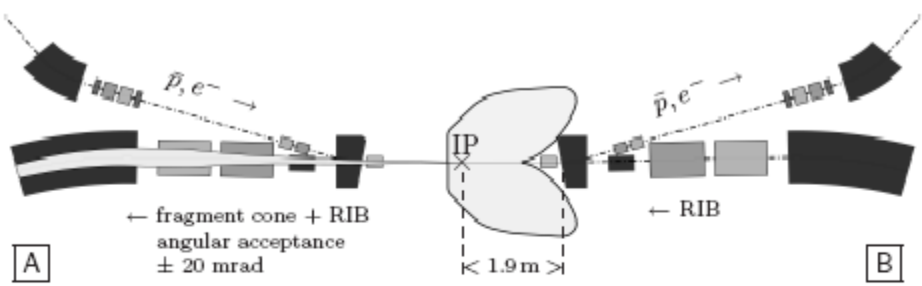


Figure 6: Interaction zone with the interaction point IP in the bypass section of the NESR.

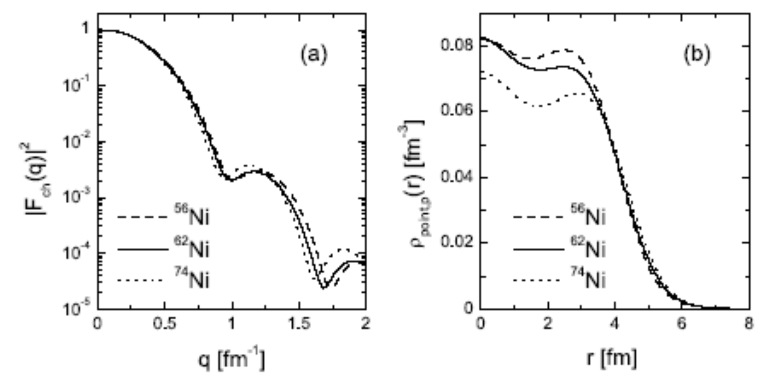
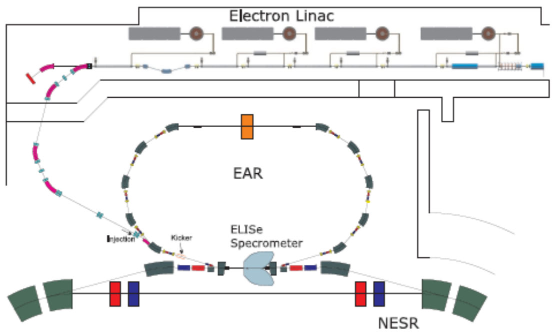


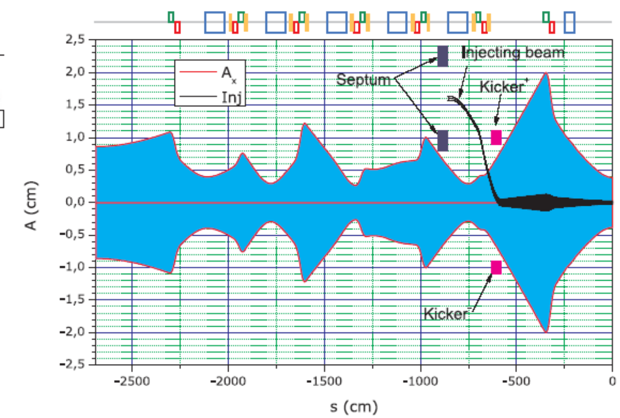
Figure 1: Charge form factors (panel (a)) calculated in DWBA and HF+BCS proton densities (panel (b)) for the unstable doubly-magic ^{56}Ni (dashed line), stable ^{62}Ni (full line) and unstable ^{74}Ni (dotted line) isotopes [7].

Associated LINAC and injection scheme

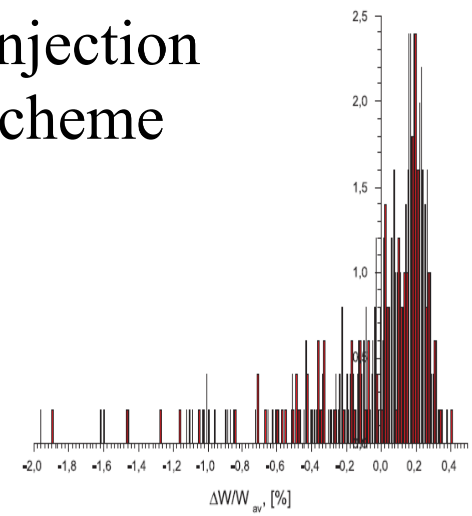
P. V. Logachev, D. Shwartz, P. Shatunov, I. Koop BINP/Novosibirsk

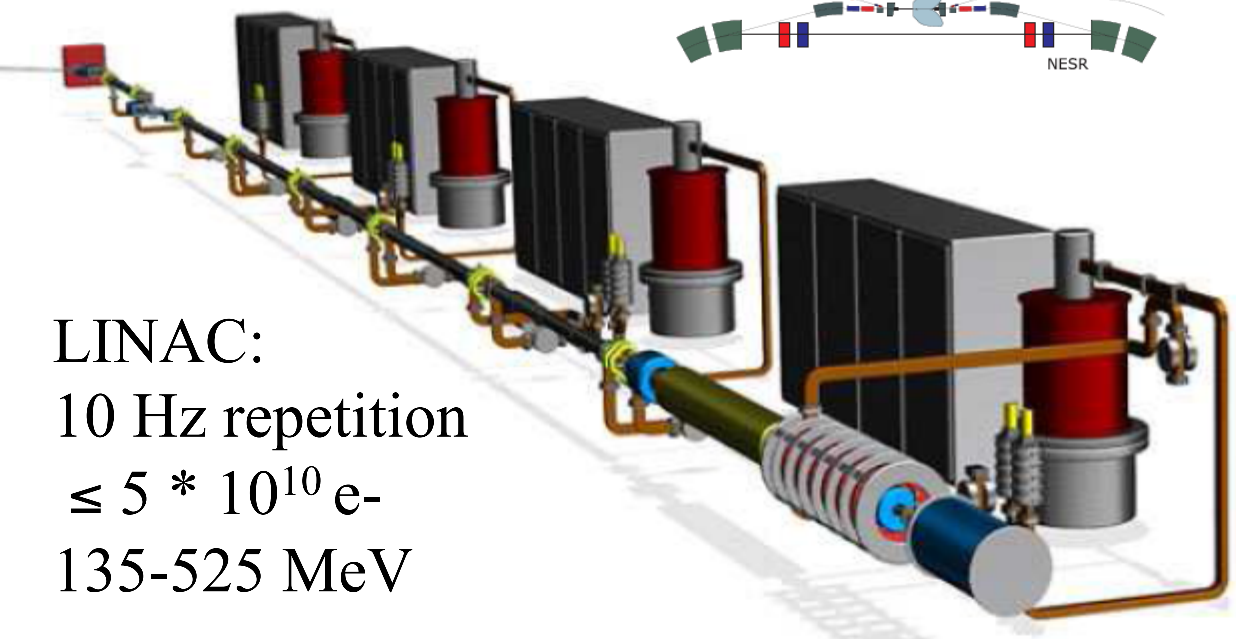
INTAS open call 2005 -2007/ FRRC 2009-





Injection scheme





LINAC:
10 Hz repetition
≤ 5 * 10^{10} e-
135-525 MeV

Paper in preparation

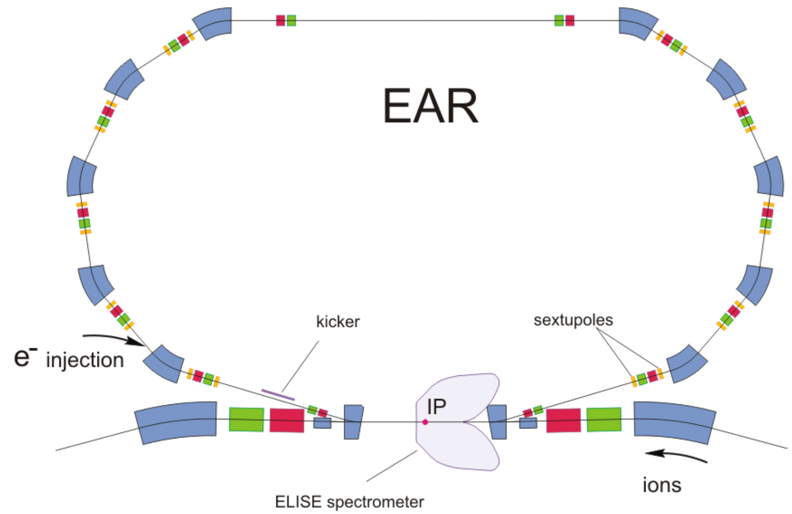
 & Interaction region design

Design of the associated interaction zone

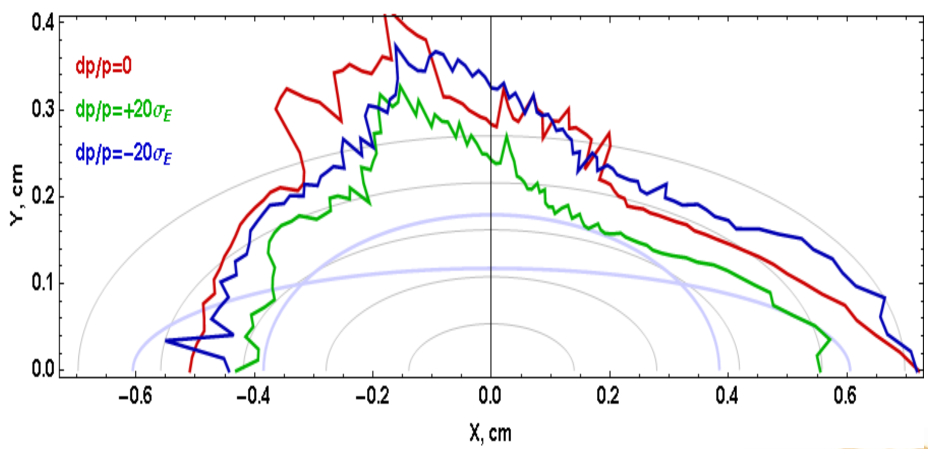
D. Shwartz, P. Shatunov, I. Koop BINP/Novosibirsk

INTAS open call 2005 -2007/ FRRC 2009-

- Overlap of the two beams 150μm × 60μm
- Emittances 50 μm·mrad

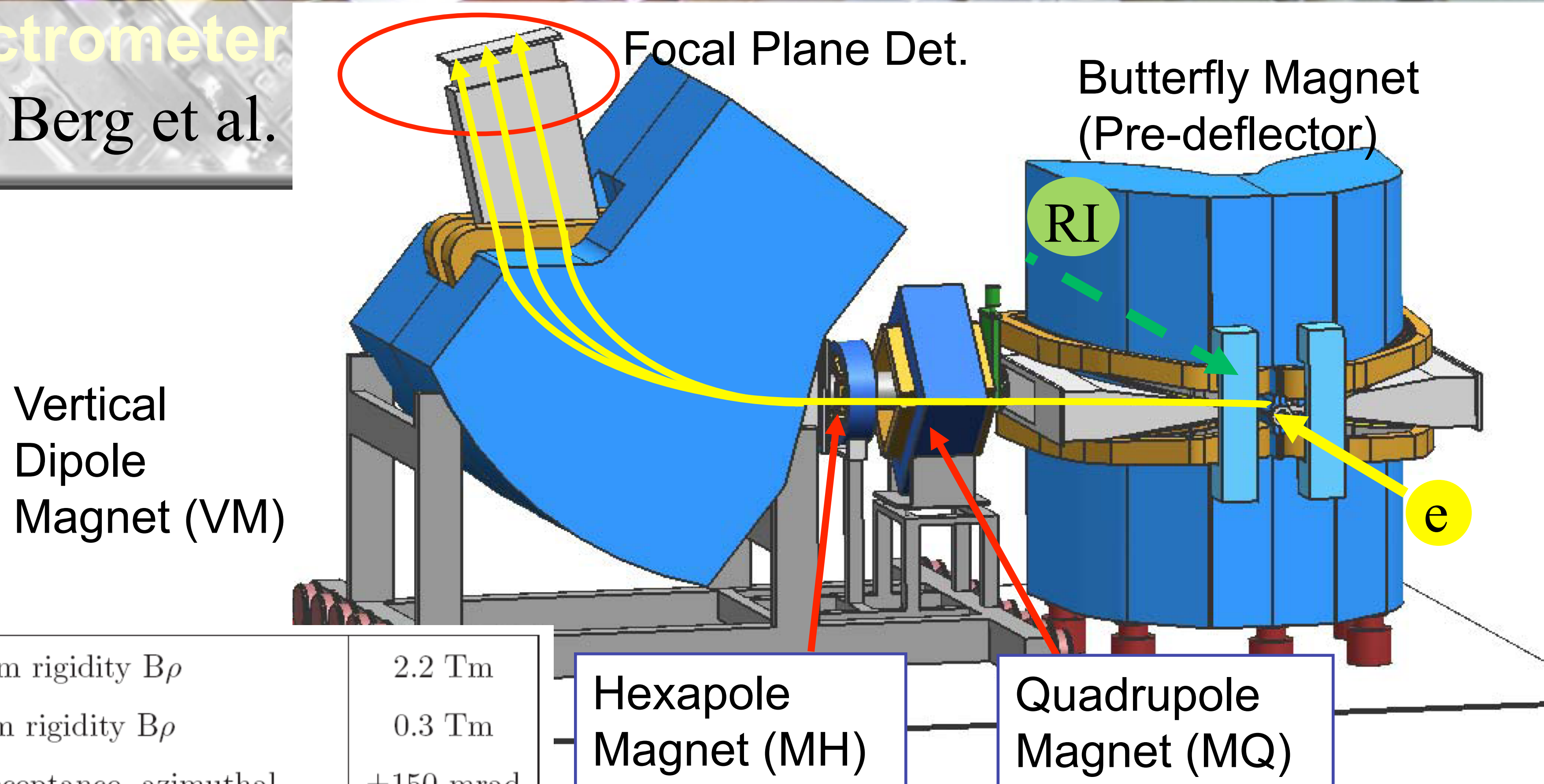


- +- 1.5% momentum acceptance and dynamic apperture
- Accepted cone +- 20 mrad for fission fragments …

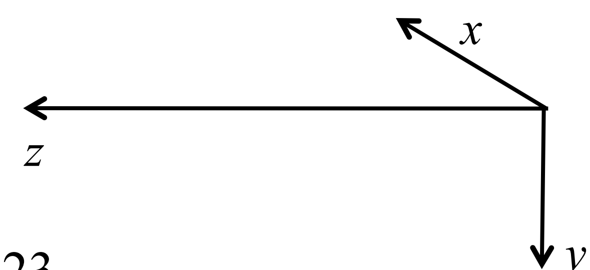


… and a suitable magn. high resolution spectrometer

GPA Berg et al.



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



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

FAIR

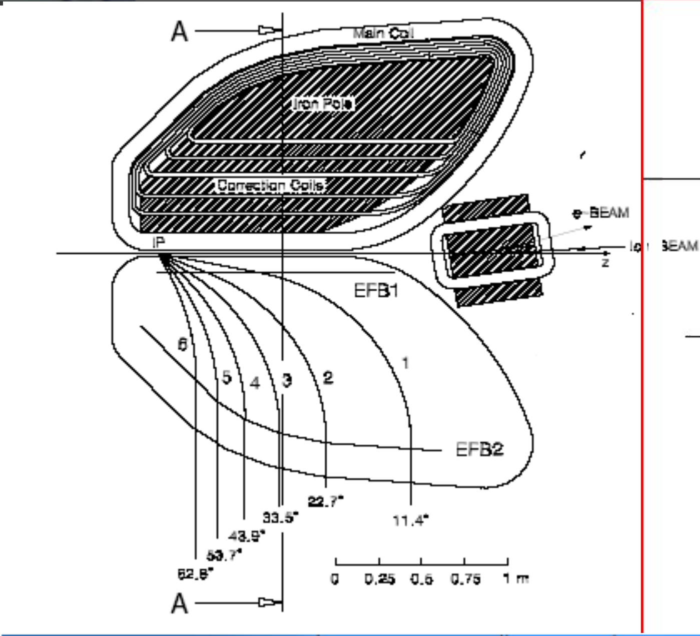
Resolution (clamp shell)

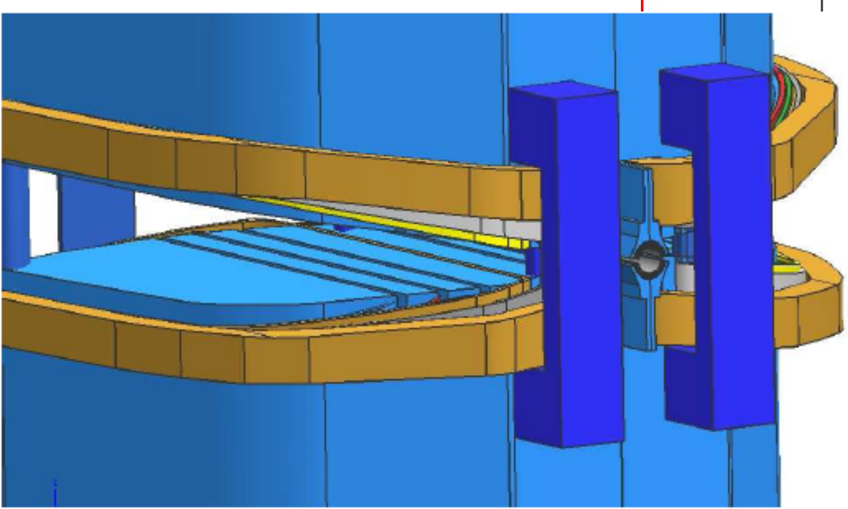
GPA Berg et al.

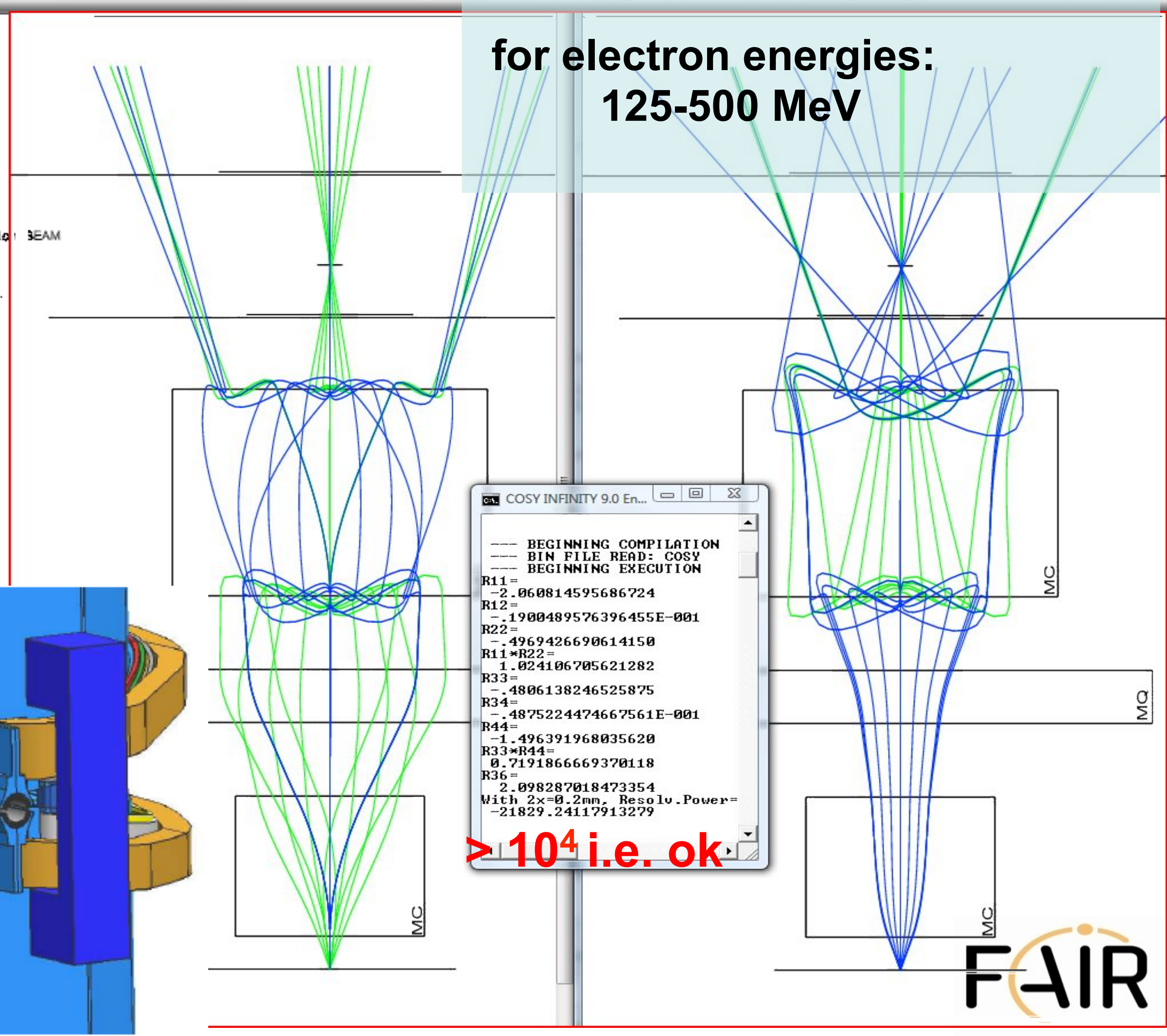
Θ_{Lab}: 10-60°

q: 20-600 MeV/c

for electron energies:
125-500 MeV



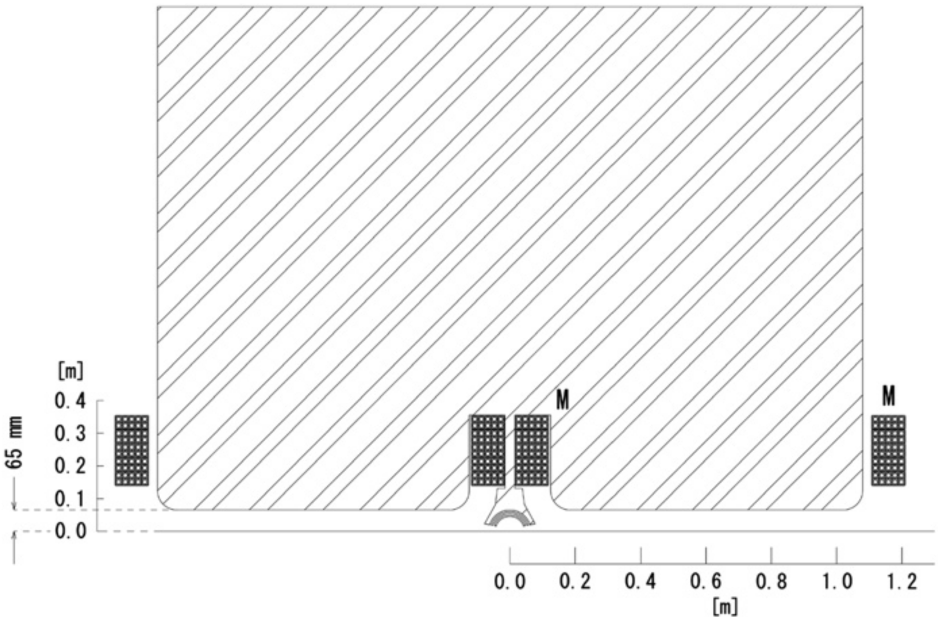


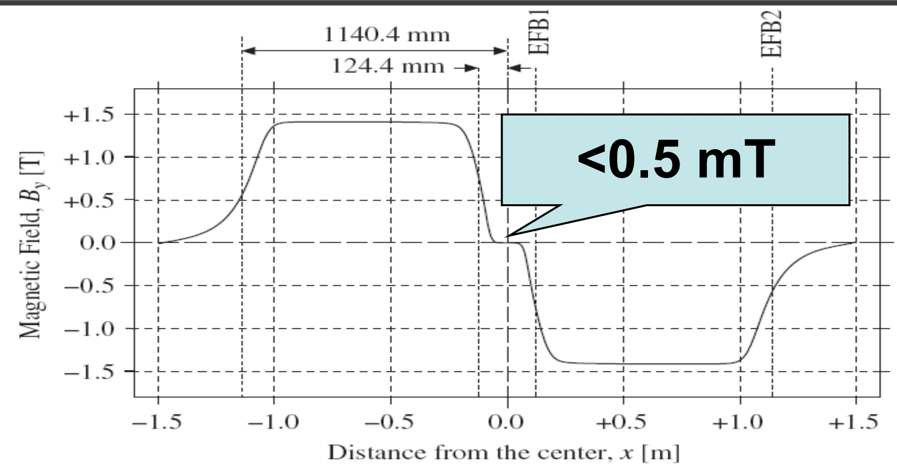


FAIR

Further improvements …

T. Adachi, GPA Berg, et al.



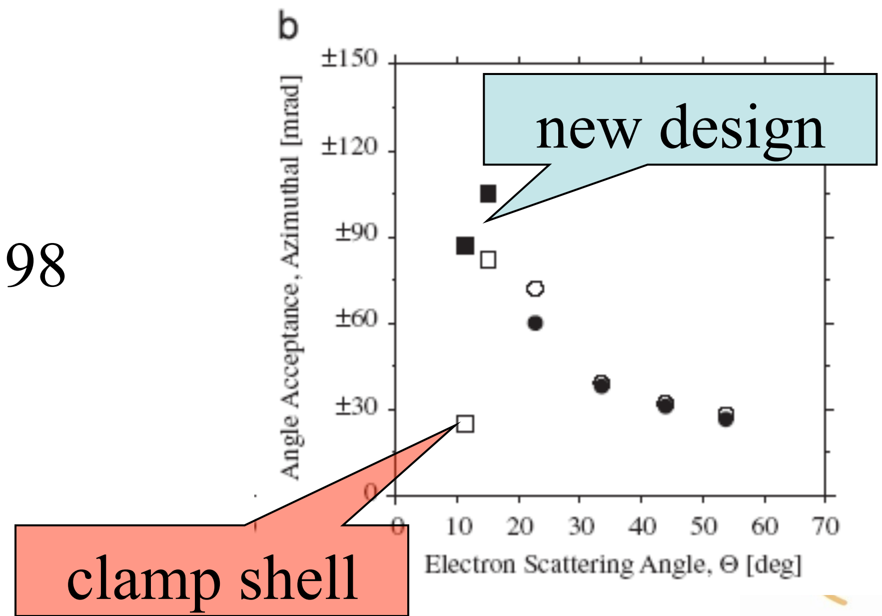


T. Adachi et al.,

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

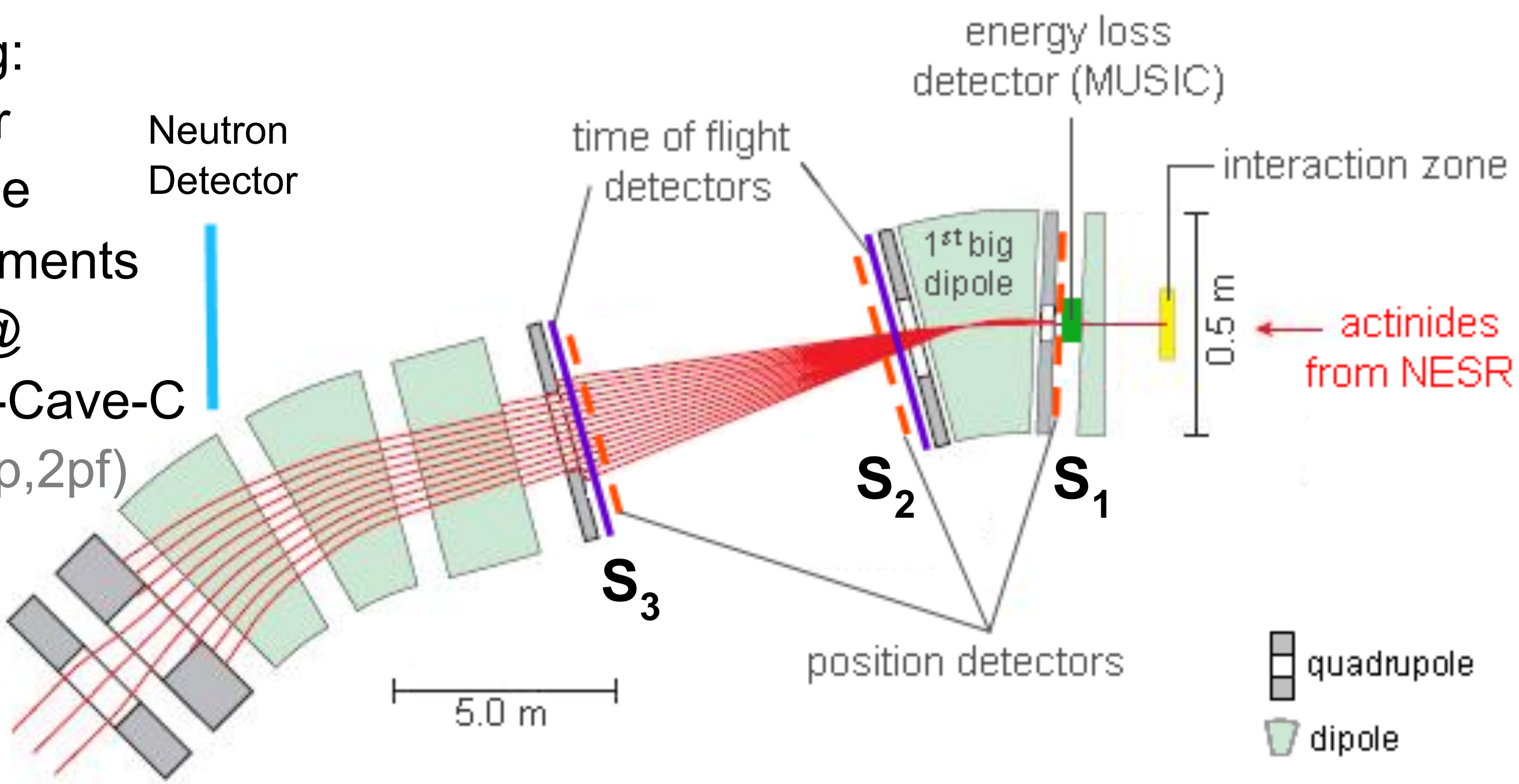
doi:10.1016/j.nima.2011.06.081

➔no correction coils needed



In-Ring spectrometer in the Bypass
CEA-DAM Bruyères-le-Châtel, JINR Dubna, GSI

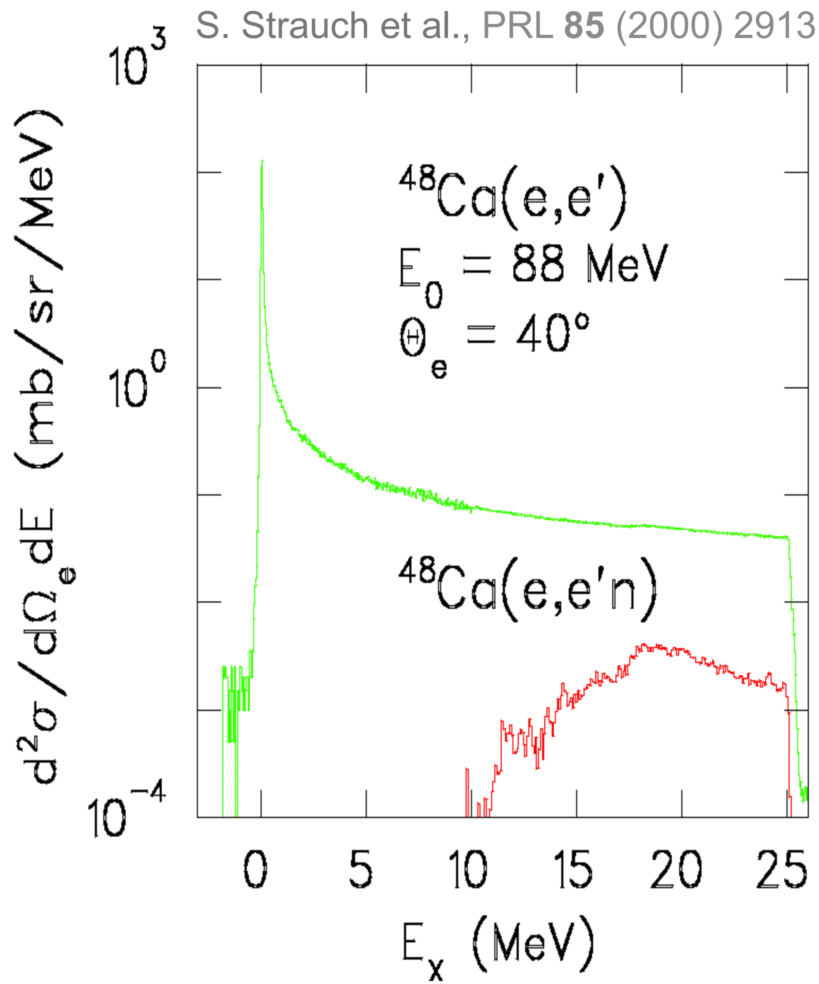
Ongoing:
Detector prototype developments
SOFIA@ R³B-Cave-C
future: (p,2pf)



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

Inelastic Scattering @ forward angles

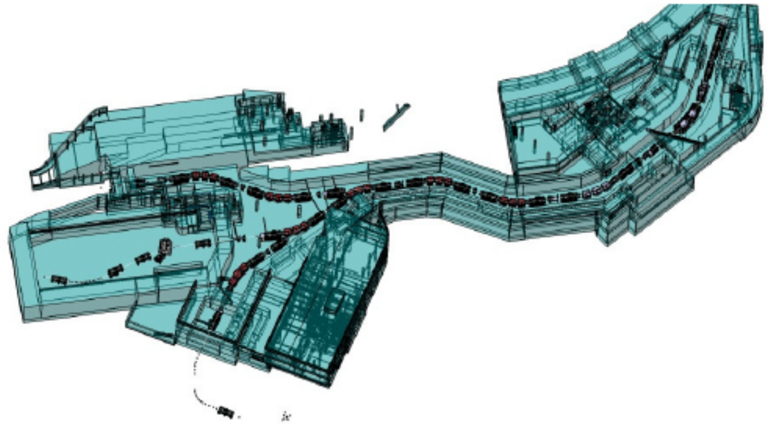
→compared to conventional (fixed target) experiments

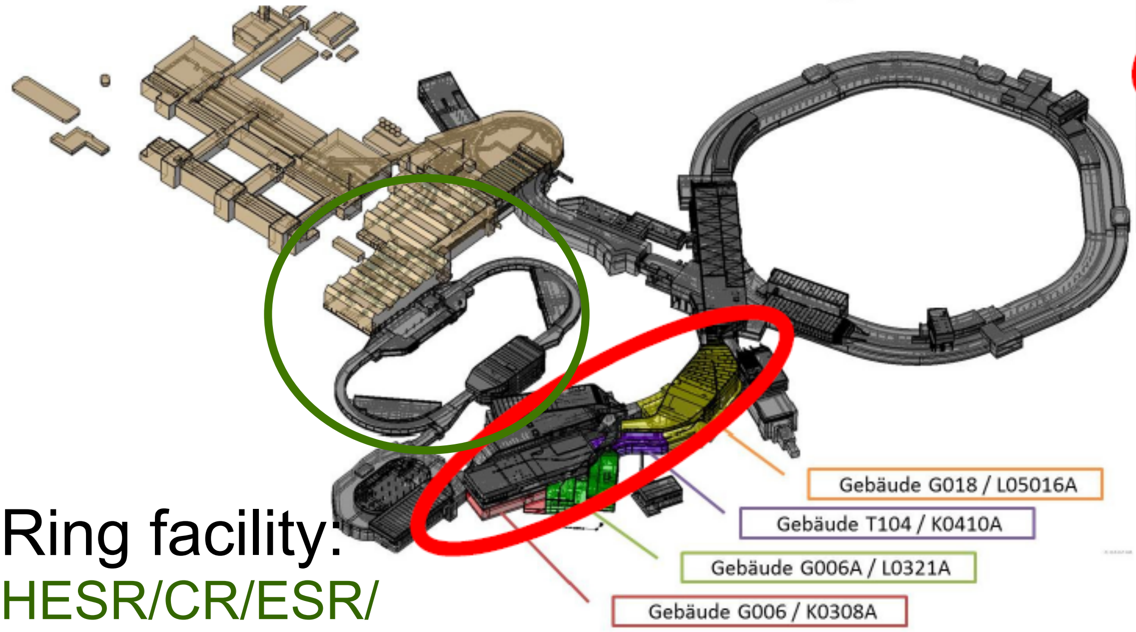


Fixed target		Collider 1.5GeV
^{48}Ca(e,e'n)		^{48}Ca(e,e'A')
Ω_n =100msr	**100**	Ω_n ~ 4π
n_{eff} =20 %	**5**	n_{eff} ~ 100 %
$\Theta_{e'}$ = 40 °	**50**	**$\Theta_{e'}$ = 5 °**
	>10^4	
L=10^{31} - 10^{32}	cm^{-2} s^{-1}	**L ~ 10^{27}**

→ Large gain through kinematics

Current status with respect to the MSV - NESR is delayed



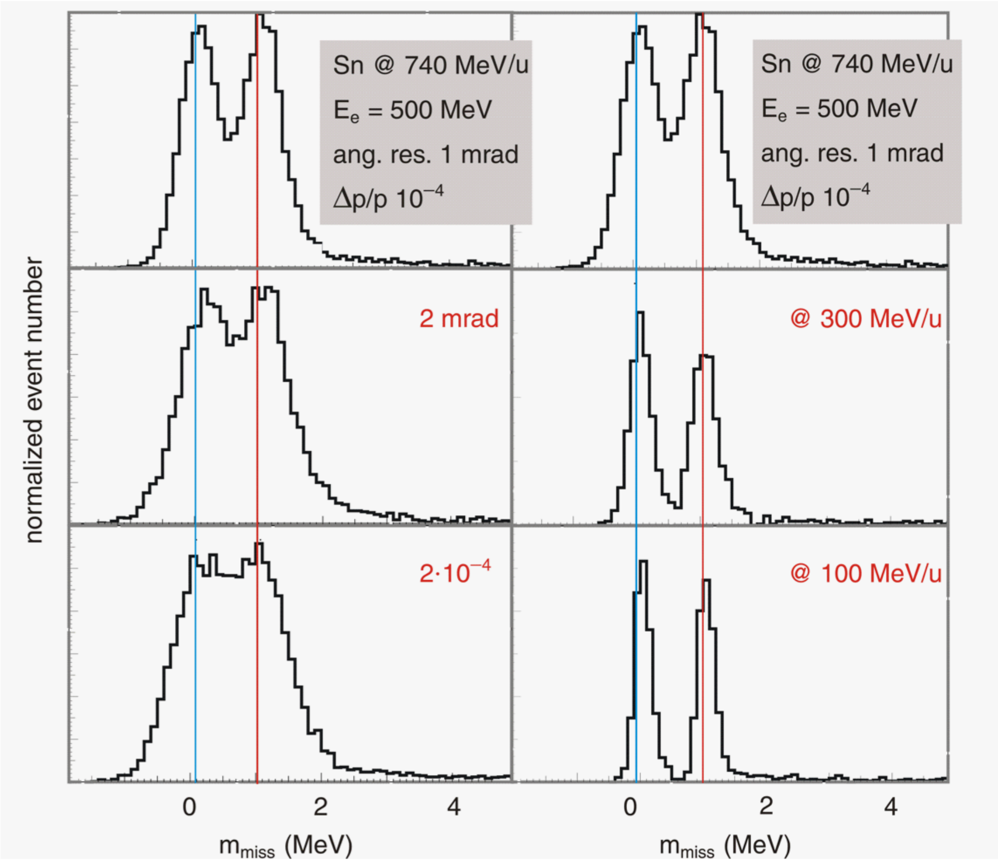


Ring facility:
HESR/CR/ESR/
Cryring complex

Where's the challenge ?

Monte Carlo Simulation: $\Delta E^* = 1$ 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

Possible realization of the ELISe experiment at the ESR

Paper in preparation

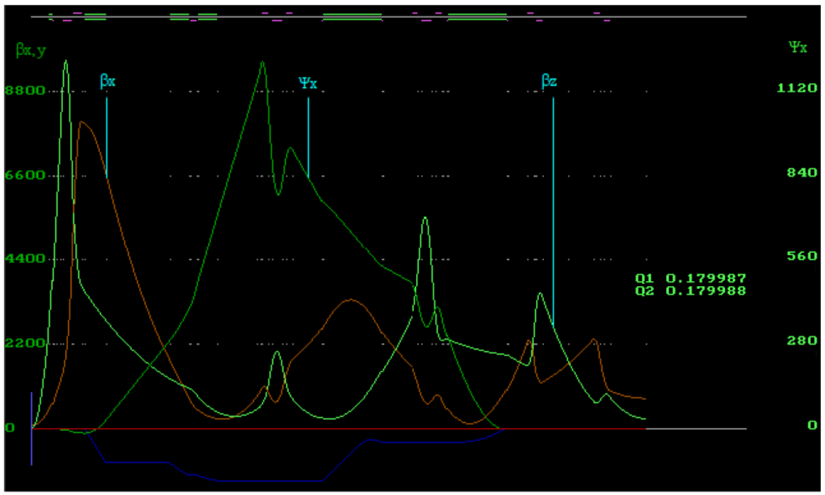
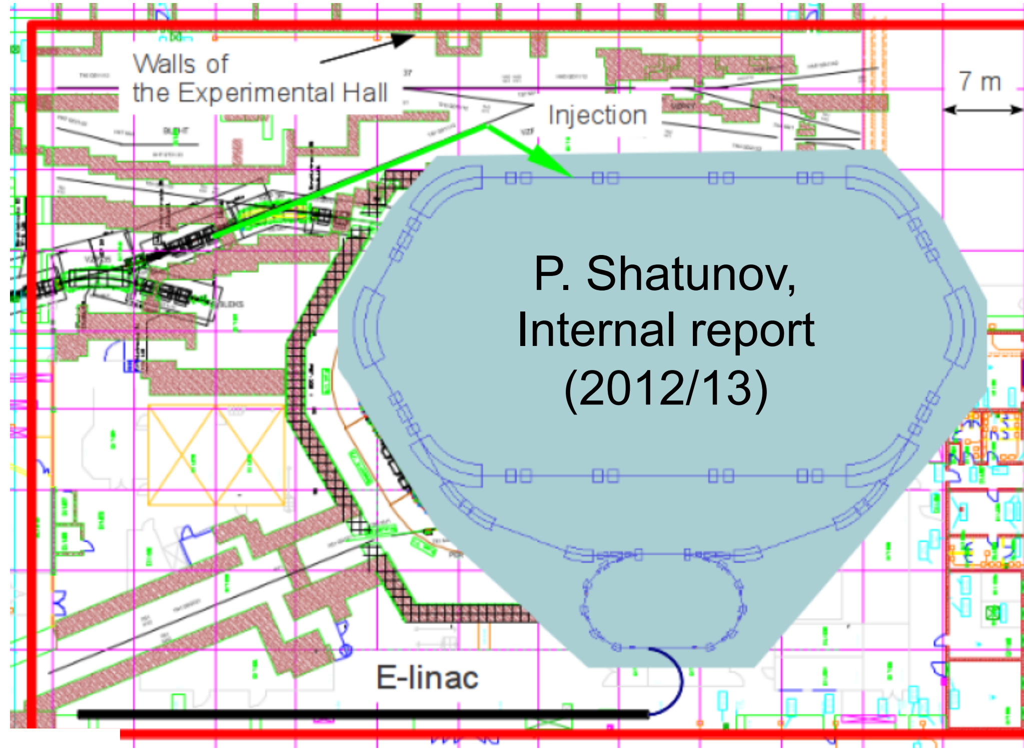
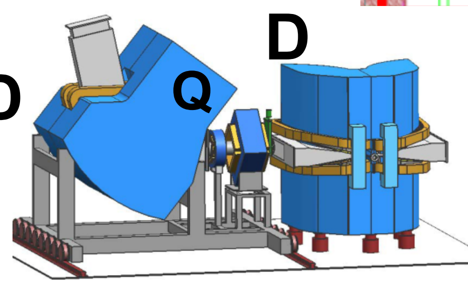


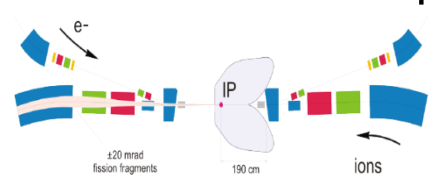
Figure 9. Beta (β, cm) and dispersion (Ψ, cm) functions of stretched ESR (1 half) in the collider mode.



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



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



Main consequences:

- Lower ion energies (340 AMeV vs. 740 AMeV)
  - less maximum luminosity (tune shift ~ factor 3…4)

- Higher resolution / better sensitivity

- No injection from SuperFRS to ESR, bad injection efficiency for non pre-cooled beams

➔ initial programme with $\sim 10^6$ less particles for most exotic species at the outskirts of the nuclear chart (flat top for isotopes close to stability)

- All properties of ESR (stability, … to be checked)
- Modifications to prolong straight sections & Cave

Summary

- Electron(Antiproton)-RIB Collider is feasible - collider mode provides optimal use for RIBs.
- Design of a Challenging spectrometer and demanding interaction zone is possible
- Options for running at the existing ESR have been studied

➔ Viable physics programme for an initial facility in the HESR/CR/ESR/Cryring complex at FAIR.

- Unique experiment for FAIR (and other RIB facilities)

➔ Not only for nuclear physics studies ?

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

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.

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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

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

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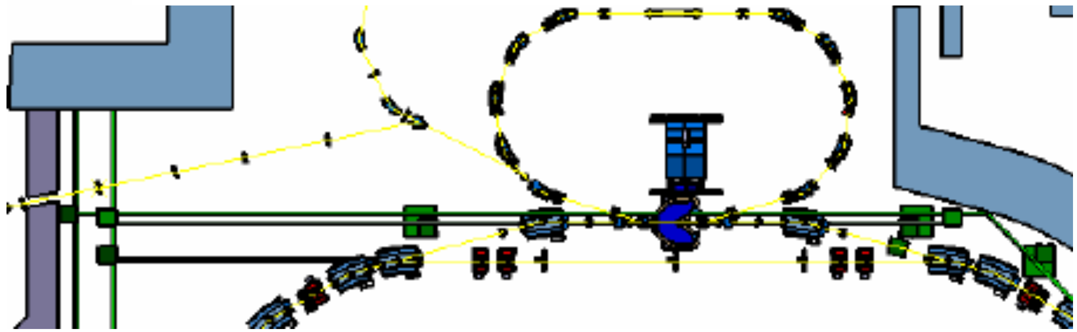
Received 25 June 2003; received in revised form 12 August 2003; accepted 26 August 2003

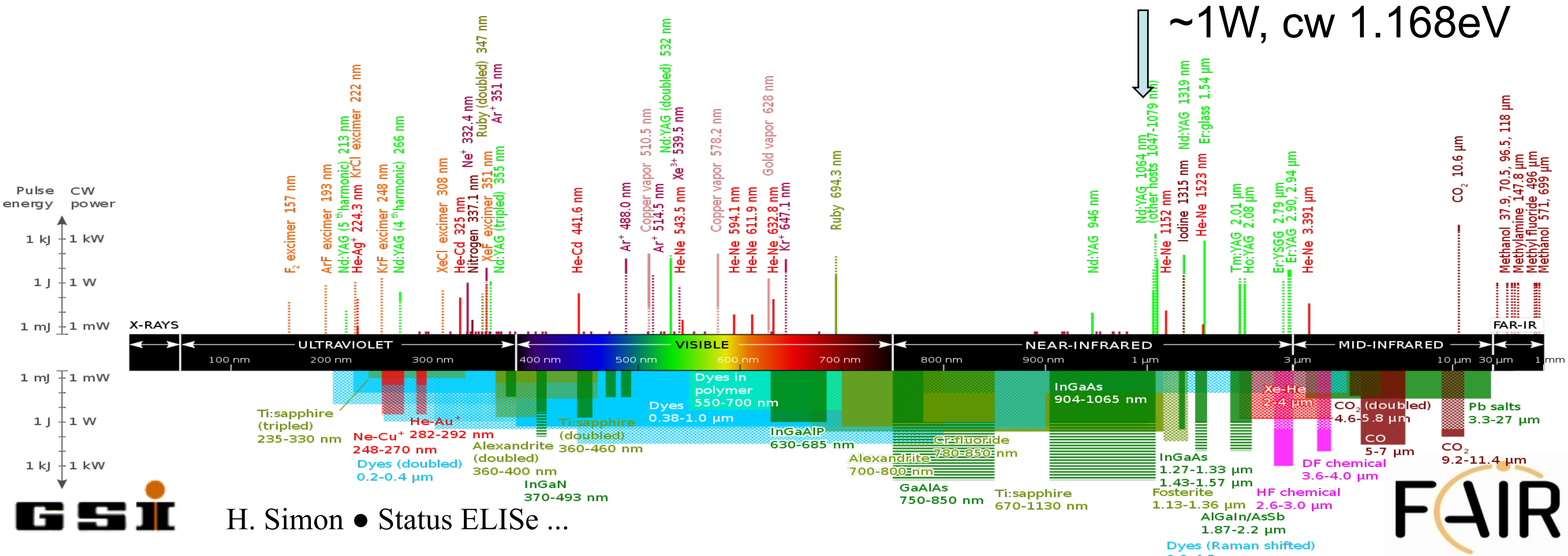
- Laser systems

➔ Compton backscattering

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

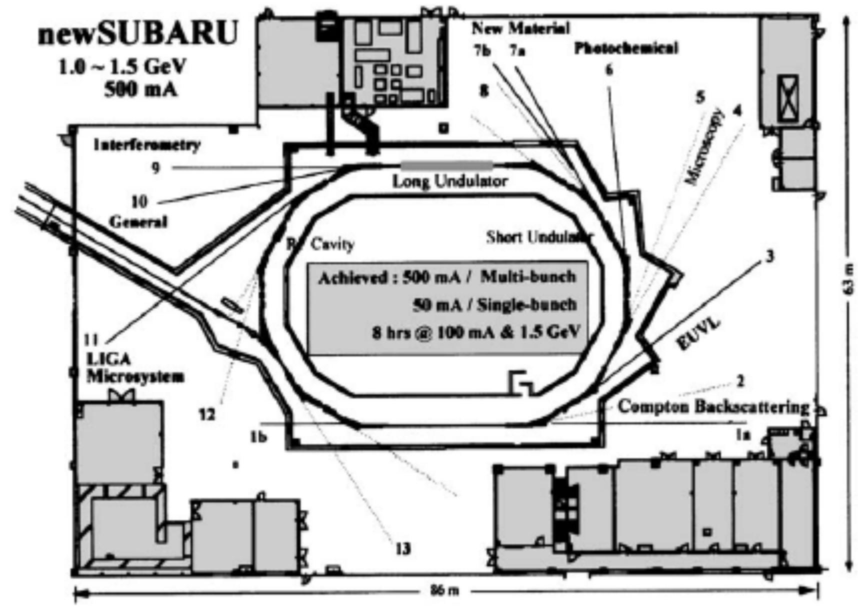


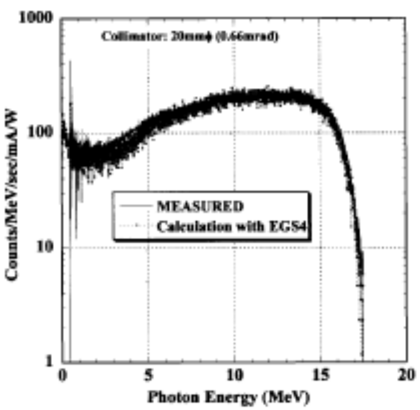
~1W, cw 1.168eV

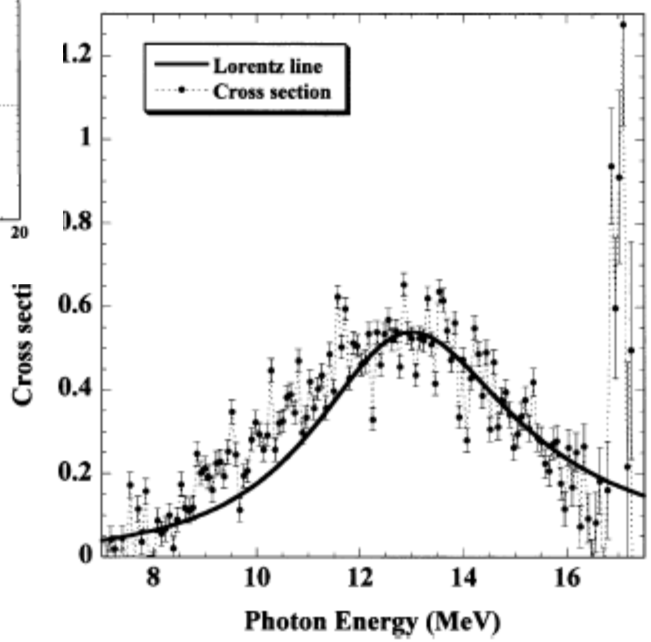


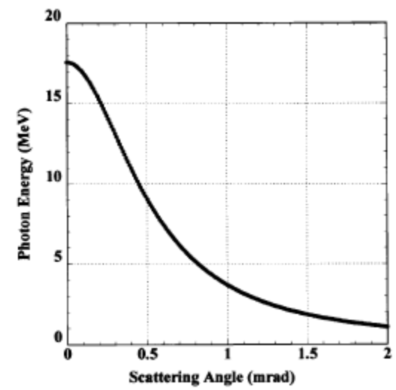
Direct comparison
➔ looks promising

- 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









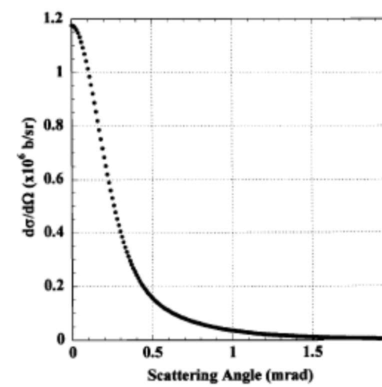


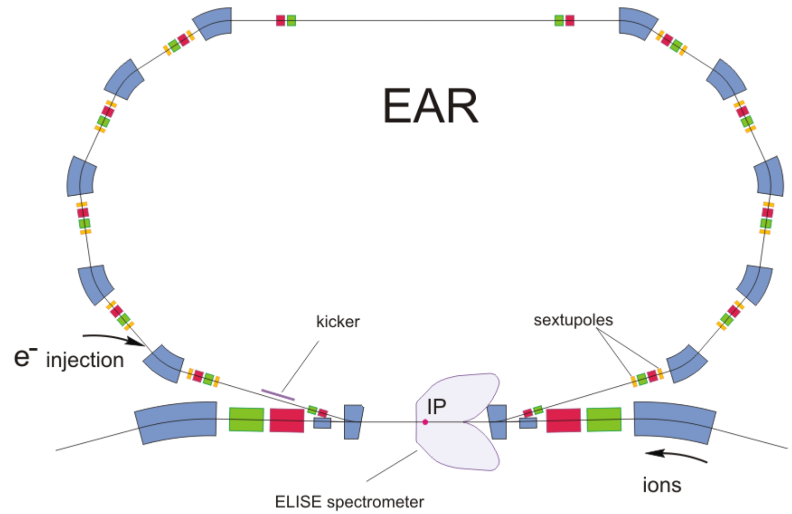
Photo-nuclear reaction
E1 (GDR) ^{197}Au

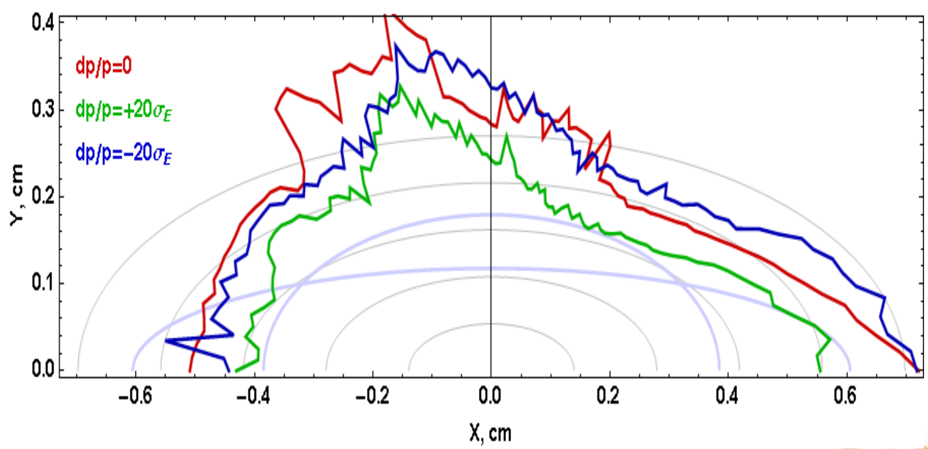
H. Sim

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 …

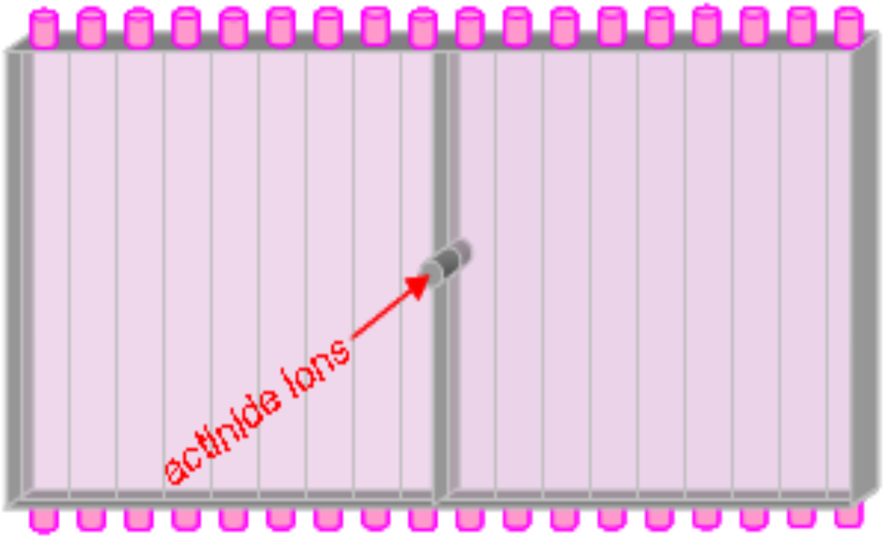




Example:ToF set-up
➔ prototype SOFIA@R³B-CaveC

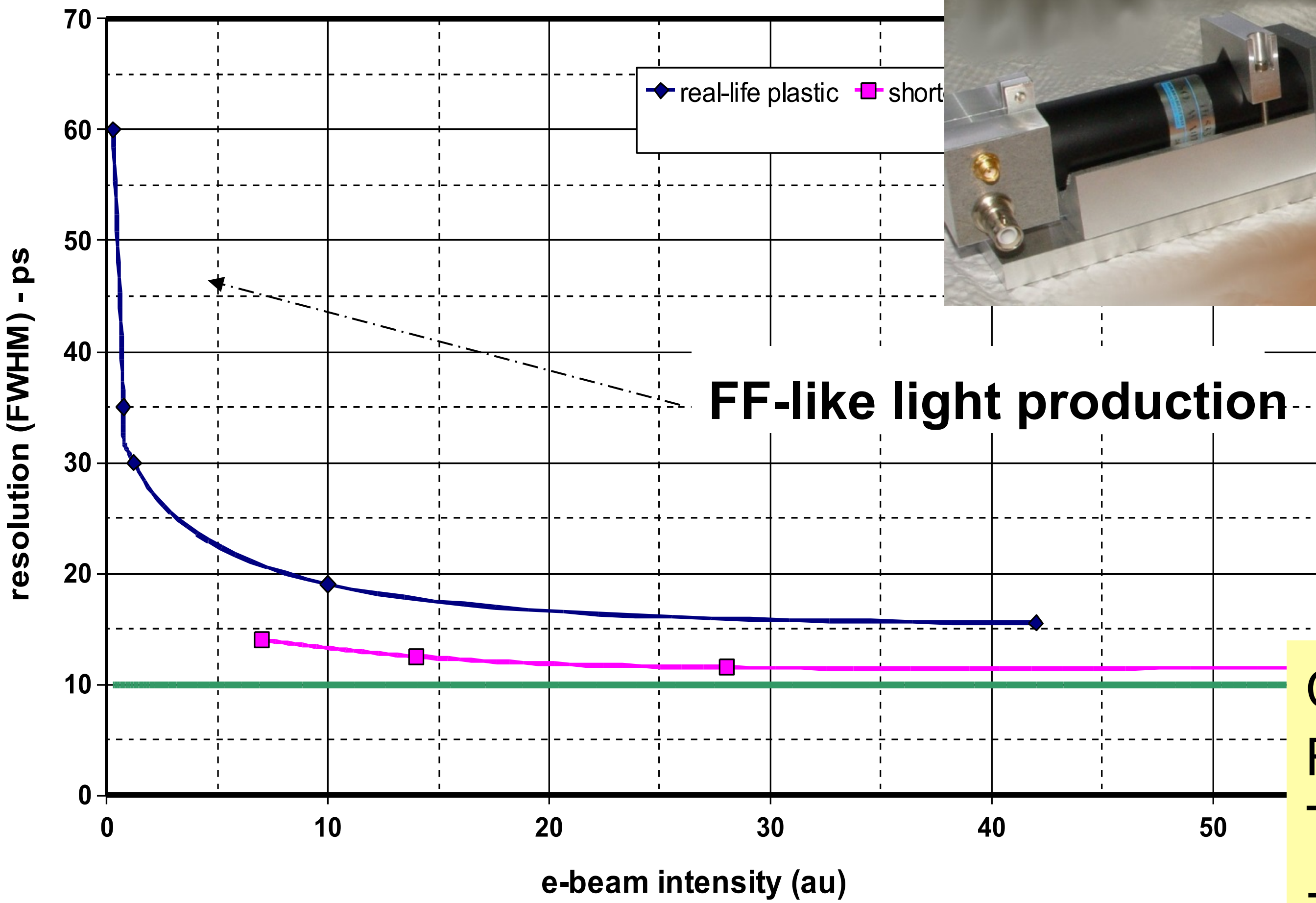
J. Taieb et al., CEA Bruyères-le-Châtel

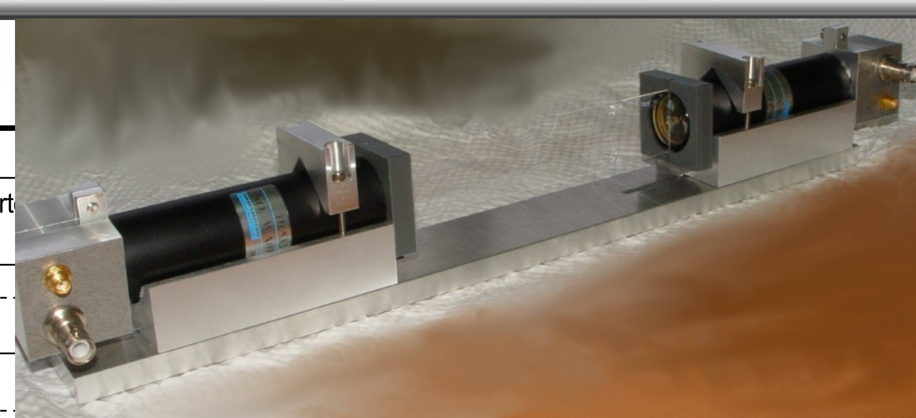
- Most demanding part : 35ps FWHM needed
  S. Nishimura et al., Nucl. Inst. Meth. A510 (2003)377
- Very fast plastic stripes
  (Eljen Technology: EJ-323 0.25% quenched 43ps rise time)
  - T_2 : 30 x 150 x 0.5 mm^3 (2 x 5 paddles)
  - T_3 : 30 x 300 x 0.5 mm^3 (2 x 10 paddles)
- Fast PMT (H6533)
- No light guide/grease



First test: ToF resolution

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

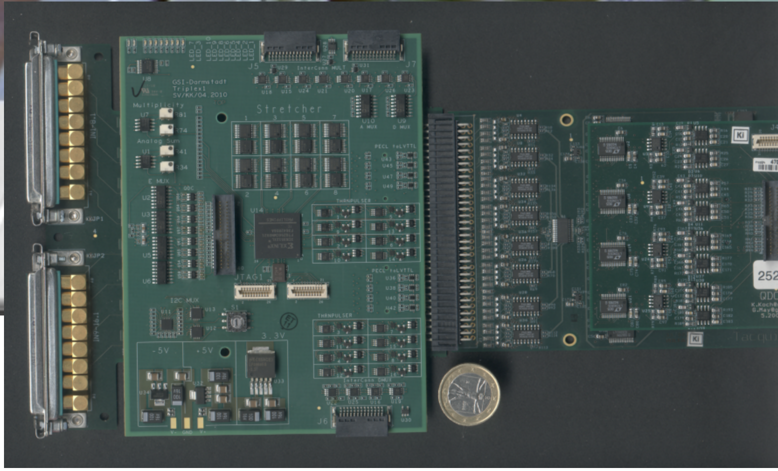


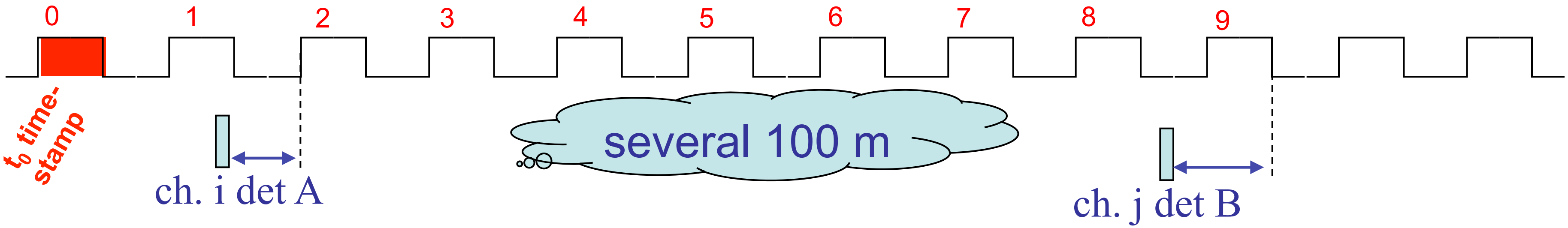


Compatible
Readout electronics:
TACQUILA
+ BuTiS/White Rabbit
TDS

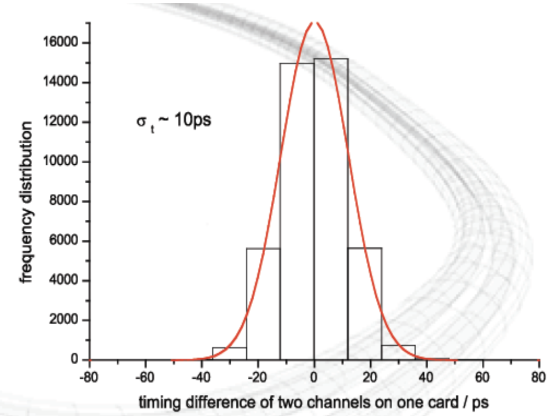
Precision timing (<50ps) vs. Campus Clock

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



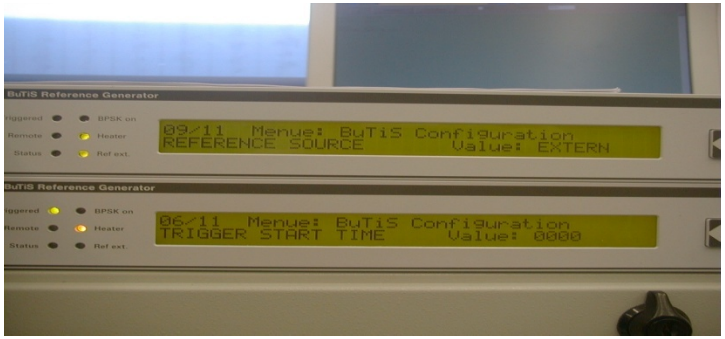


- synchronized precision oscillators 17ps R.M.S (abs.100ps/km, <1ps jitter)



Tacquila system (ASIC FhG/GSI)

New systems (ASIC dev. GSI FPGA based TDC)

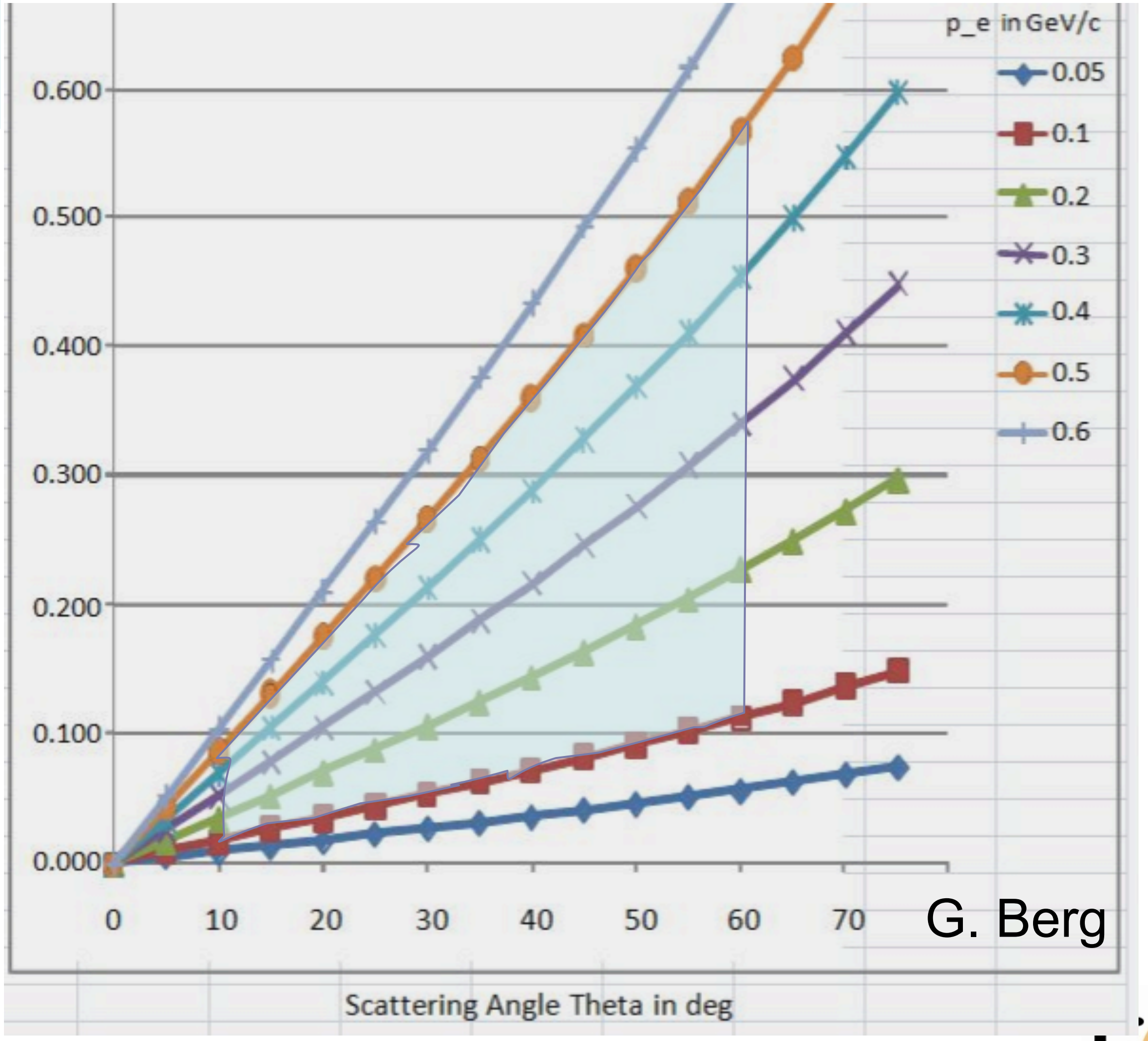


… you can measure ToF over long distances !

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)

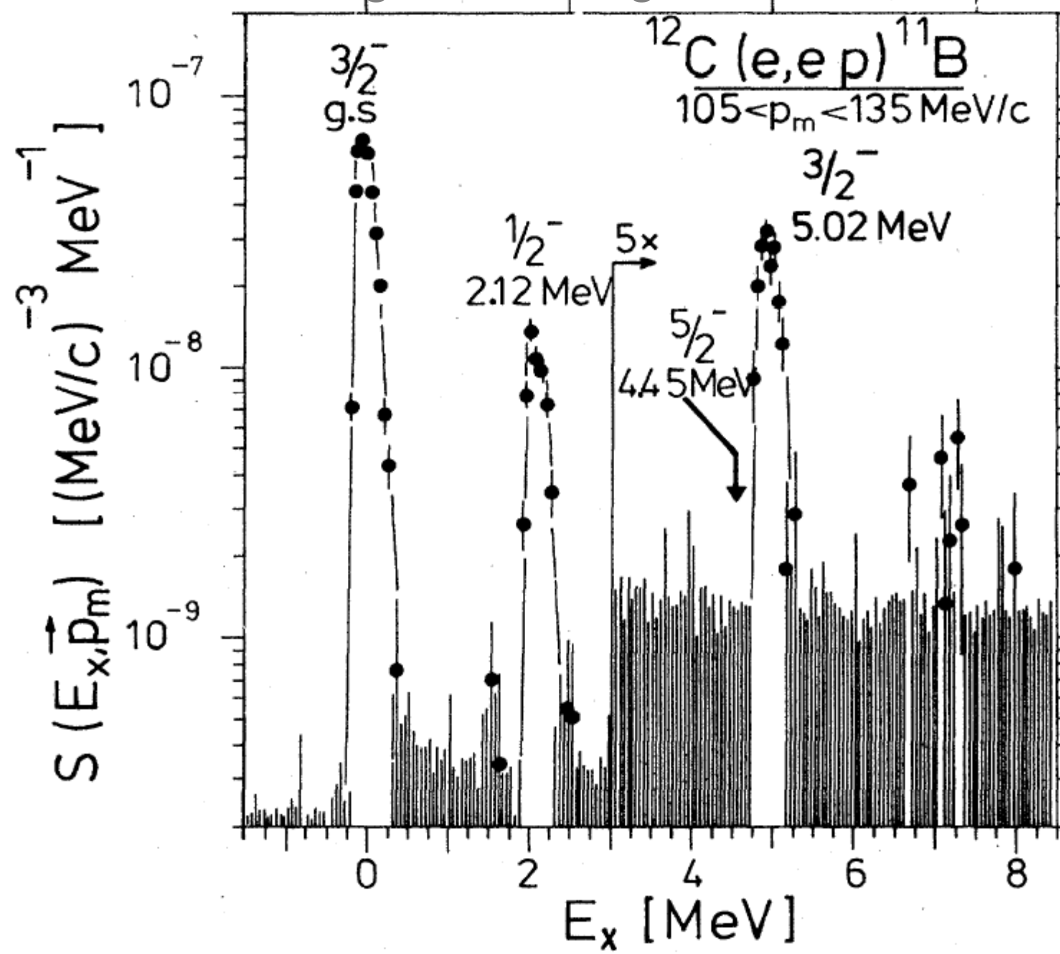
➔ spectroscopic factors / spectral functions

- Spectrometer resolution requirements moderate

- cross sections small (!b)

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

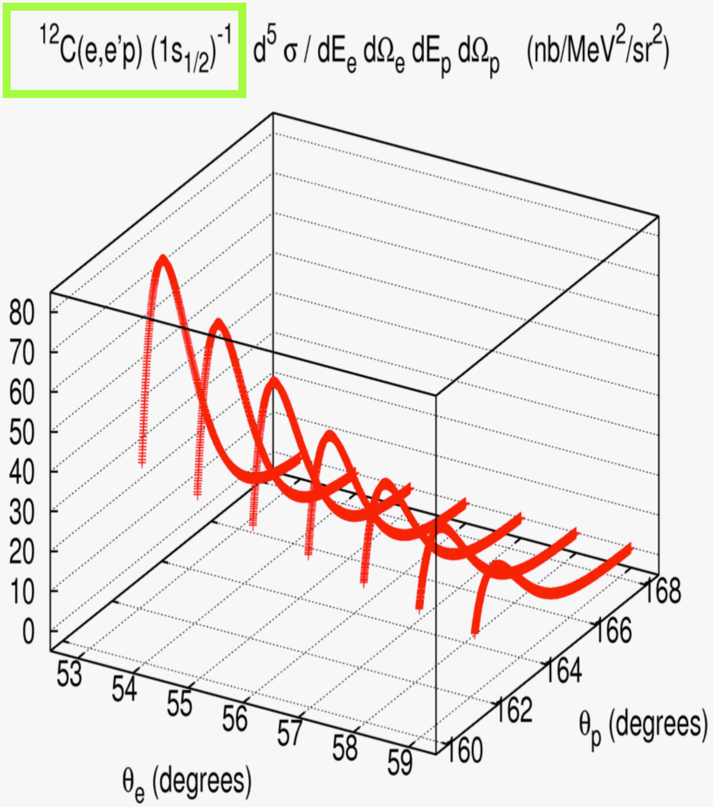
15mg/cm² C target / res. 300keV

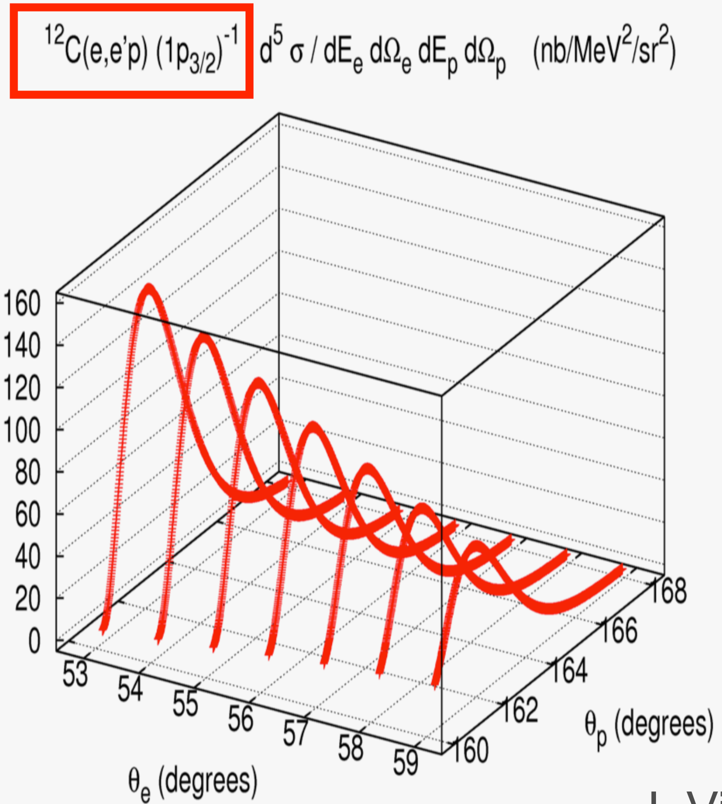


Phys. Rev. C32 (1985) 1787

FAIR

Cross section

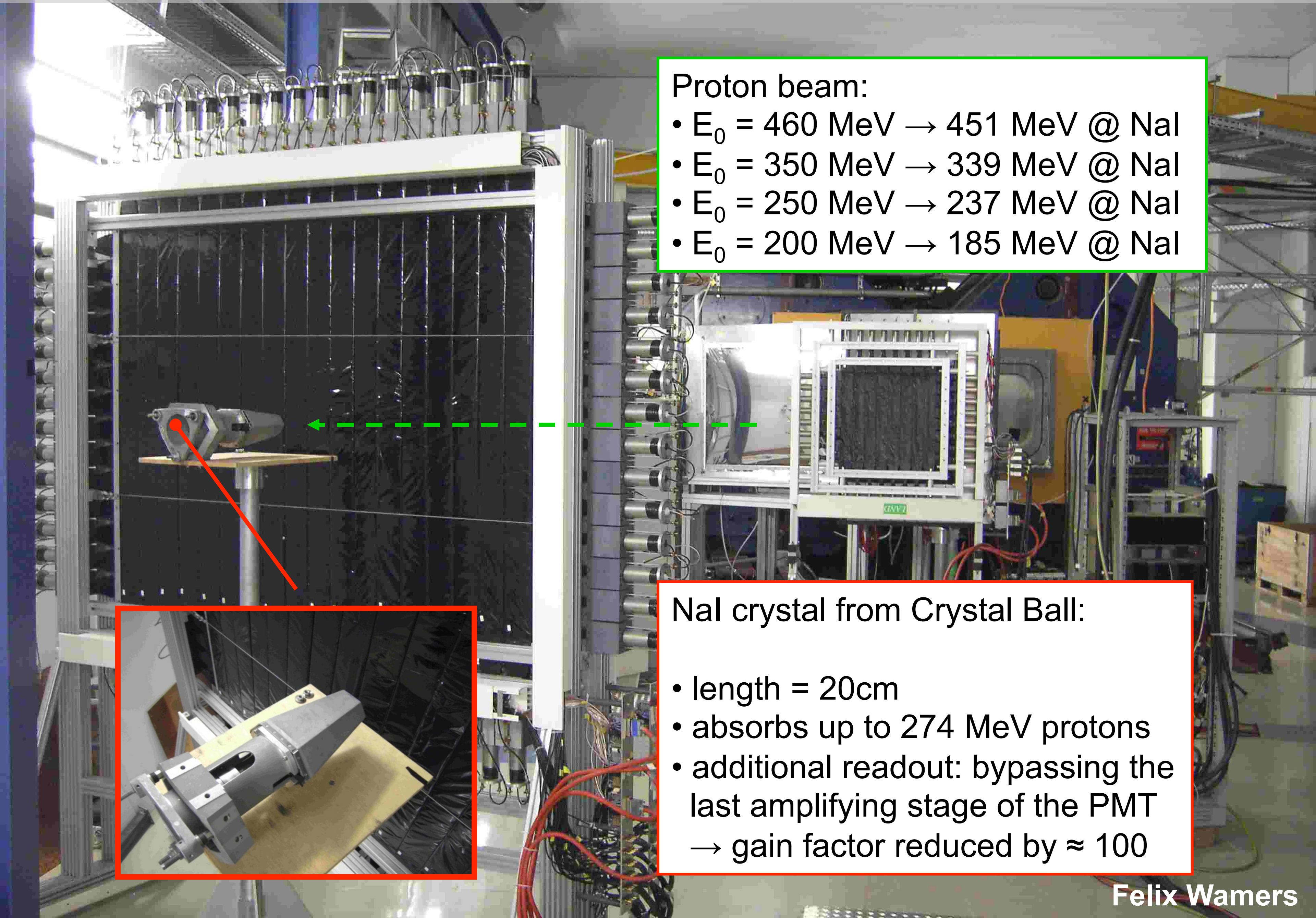




J. Vignote

➔ proton detection [160,164]°

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



Proton beam:

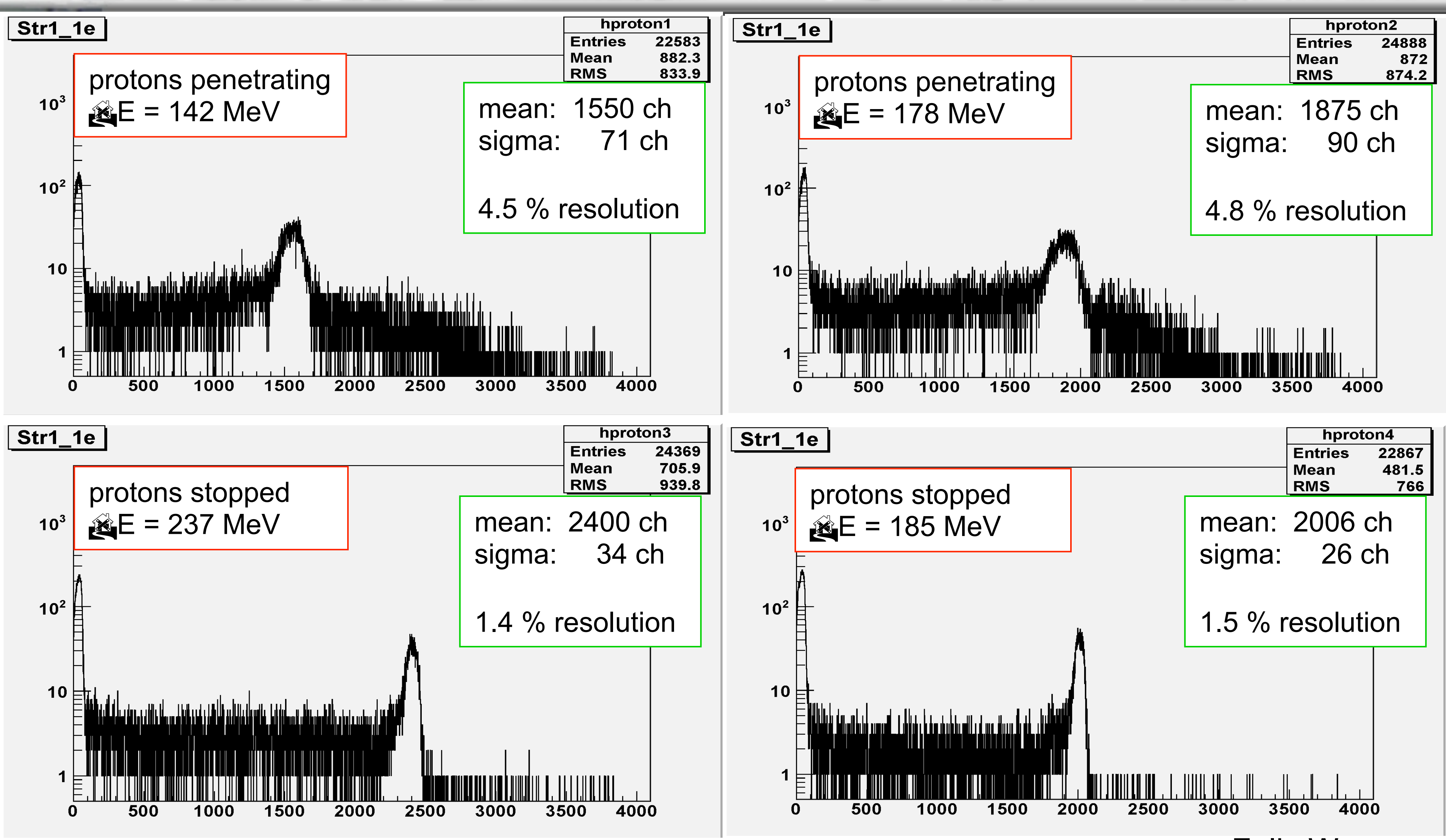
- E_0 = 460 MeV → 451 MeV @ NaI
- E_0 = 350 MeV → 339 MeV @ NaI
- E_0 = 250 MeV → 237 MeV @ NaI
- E_0 = 200 MeV → 185 MeV @ NaI

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

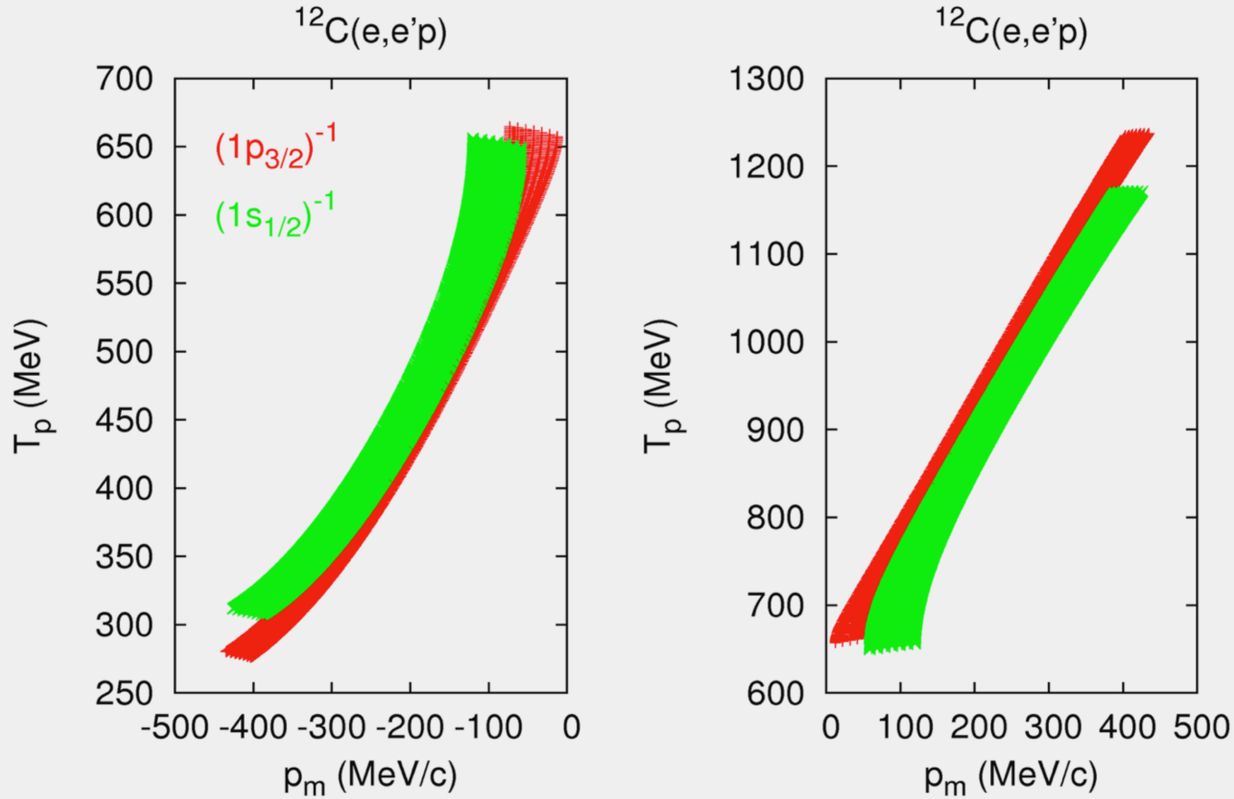
Raw spectra of protons in NaI crystal



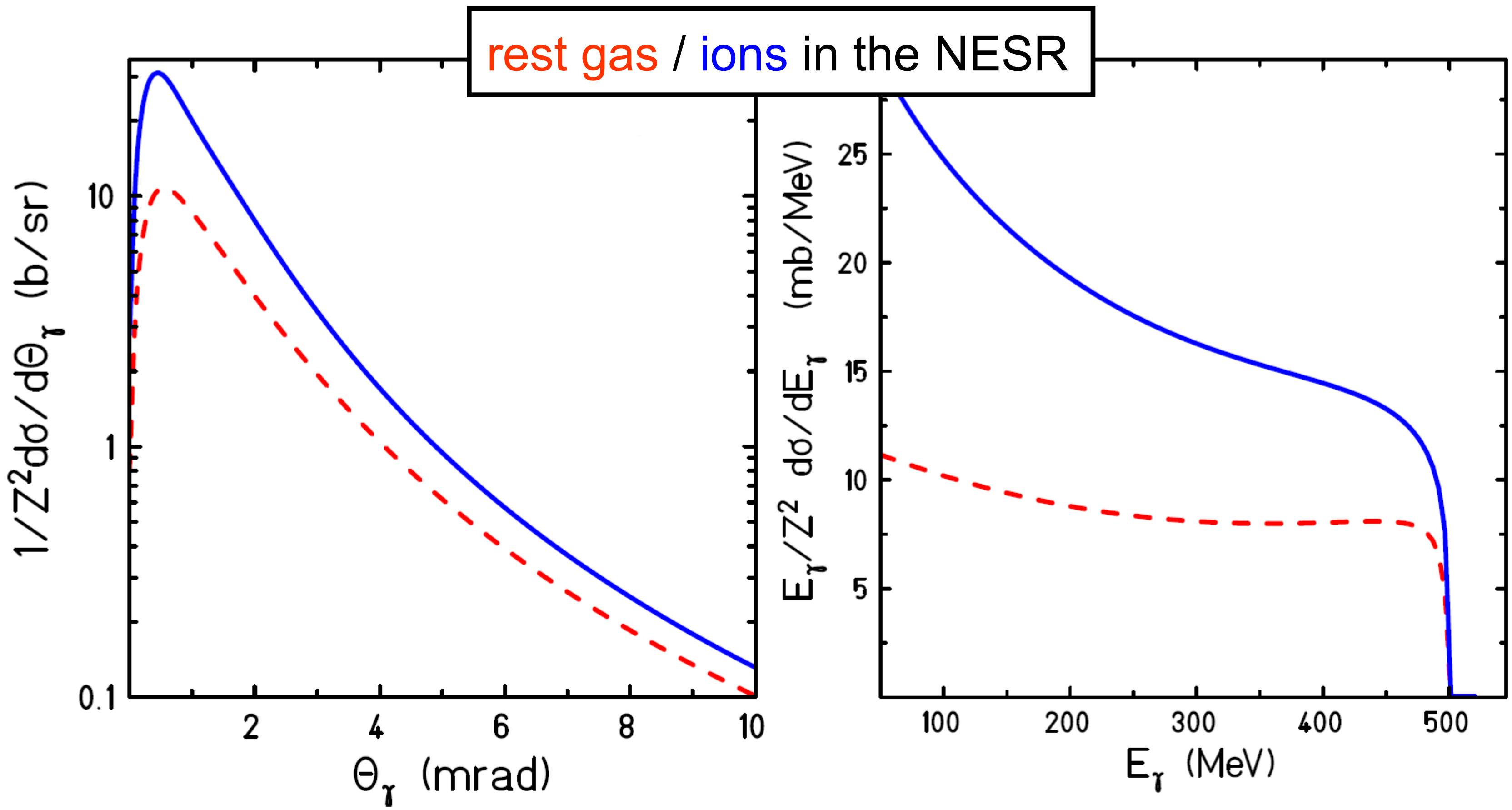
Felix Wamers

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

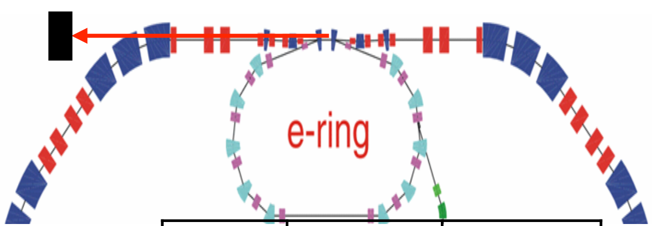


Bremstrahlung: spectrum and angular distribution



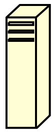
Luminosity Monitor via photons: Concept

position sensitive (i)
■-detector



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

(ii)

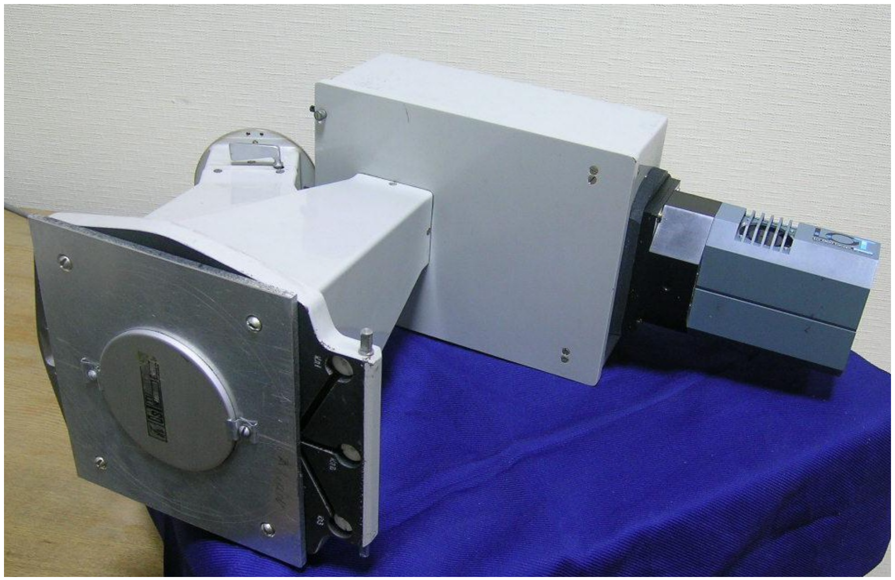


	Luminosity [$cm^{-2}s^{-1}$]	Effect, [*kHz*]	Background [*kHz*]
$^{238}U^{92+}$	1.0×10^{28}	6800	0.13
$^{56}Ni^{28+}$	3.3×10^{28}	2100	0.13
$^{69}Ni^{28+}$	2.4×10^{28}	1500	0.13
$^{71}Ni^{28+}$	4.5×10^{26}	29	0.13
$^{104}Sn^{50+}$	9.9×10^{26}	200	0.13
$^{132}Sn^{50+}$	1.8×10^{28}	3800	0.13
$^{133}Sn^{50+}$	4.5×10^{26}	90	0.13

(iii)

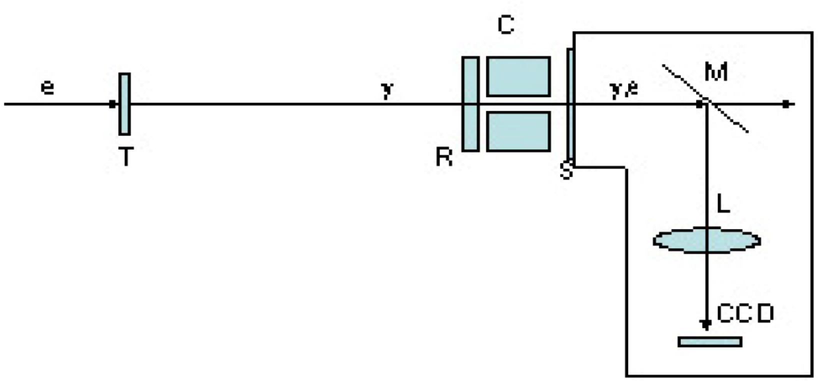
Absolute calibration via small angle scattering:
$q \rightarrow 0 : F(q) \approx 1$ → Pure Mott cross section

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

NESR is postponed ...

still …

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FAIR

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s.richter@gsi.de

February 26, 2010

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

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

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