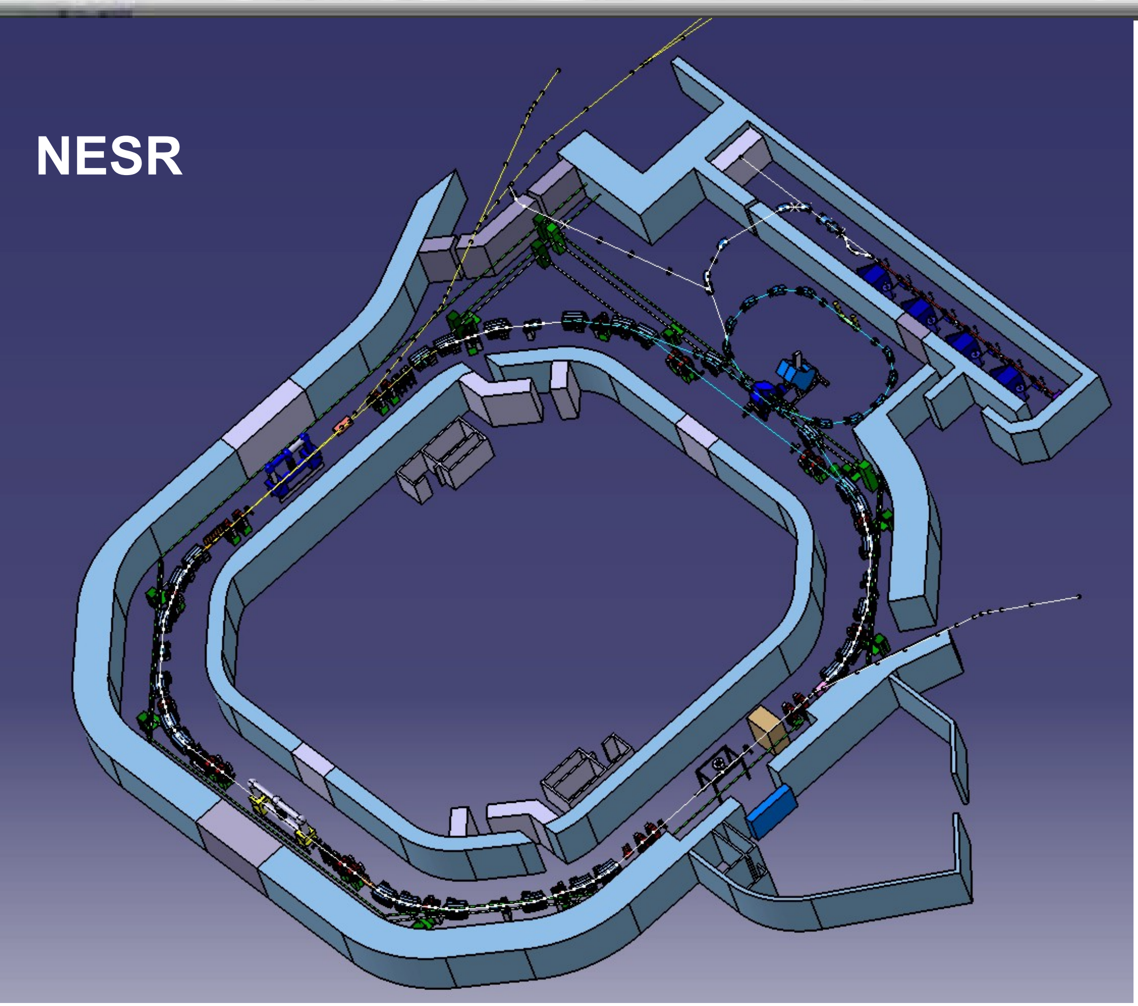
Realization of an RIB electron collider setup

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

We address the future…

With our best regards

Jacek Gierlinski
Chairman FAIR ISC

Örjan Skeppstedt
Chairman FAIR AFI

Alex C. Mueller
Chairman FAIR STI

1. Handing in of preplanning documents to hbm
2. Clarification of user requirements Modularized Start Version (MSV)
3. Start revised preplanning for MSV
4. Expected approval of revised planning for MSV
5. Preparation of documents for building permit
6. Expected approval for (partial) building permit
7. Start site preparation (clearing trees)
8. Award contracts on civil construction work lot 1 … 4
9. Completion of civil construction work lot 1 … 4
10. Start installation of accelerators and detectors

Facility for Antiproton and Ion Research

FAIR

Dr. Jacek T. Gierlinski
Chairman of the FAIR International Steering Committee

Warsaw, April 7, 2010

To the Delegates to the FAIR International Steering Committee
To the Delegates to the STI and AFI Working Groups

The picture above shows the envisaged road map to obtain the FAIR Site & Buildings permit, focussing on the appropriate steps in the upcoming two years."

We're PHASE B !

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

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.

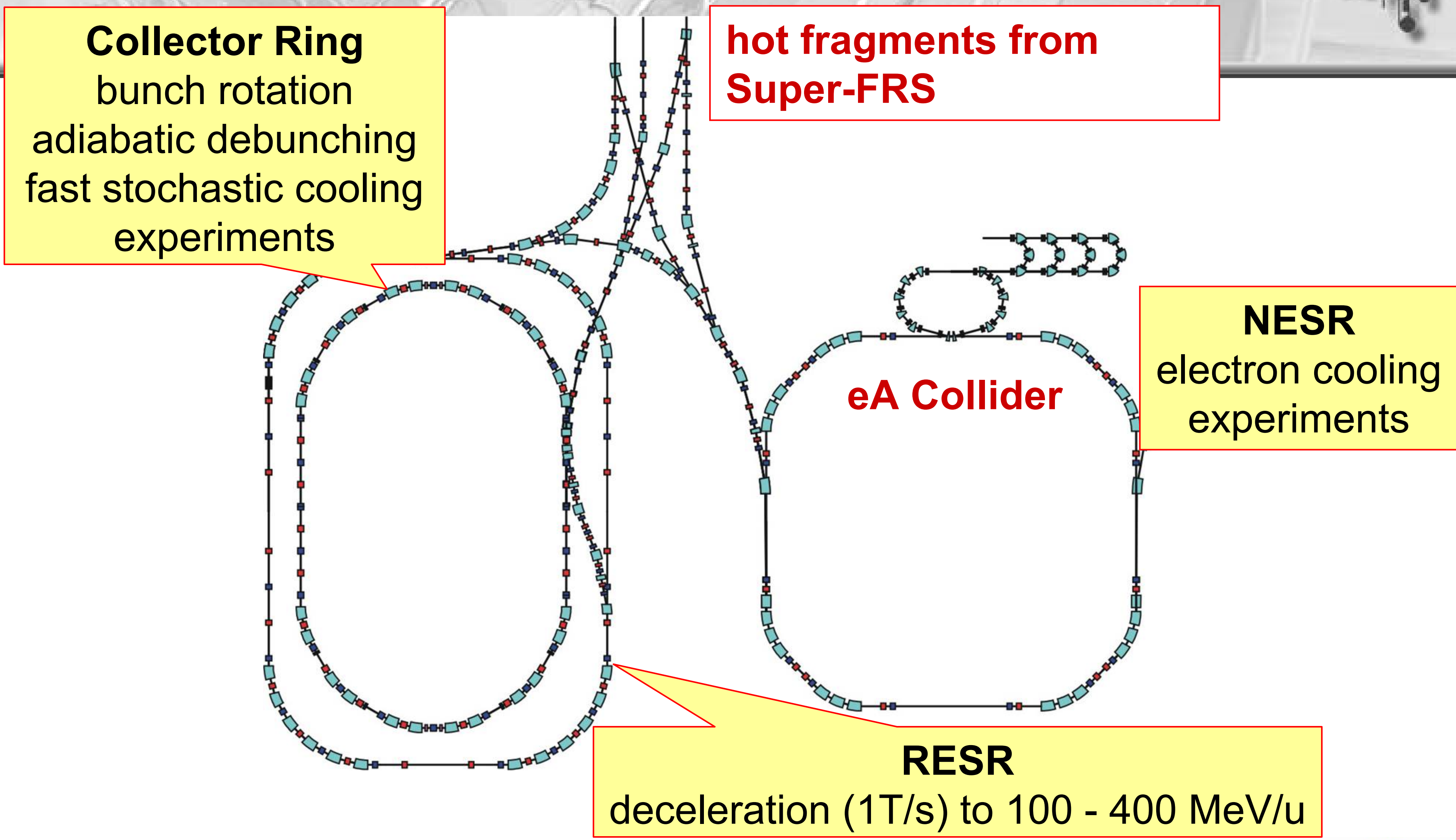
Kind regards,

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

Prof. Zbigniew Majka

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

The Ring Branch (schematic)



Why electron scattering ?

Pointlike, pure e.m. probe ➔

• Formfactors F(q)
 - elastic scattering

• $F_\ell(q)$ transition formfactors
 - excitation energy E*
 - high selectivity to certain multipolarities
 - access to interior
 - inelastic scattering

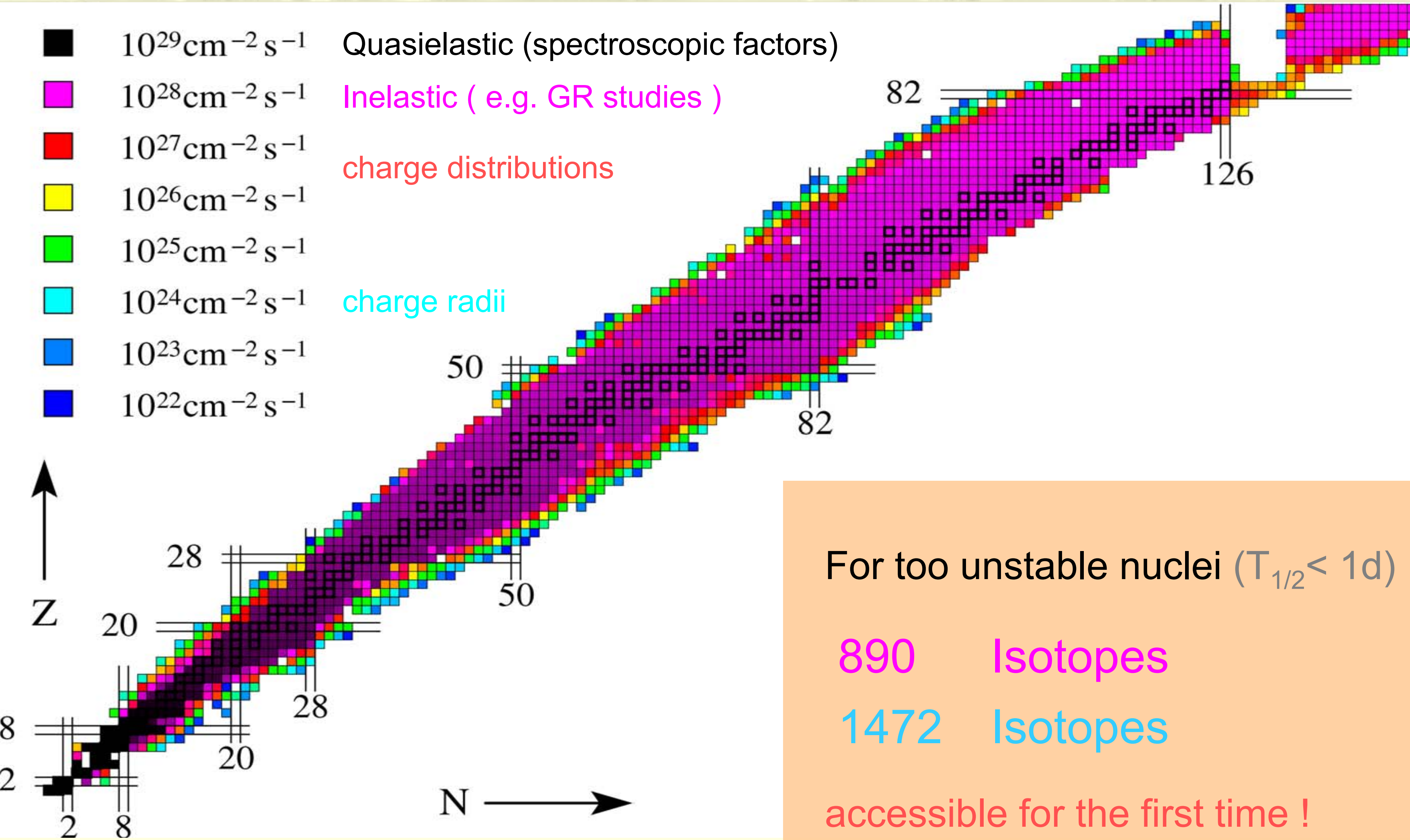
Large recoil velocities
 - full identification (Z,A) complete kinematics

Physics goals

- Charge distribution of exotic nuclei (radius, diffuseness, higher moments...) req. luminosity: about 10^{24} cm^{-2} s^{-1}
- Selective electromagnetic excitation Full identification of electric & magnetic multipolarities and of the final state (*new* collective *soft* modes) req. luminosity: about 10^{28} cm^{-2} s^{-1}
- Quasi-free scattering (single-particle structure) req. luminosity: about 10^{29} cm^{-2} s^{-1}

Expected Luminosities

➔ Full simulation of production, transport and storage



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

890 Isotopes

1472 Isotopes

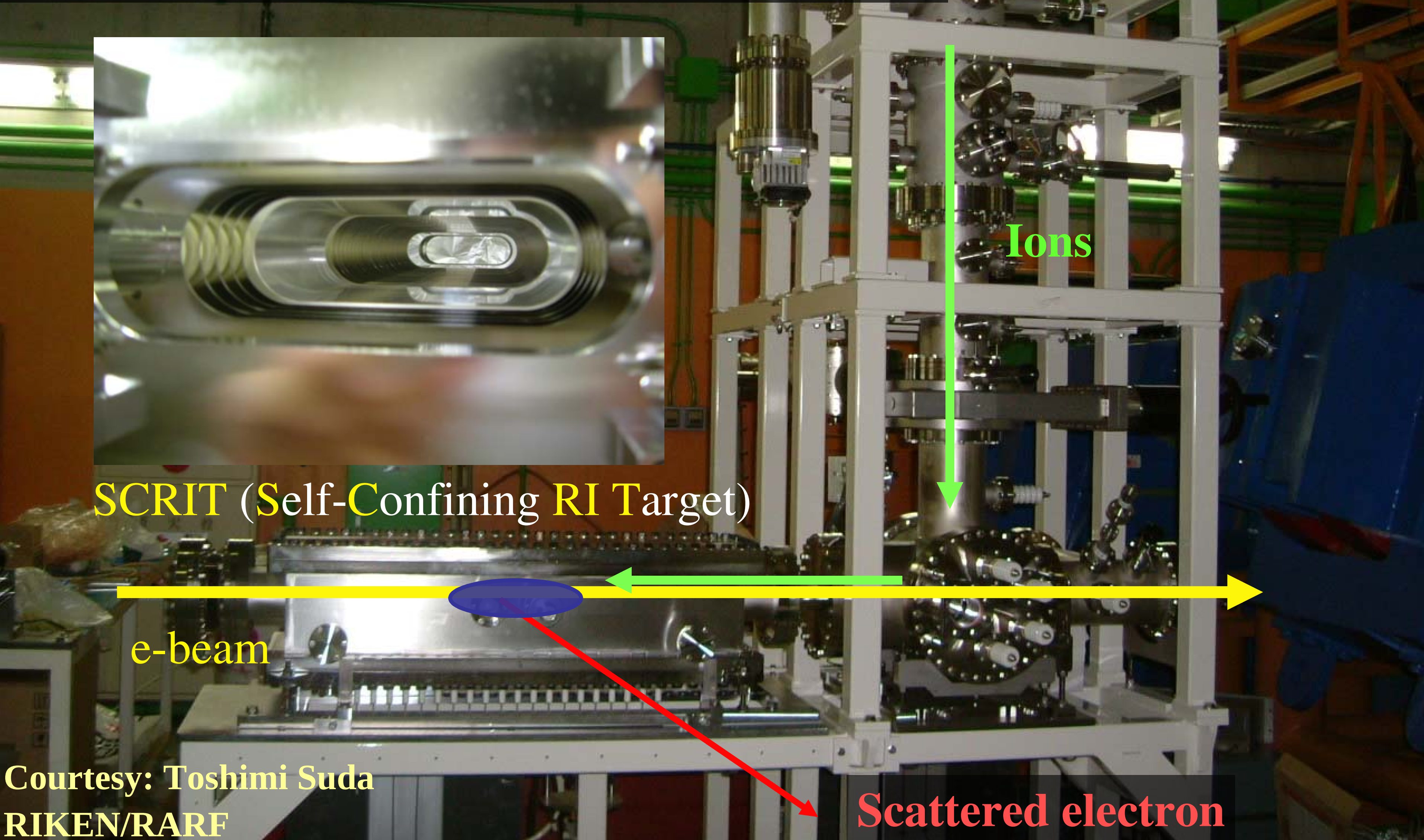
accessible for the first time !

Competing project: SCRIT for RARF

Test setup @ KSR Kyoto Univ. — **100 MeV/100mA**

Installation: AURORA — **200-300 MeV/300mA**

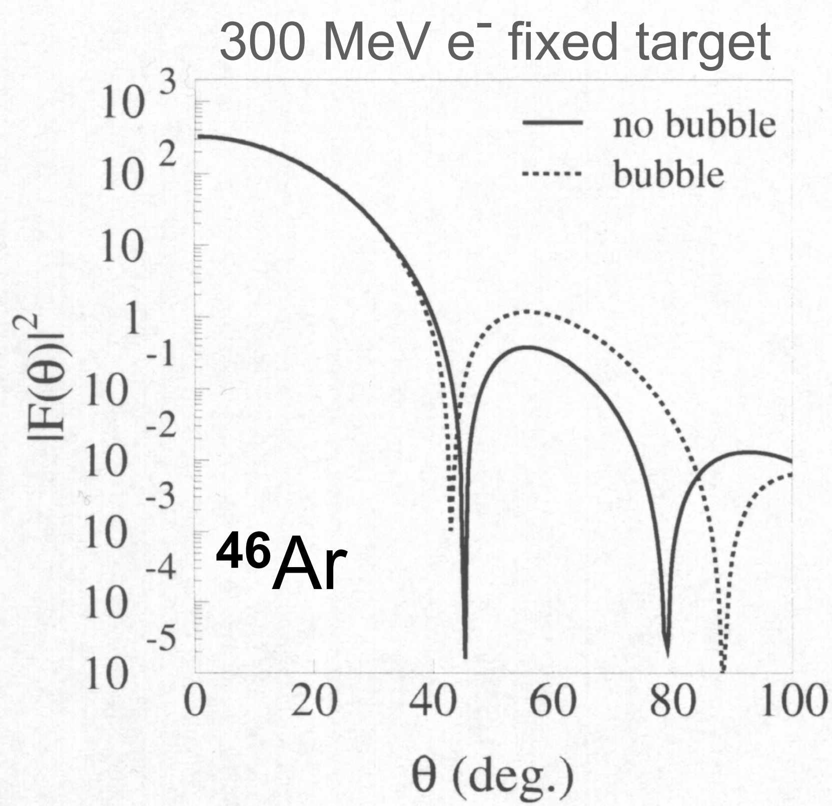
ISOL facility planned — **$\sim 10^{26..28}$cm^{-2}s^{-1}(stable)**



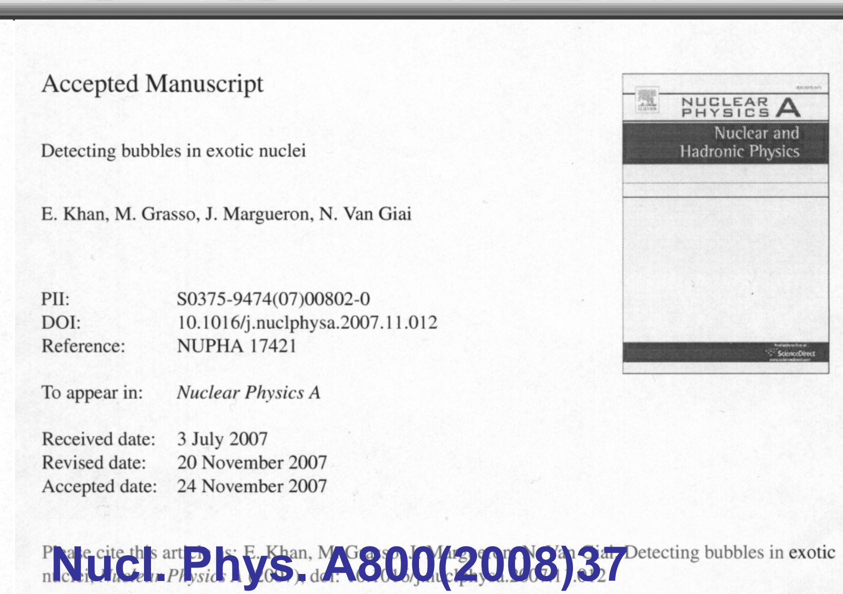
Courtesy: Toshimi Suda
RIKEN/RARF

Elastic Scattering

→ reference measurements for e.g. laser spectroscopy or DR



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

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

→Absolute measurement
→Charge distributions

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

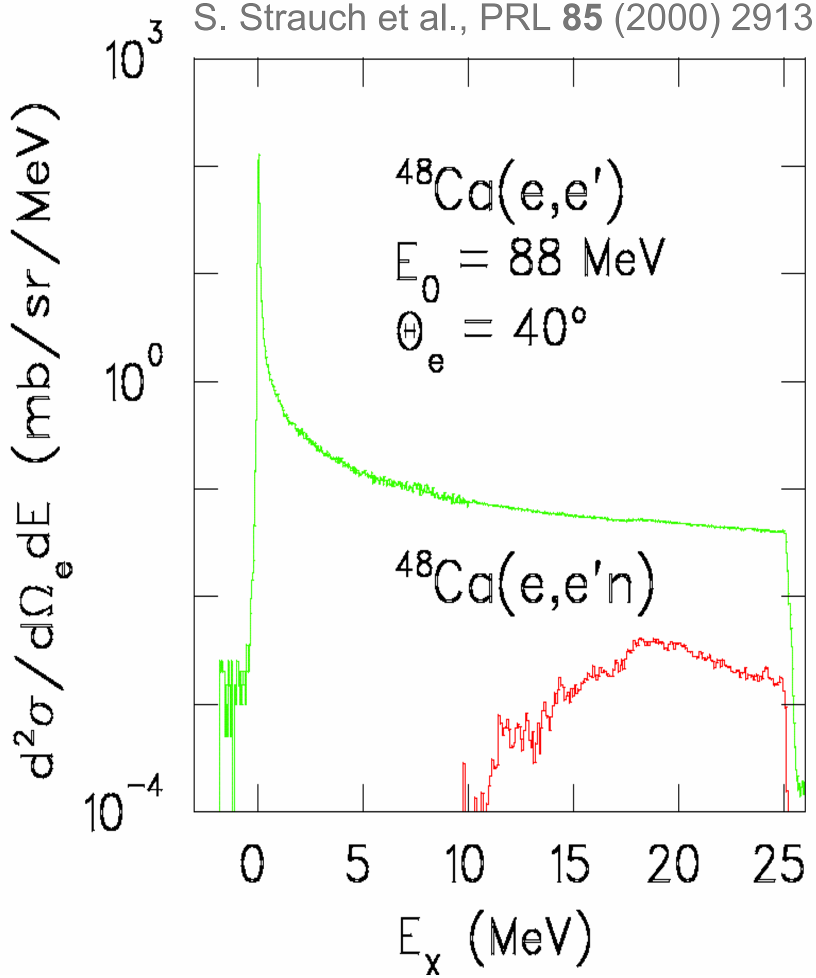
• kinematical focusing
➔ solid angle
➔ Mott cross section enhanced (small angles)

• luminosity for unstable nuclei (no target)
➔ 100µm x 100µm interaction area
vs e.g. dilute ions in a trap

Inelastic Scattering

→compared to conventional (fixed target) experiments

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

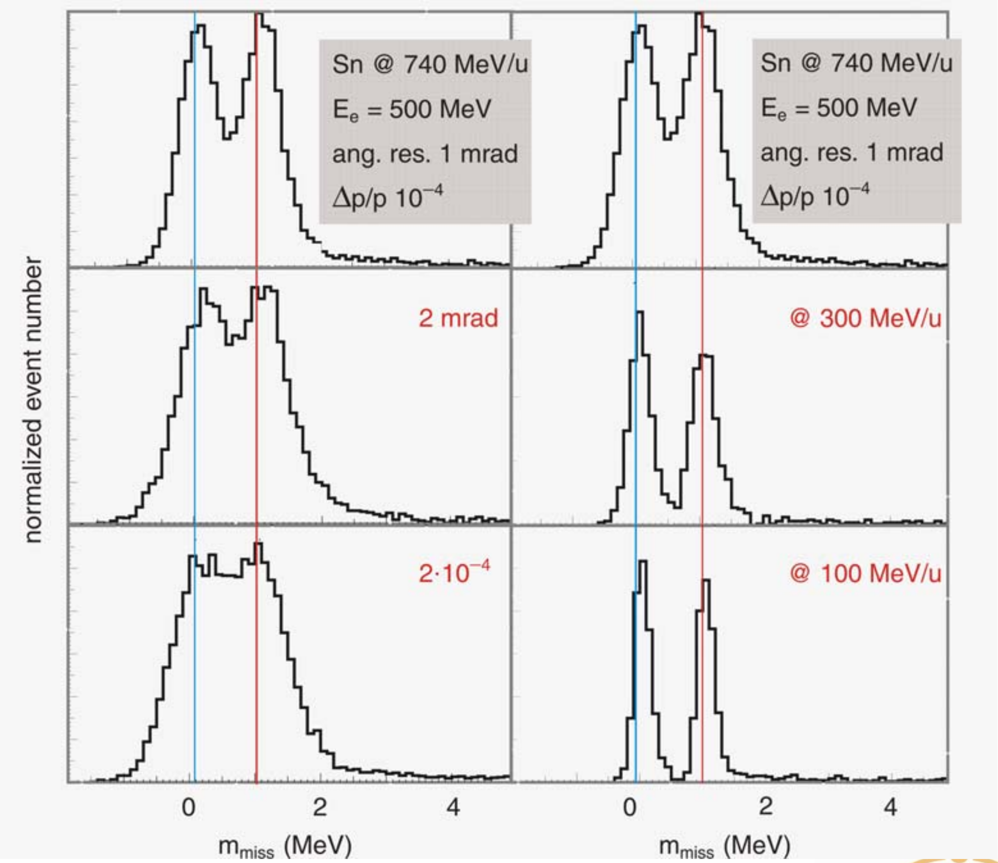


Fixed target		Collider 1.5GeV
^{48}Ca(e,e‘n)		^{48}Ca(e,e‘A‘)
Ω_n =100msr	**100**	Ω_n ~ 4π
n_{eff} =20 %	**5**	n_{eff} ~ 100 %
$\Theta_{e‘}$ = 40 °	**50**	$\Theta_{e‘}$ = 5 °
	<u>>10⁴</u>	
L=10^{31} - 10^{32}	cm^{-2} s^{-1}	**L ~ 10^{27}**

Where's the challenge ?

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

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

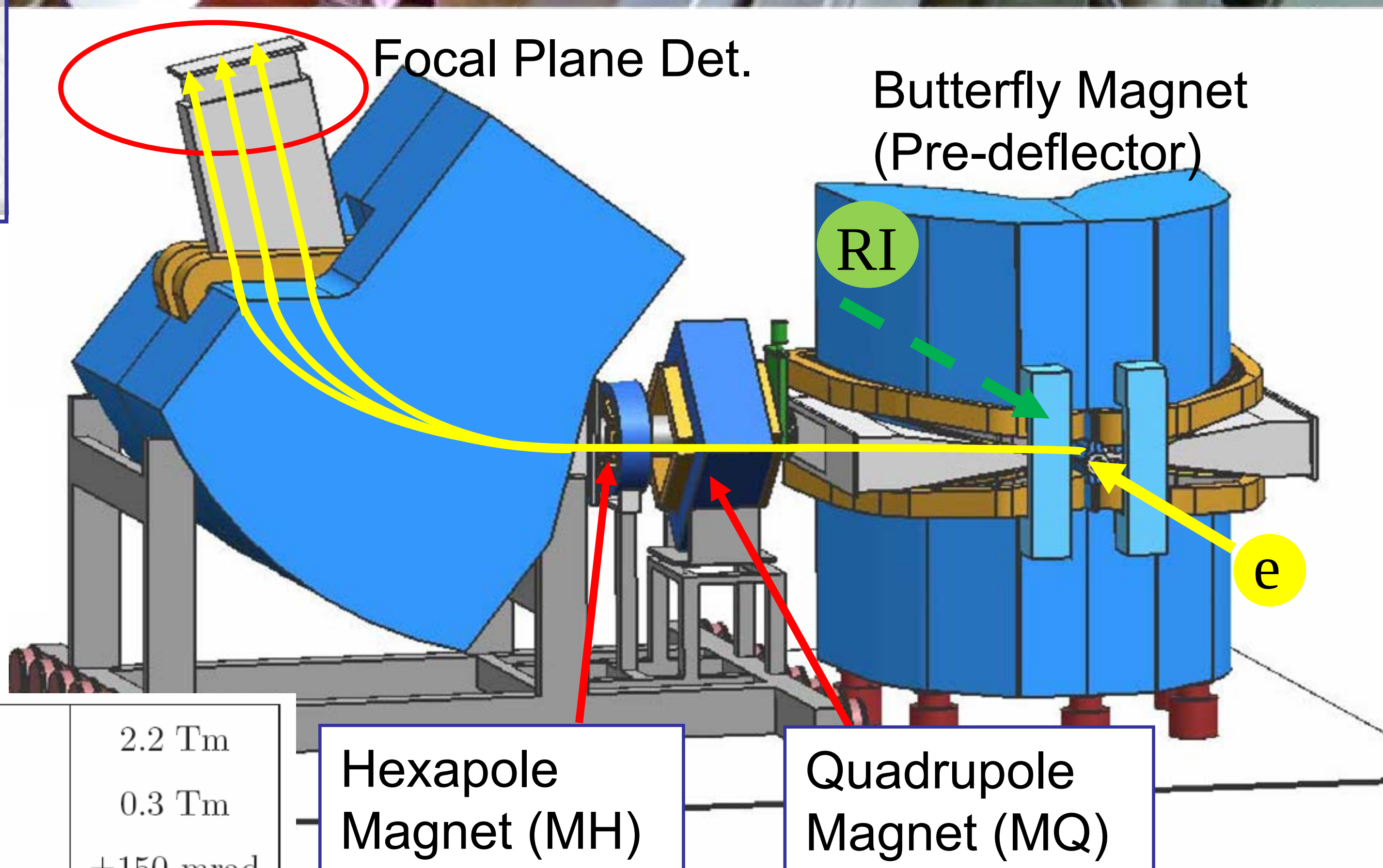


Pure kinematics calculus:

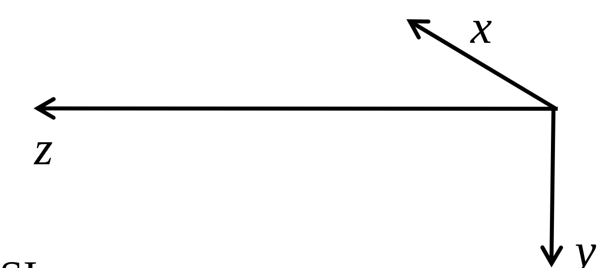
- colliding beam kinematics
- angular and energy resolution coupled
- achievable resolution can be improved by getting the "target" to "rest"

  ➔ reduced luminosity

High Resolution Large Acceptance Spectrometer

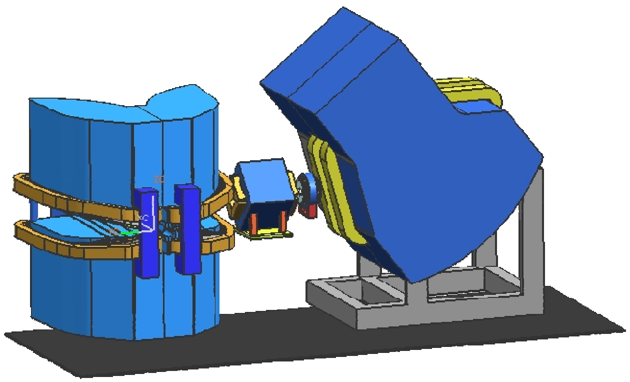


Maximum rigidity $B\rho$	2.2 Tm
Minimum rigidity $B\rho$	0.3 Tm
Angle acceptance, azimuthal	±150 mrad
Angle acceptance, polar at 11.4°	±24 mrad
Angle acceptance, polar at 22.7°	±70 mrad
Energy acceptance	± 5 %
Resolving Power $E/\Delta E$	$\approx 10^4$
Angle resolution	1 mrad
Kinematic compression factor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



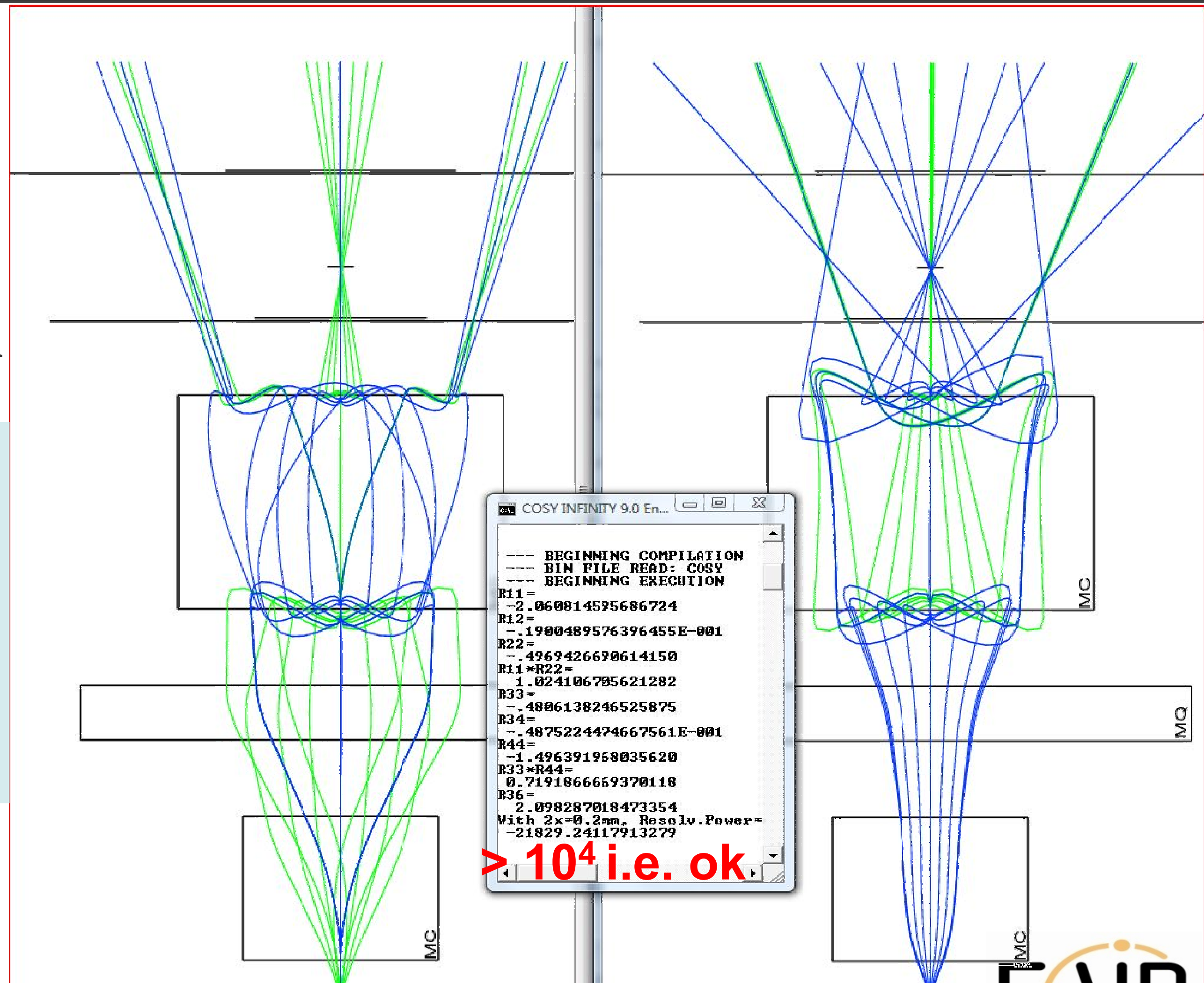
KVI/BINP/GSI

CAD model & Beam optics calculations
→ Technical feasibility



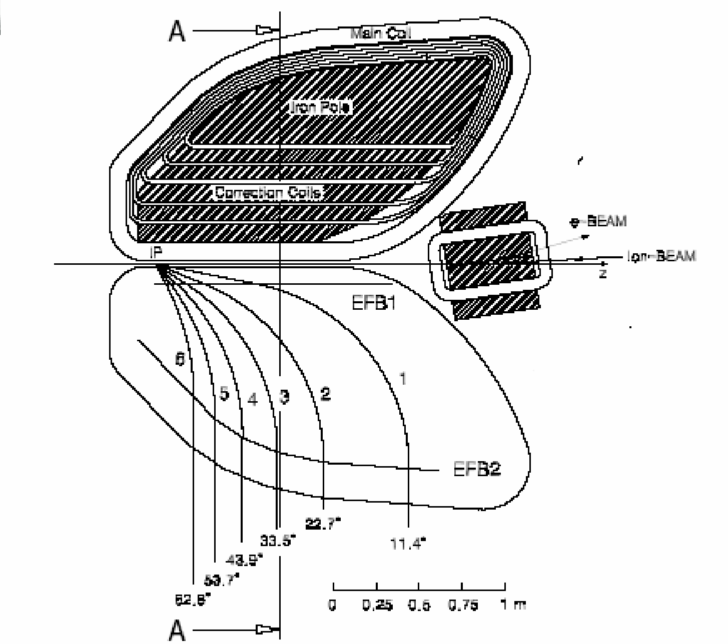
Θ_{Lab}: 10-60°
q: 20-600 MeV/c

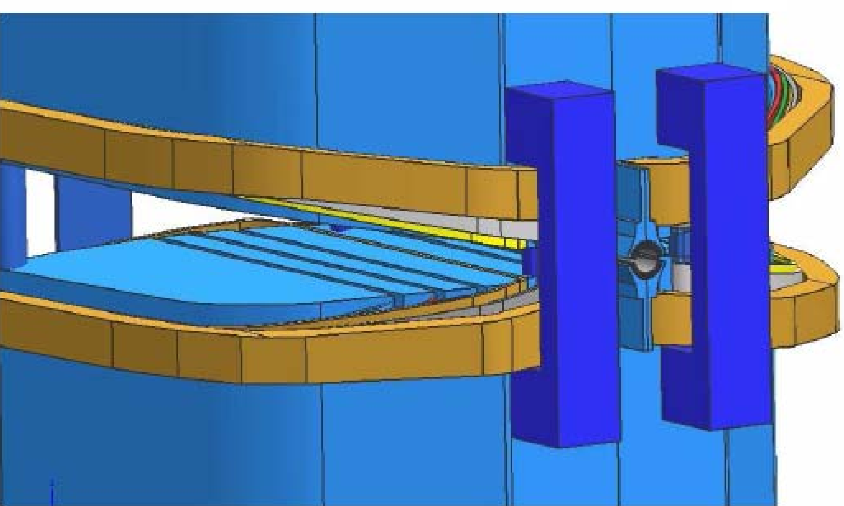
for electron energies:
125-500 MeV



G. Berg
20080808

Related NIM paper
→ TDR Q4/2010





A Novel Spectrometer for Studying Exotic Nuclei with the Electron/Ion Collider ELISe

G. P. A. Berg [1]

Department of Physics and the Joint Institute for Nuclear Astrophysics, University of Notre Dame, Notre Dame, IN 46556, U.S.A., and Kernfysisch Versneller Instituut, University of Groningen, Zernikelaan 25, NL-9747 AA Groningen, The Netherlands

T. Adachi, M. N. Harakeh [2], N. Kalantar-Nayestanaki, H. J. Wörtche

Kernfysisch Versneller Instituut, University of Groningen, Zernikelaan 25, NL-9747 AA Groningen, The Netherlands

H. Simon

GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, D-64291 Darmstadt, Germany

I. A. Koop

Budker Institute for Nuclear Physics, 11 Prosp. Akademika Lavrentieva, Novosibirsk 630090, Russian Federation

M. Couder

Department of Physics and the Joint Institute for Nuclear Astrophysics, University of Notre Dame, Notre Dame, IN 46556, U.S.A.

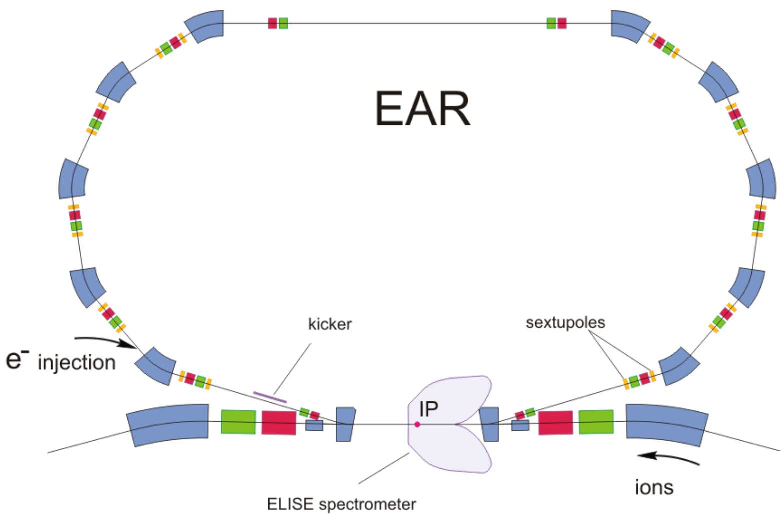
M. Fujiwara

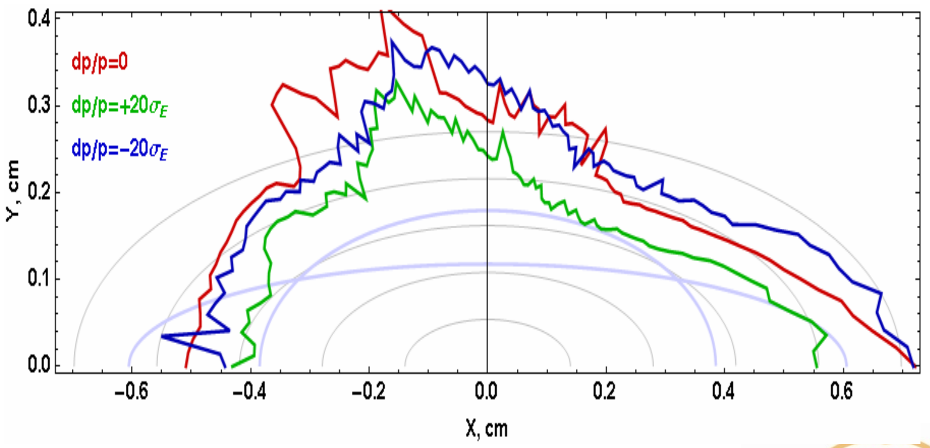
esearch Center for Nuclear Physics, Osaka University, Mihogaoka 10-1, Ibaraki 567-0047, Osaka, Japan

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 …

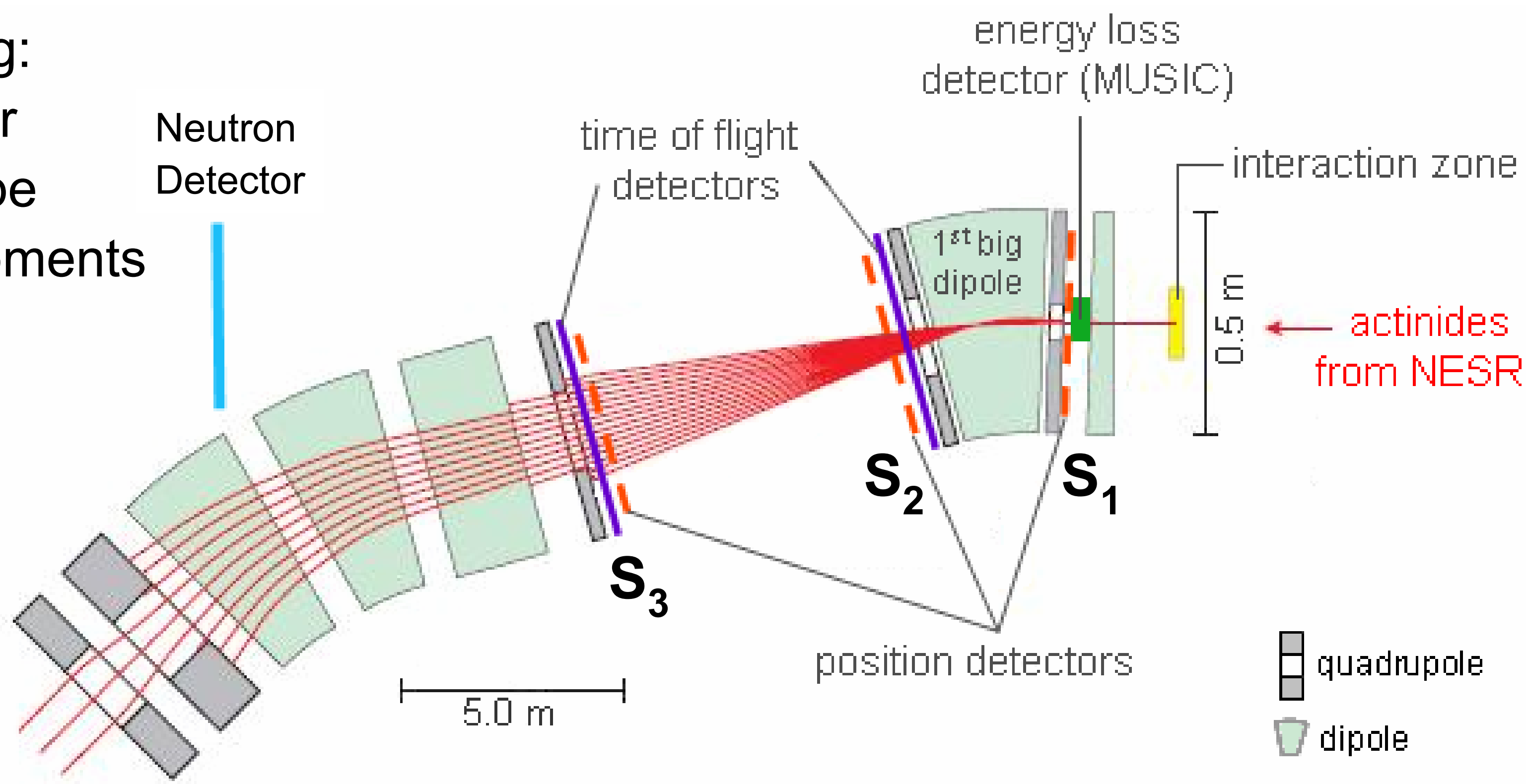




In-Ring spectrometer in the Bypass

CEA-DAM Bruyères-le-Châtel, JINR Dubna, GSI

Ongoing:
Detector prototype developments

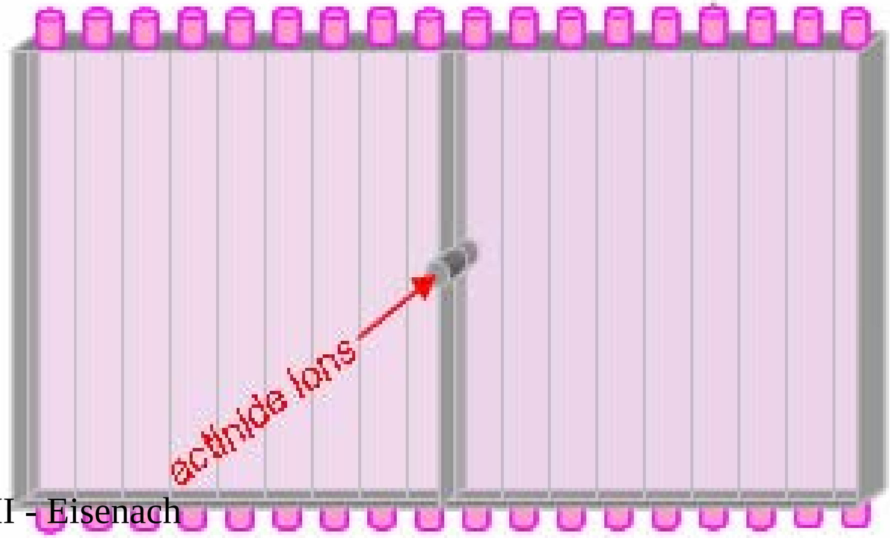


Most demanding physics case: Electrofission studies
-coincident identification of both fission fragments
-excitation energy directly measured (multipole decomposition)

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

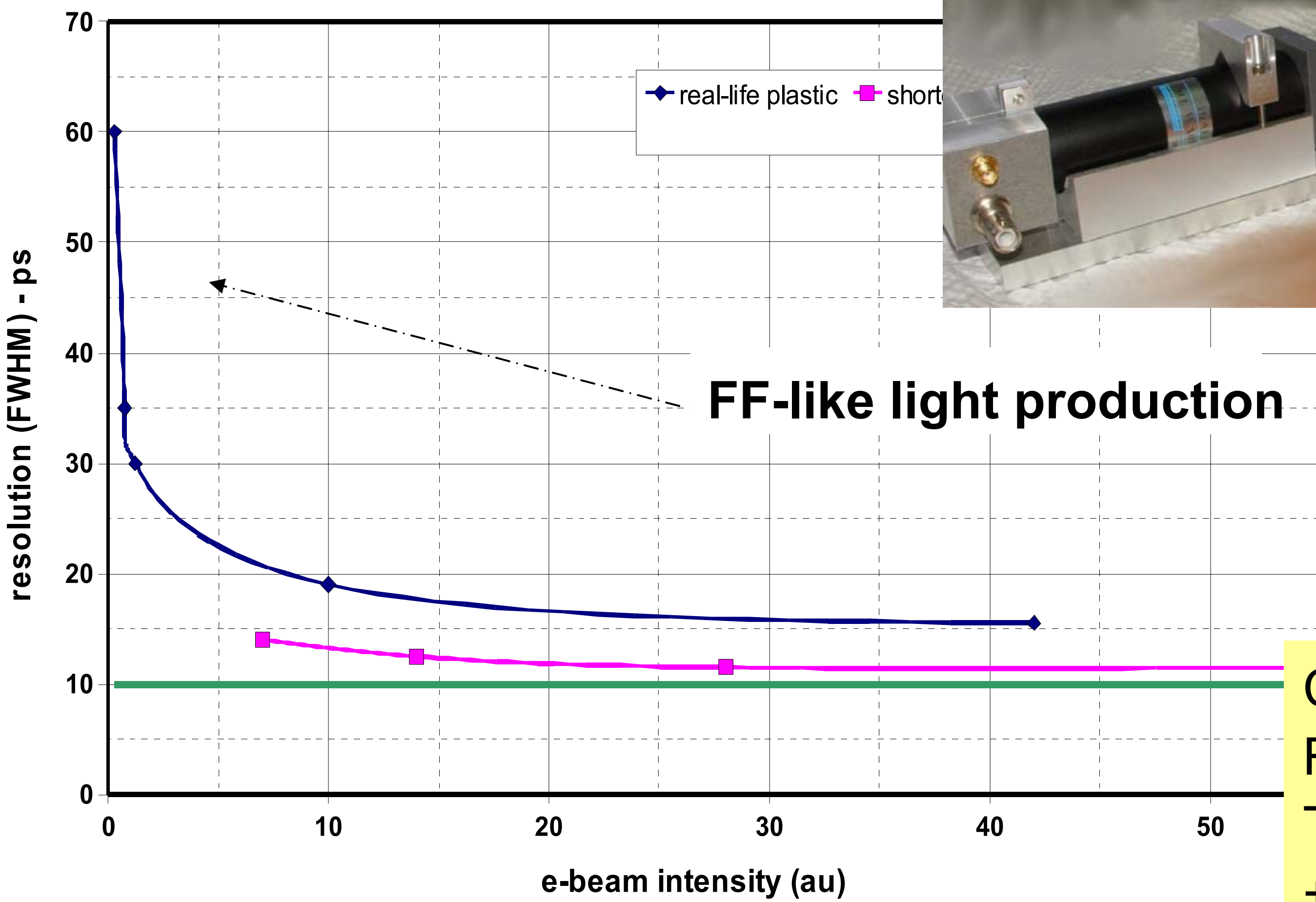
J. Taieb et al., CEA Bruyères-le-Châtel

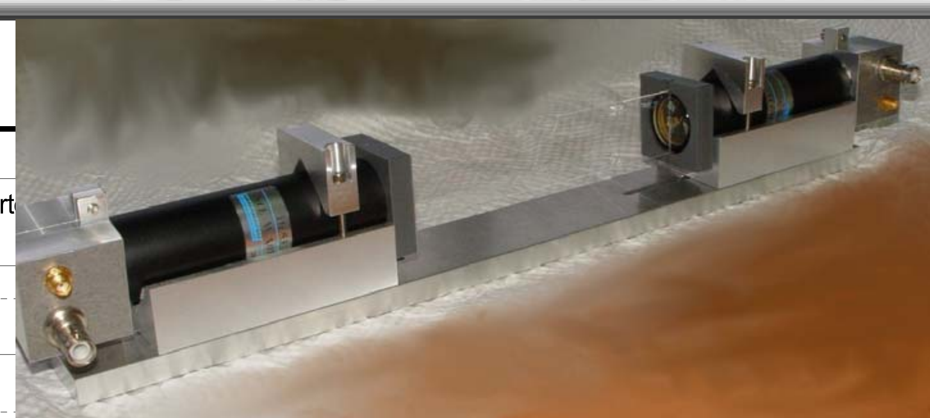
- Most demanding part : 35ps FWHM needed
  S. Nishimura et al., Nucl. Inst. Meth. A510 (2003)377
- Very fast plastic stripes
  (Eljen Technology: EJ-323 0.25% quenched 43ps rise time)
  - T_2 : 30 x 150 x 0.5 mm^3 (2 x   5 paddles)
  - T_3 : 30 x 300 x 0.5 mm^3 (2 x 10 paddles)
- Fast PMT (H6533)
- No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



First test: ToF resolution

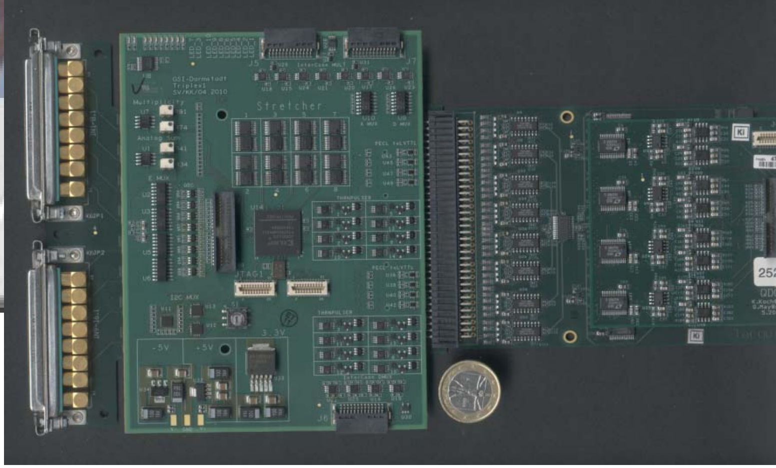
J. Taieb et al., CEA Bruyères-le-Châtel



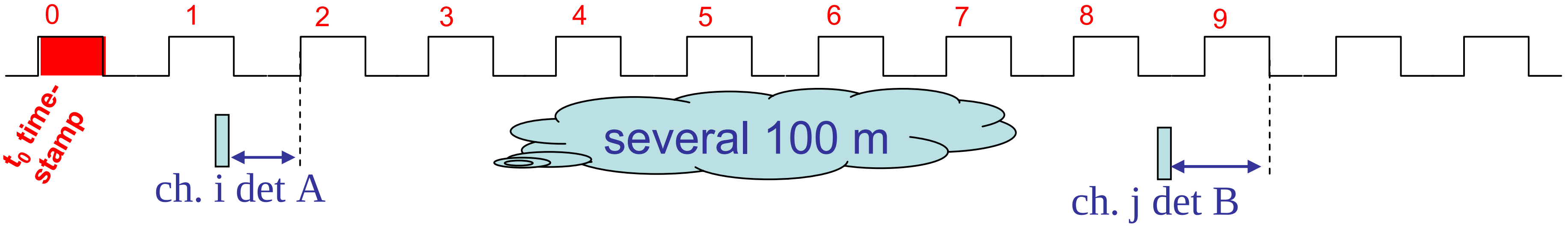


Compatible
Readout electronics:
TACQUILA
+ BuTiS/White Rabbit
TDS

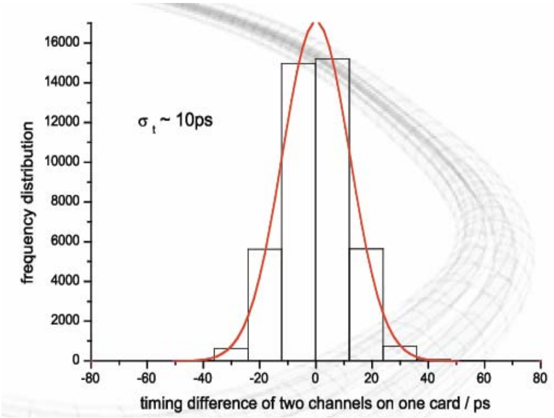
Precision timing (<50ps) vs. Campus Clock



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

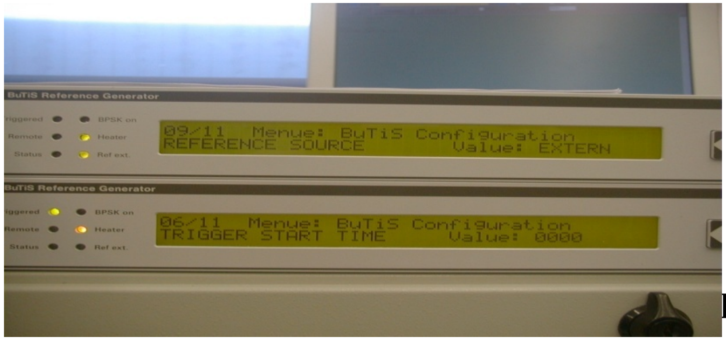


- synchronized precision oscillators 17ps R.M.S (abs.100ps/km, <1ps jitter)



Tacquila system (ASIC FhG/GSI)

New systems (ASIC dev. GSI FPGA based TDC)



… you can measure ToF over long distances !

General NIM paper

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

...

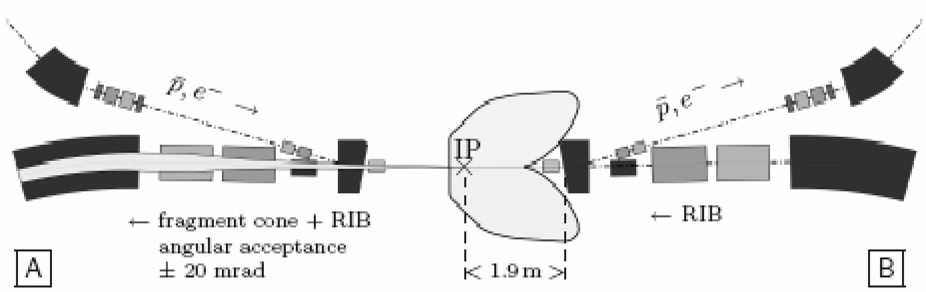
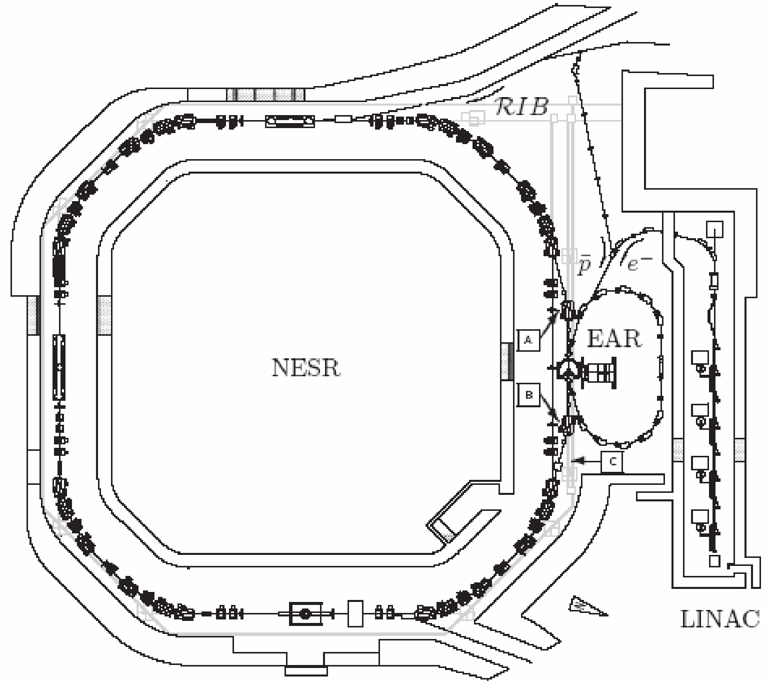


Figure 6: Interaction zone with the interaction point IP in the bypass section of the NESR.



close to be accepted
(theory issue !)

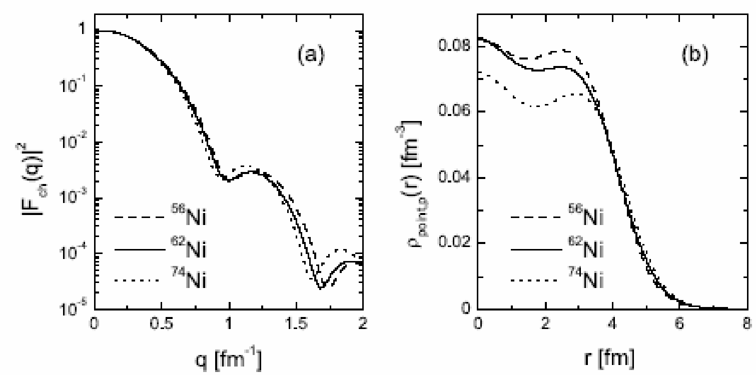


Figure 1: Charge form factors (panel (a)) calculated in DWBA and HF+BCS proton densities (panel (b)) for the unstable doubly-magic ^{56}Ni (dashed line), stable ^{62}Ni (full line) and unstable ^{74}Ni (dotted line) isotopes [7].

Other ideas …

- Laser systems

→ Compton backscattering

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

e.g. New SUBARU/Spring-8

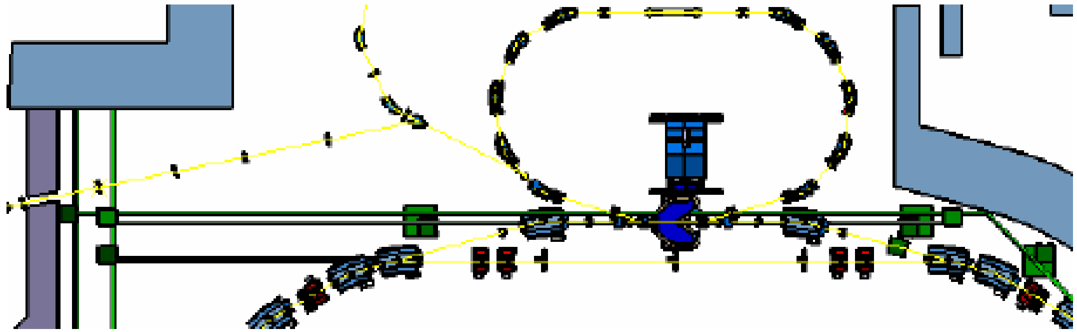
ELSEVIER Nuclear Instruments and Methods in Physics Research A 516 (2004) 228–236
Section A
www.elsevier.com/locate/nima

High-energy photon beam production with laser-Compton backscattering

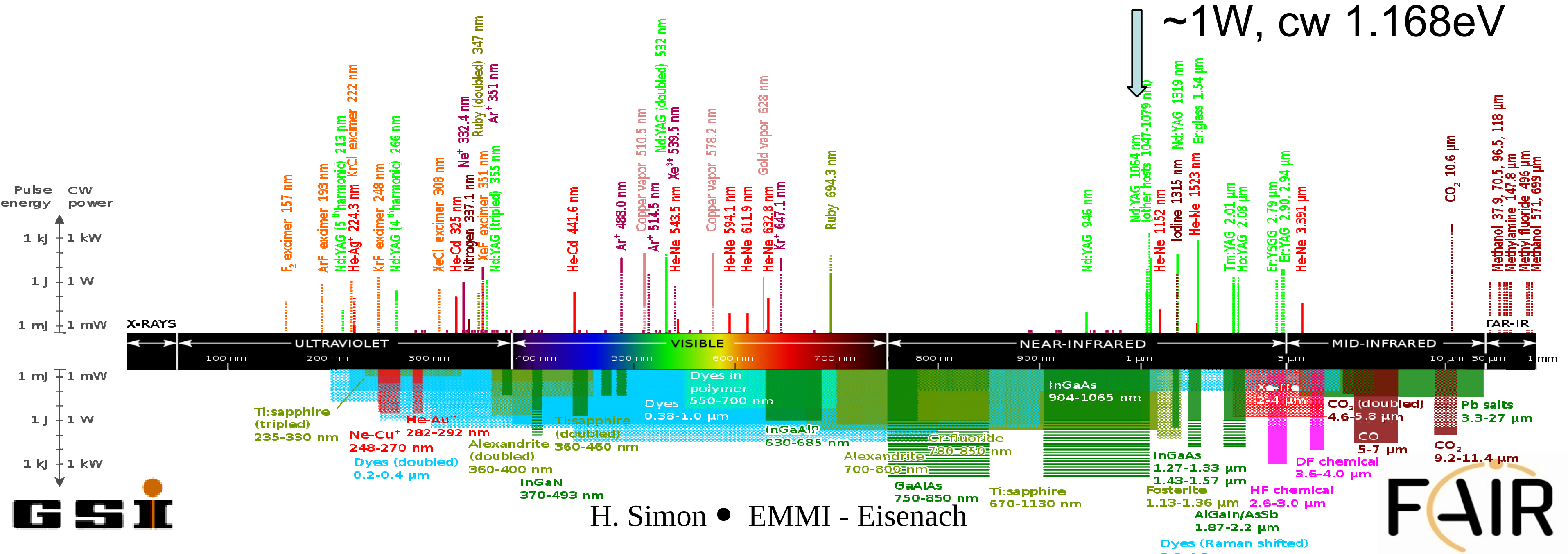
K. Aoki[a], K. Hosono[a,*], T. Hadame[a], H. Munenaga[a], K. Kinoshita[a], M. Toda[a], S. Amano[b], S. Miyamoto[b], T. Mochizuki[b], M. Aoki[c], D. Li[c]

[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

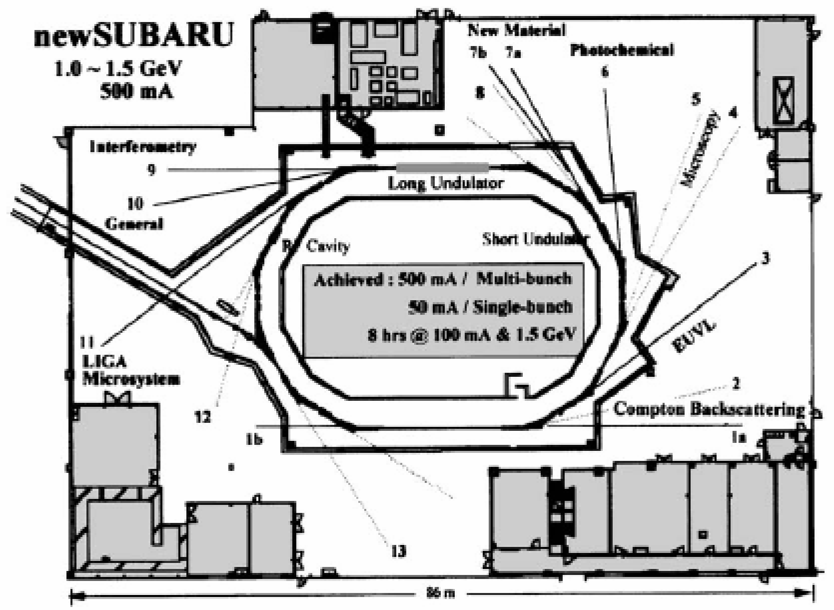


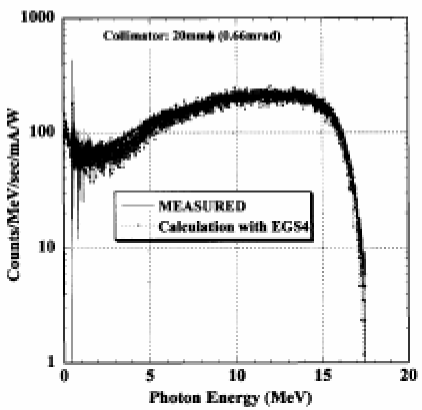
~1W, cw 1.168eV

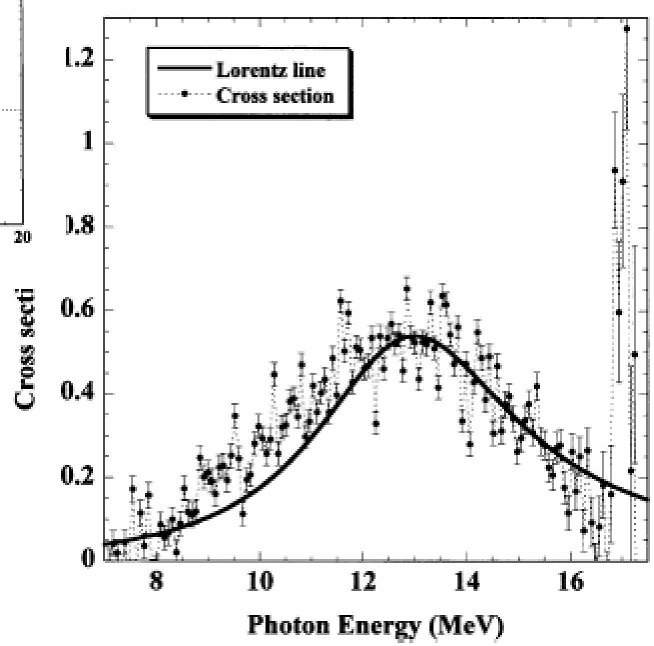


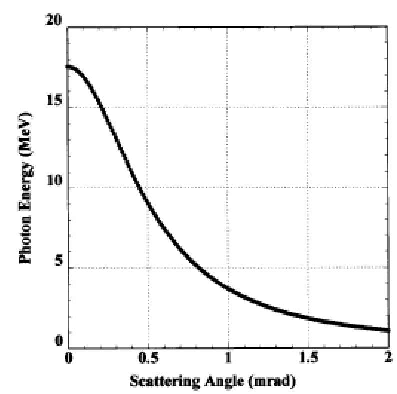
Direct comparison
➔ looks promising

- 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









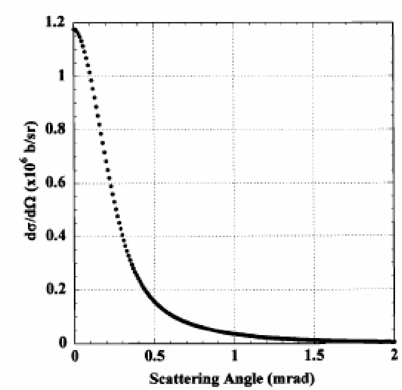
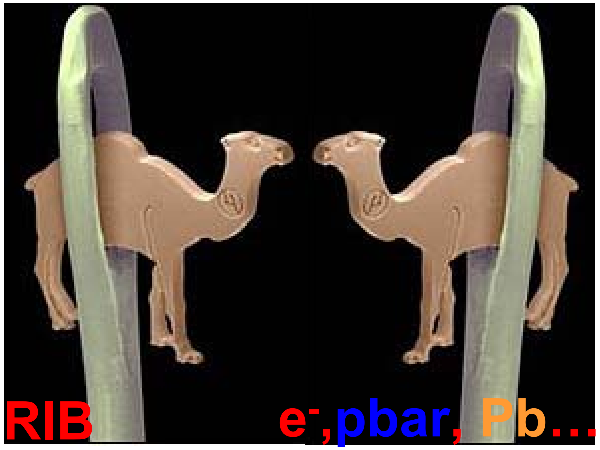


Photo-nuclear reaction
E1 (GDR) ^{197}Au

So the camel part works.



- colliding (unstable) beams @ FAIR
➔ technically challenging but feasible.

- electron/antiproton ring is to be used for ELISe and AIC, and also SPARC?

Technical Design Report 2010

Summary

- Electron(Antiproton)-RIB Collider is feasible
- Design of a Challenging spectrometer and demanding interaction zone close to final

➔ TDRs for the experiment/facility

- Detector developments
  (prototypes for experiments/tests in the existing facility)

- Unique experiment for FAIR

➔ Not only for nuclear physics studies ?

http://www.gsi.de/fair/experiments/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., 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

RIKEN - 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.

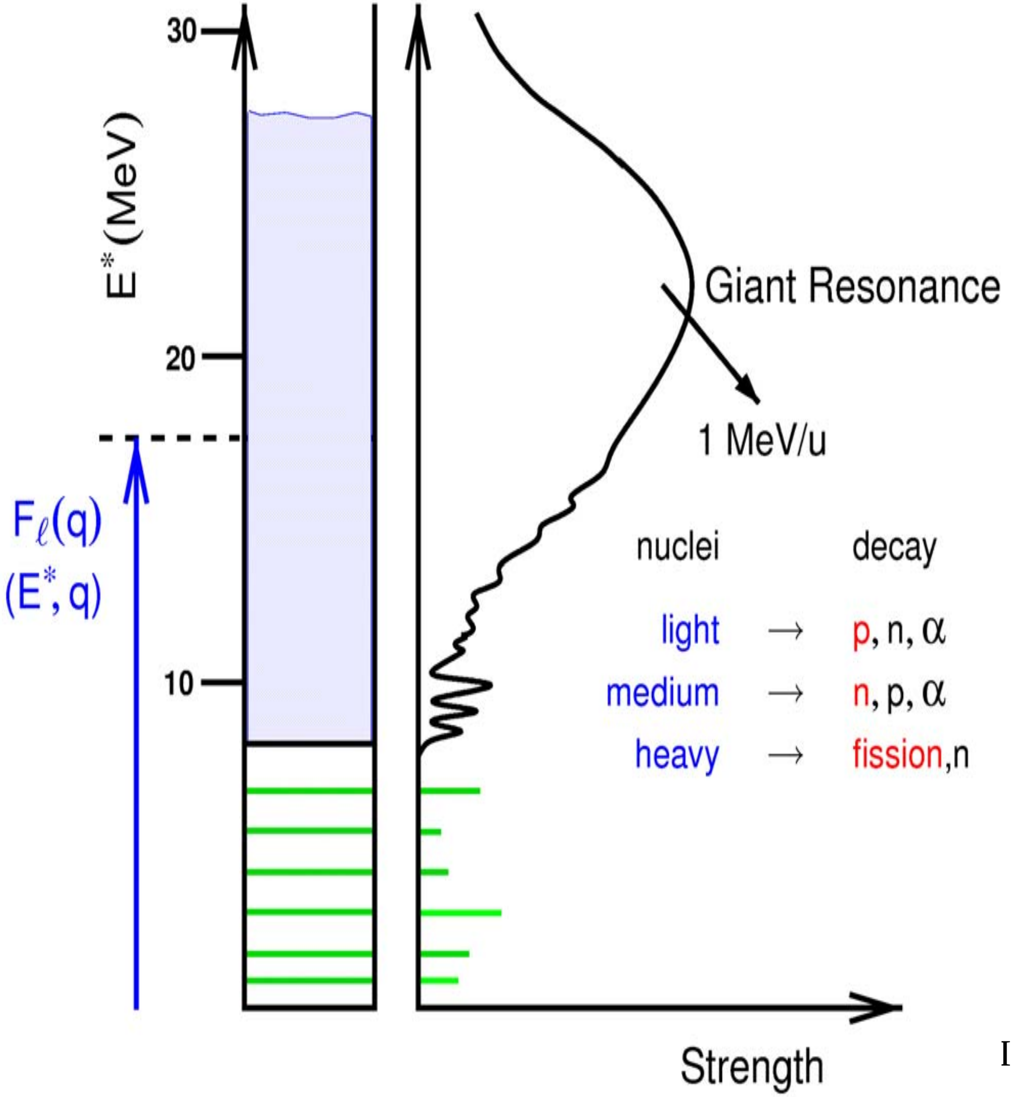
Universities of Liverpool/ Manchester/Surrey/York - United Kingdom
Chartier, M., Cullen, Stevenson, P., Johnson, R., Catford, W., Al-Khalili, J., Barton, C., Jenkins, D.

Yale University – USA Heinz, A.

Yamagata University – Japan Kato, S.

135 Collaborators / 36 Institutes / 12 countries

Inelastic scattering in the eA collider

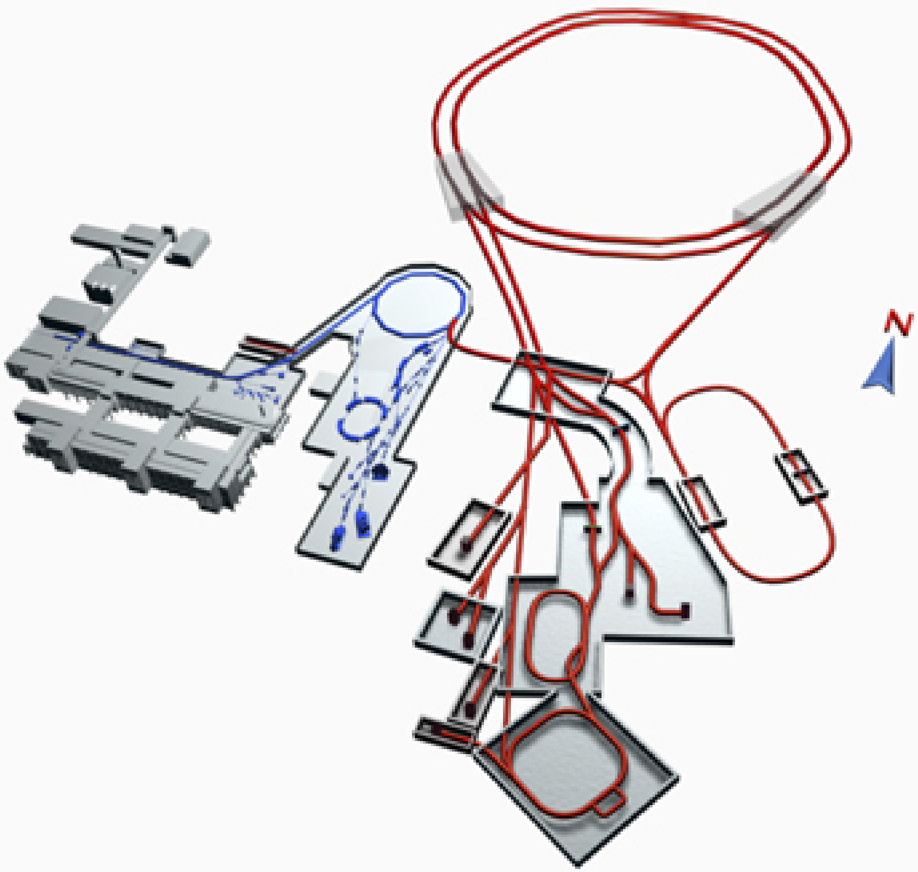


- Excitation energy is measured directly
  (below and above particle tresh.)
- momentum transfer ➔ multipolarity of transition can be determined
- final state identification with unprecendented efficiency
  (e,e'X) ➔ (e,e' A') ➔
  suppression of elastic radiative tail (no background)

➔Full measurement with purely electromagnetic probe

FAIR

The FAIR facility



Primary Beams

- 5×10^{11}/s; 1.5 GeV/u; $^{238}U^{28+}$
- $2(4)\times 10^{13}$/s 30 GeV protons
- 10^{10}/s $^{238}U^{73+}$ up to 25 (- 35) GeV/u

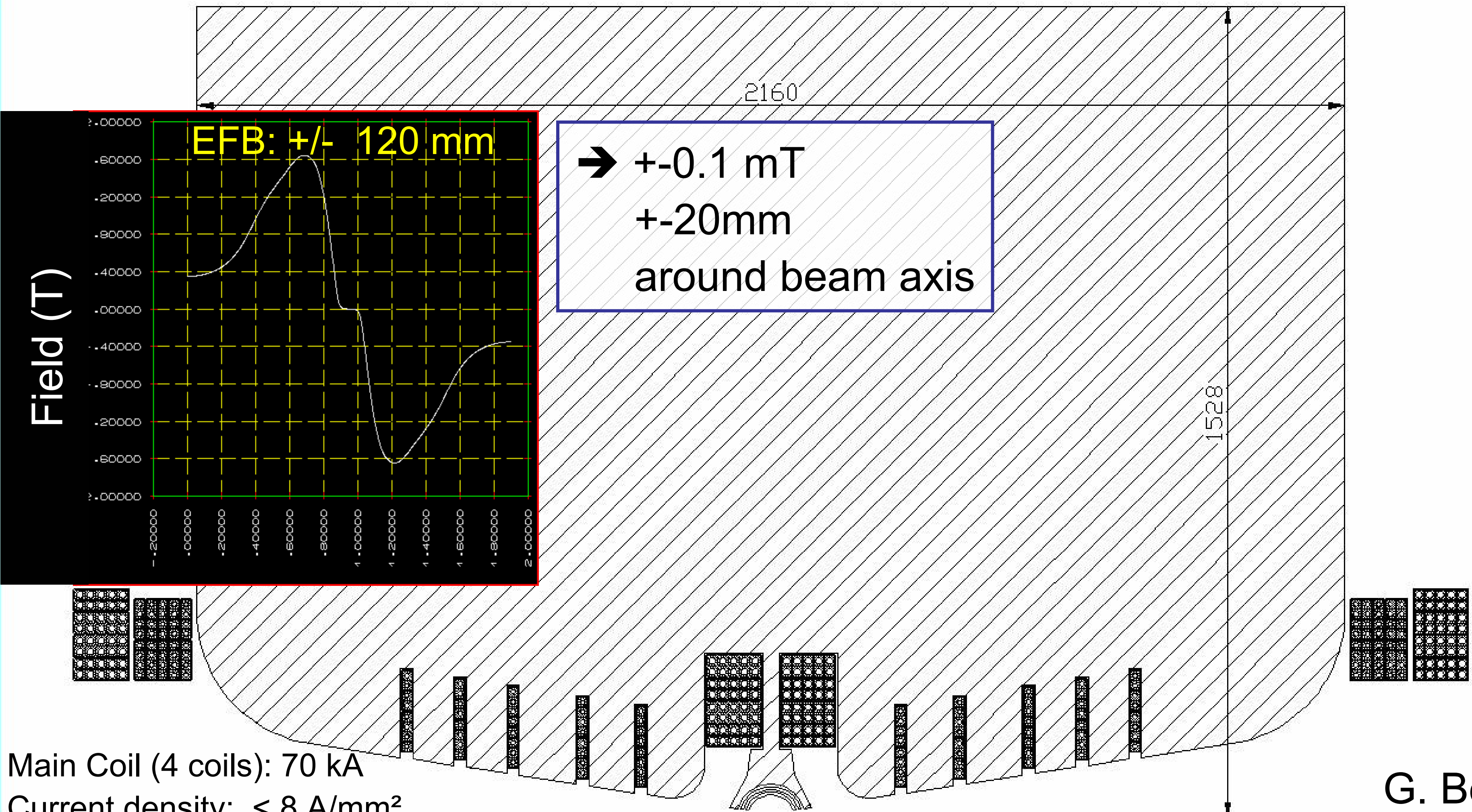
Secondary Beams

- Broad range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 in intensity over present
- Antiprotons 3 - 30 GeV

Storage and Cooler Rings

- Radioactive beams (ca. 2016)
- e – A collider (ca. 2019)
- 10^{11} stored and cooled 0.8 - 14.5 GeV antiprotons

Cross Section, Coil design



➔ +-0.1 mT
+-20mm
around beam axis

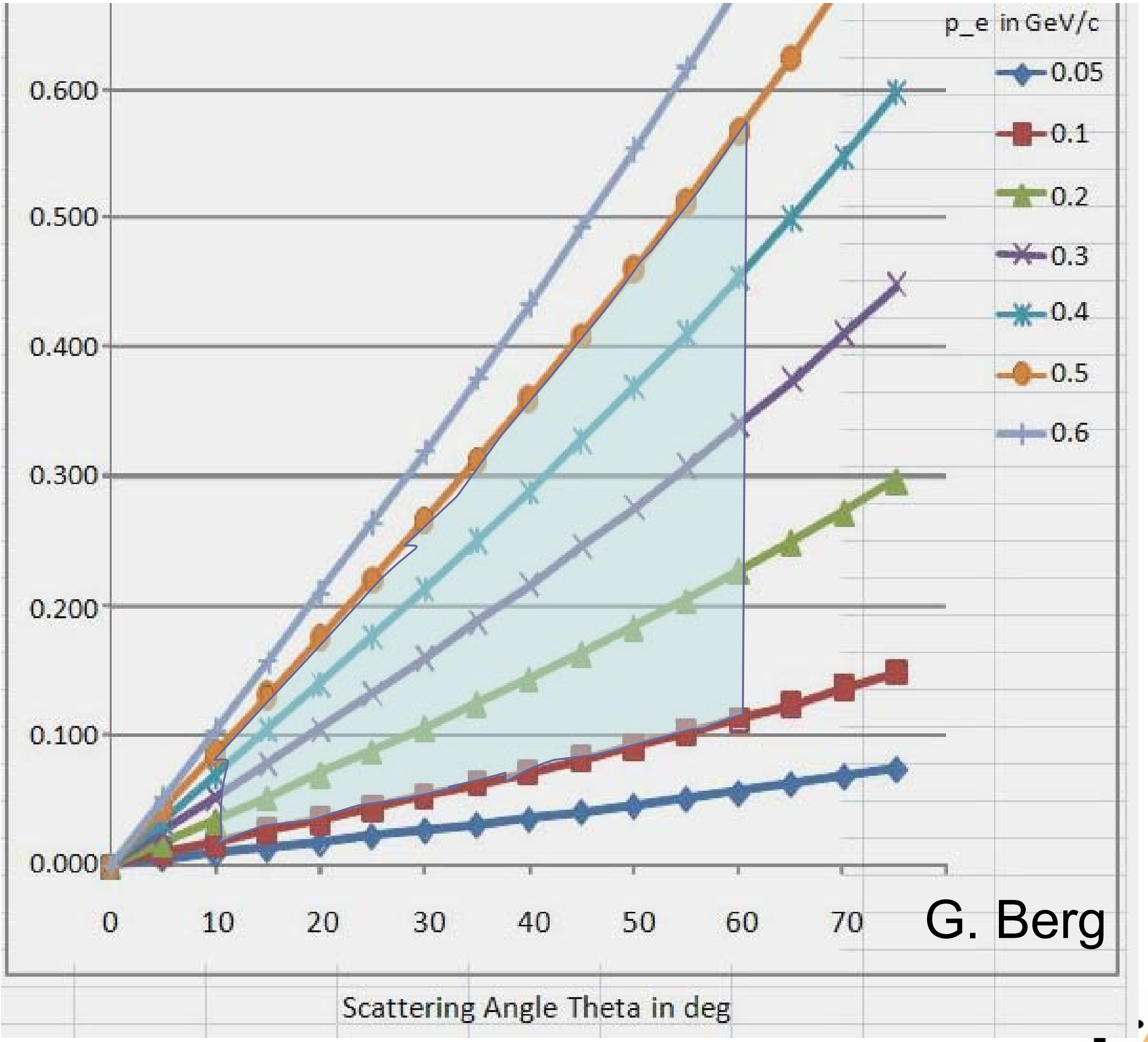
Main Coil (4 coils): 70 kA
Current density: < 8 A/mm²
Ht coils: 18, 27,20.5,15.5,24 kA

G. Berg

20080420

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)

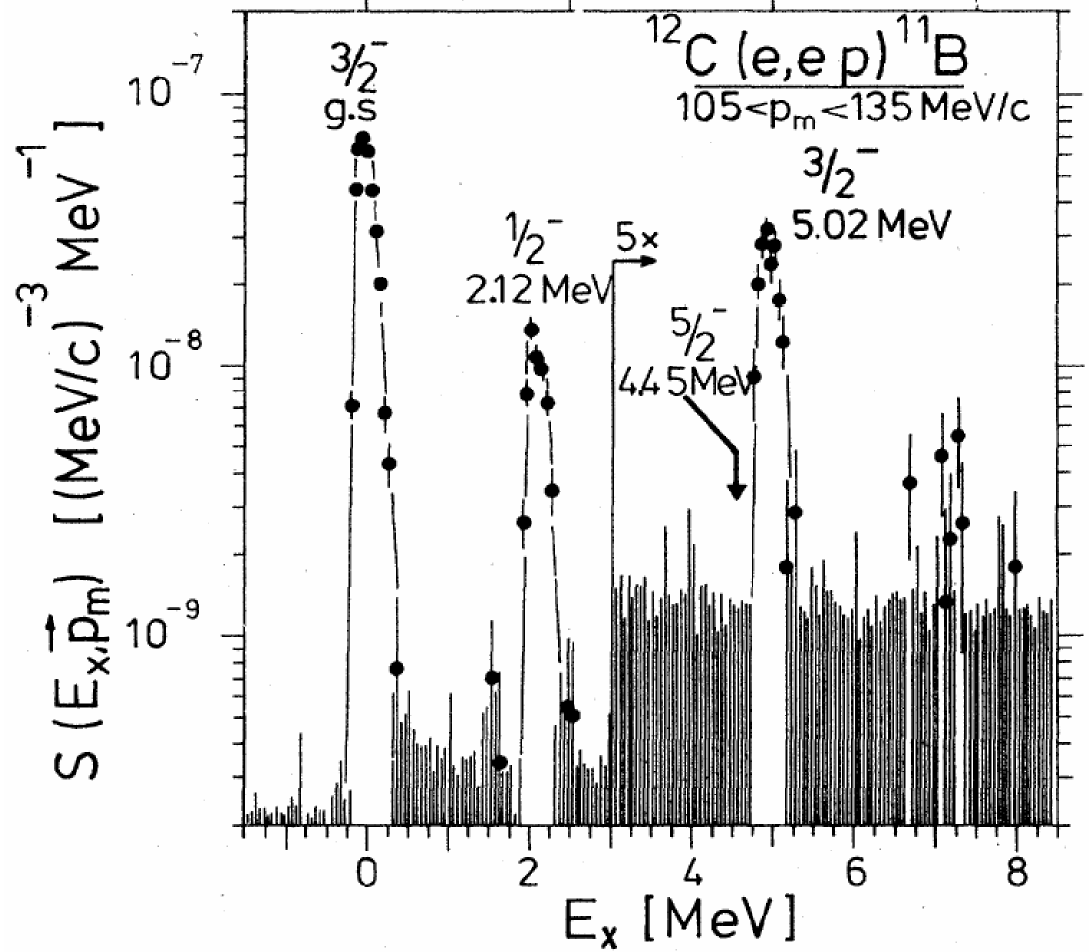
→ spectroscopic factors / spectral functions

- 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



Phys. Rev. C32 (1985) 1787

FAIR

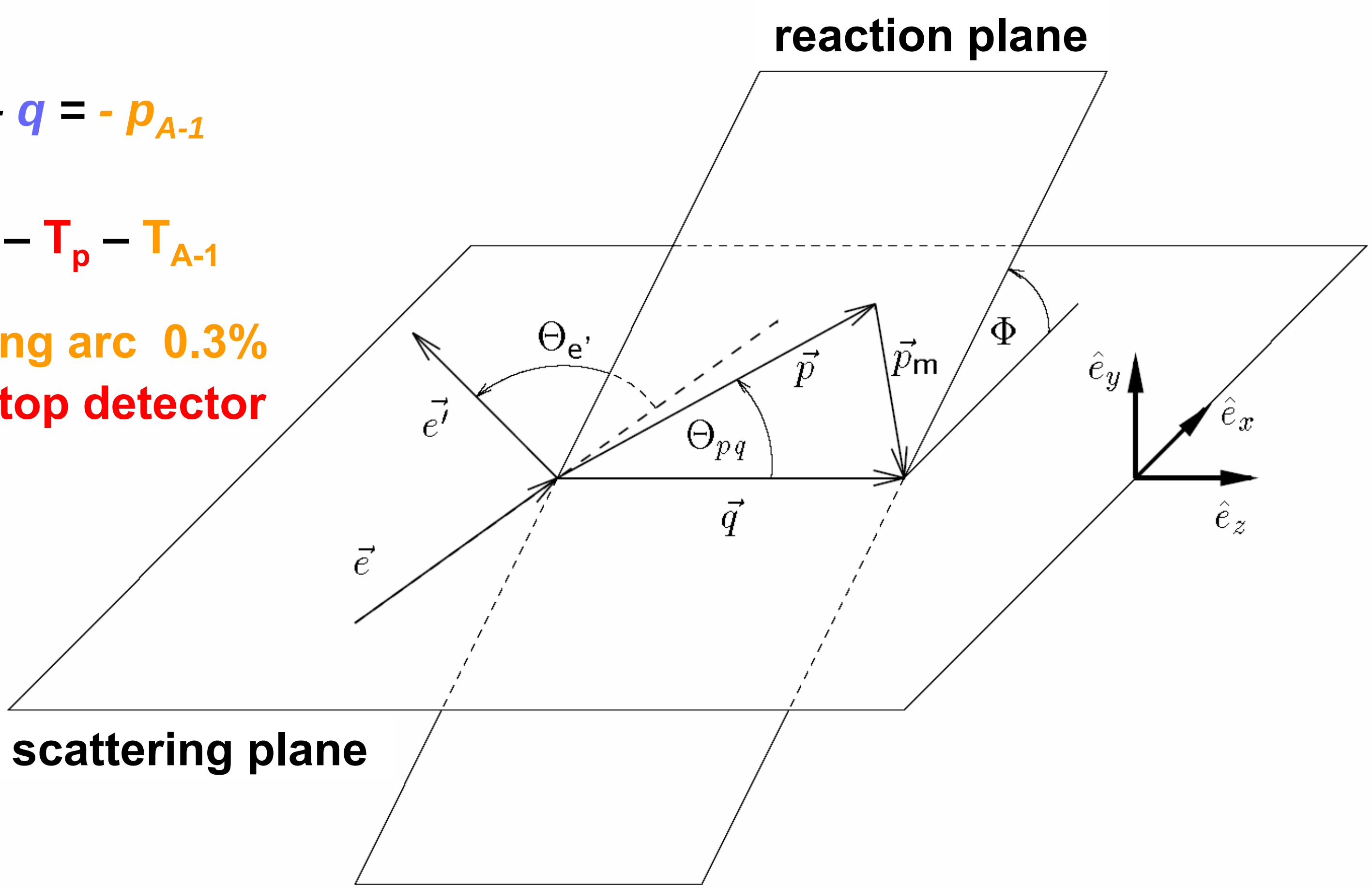
Reaction kinematics
(as seen from the moving target)

$p_m = p - q = - p_{A-1}$

$E_m = \omega - T_p - T_{A-1}$

T_{A-1} ring arc 0.3%

T_p stop detector



Quasifree scattering

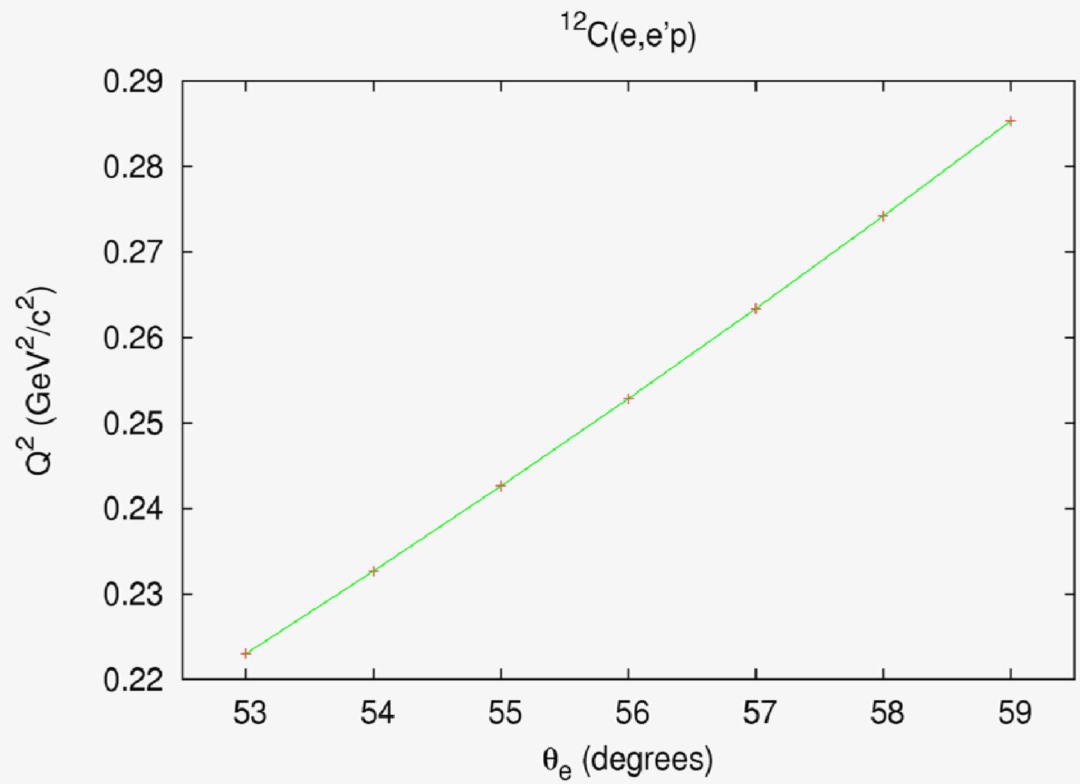
$x = Q^2/2M\omega_0 \approx 1$

Chosen example:

^{12}C @ 740 MeV/u
e^- @ 500 MeV

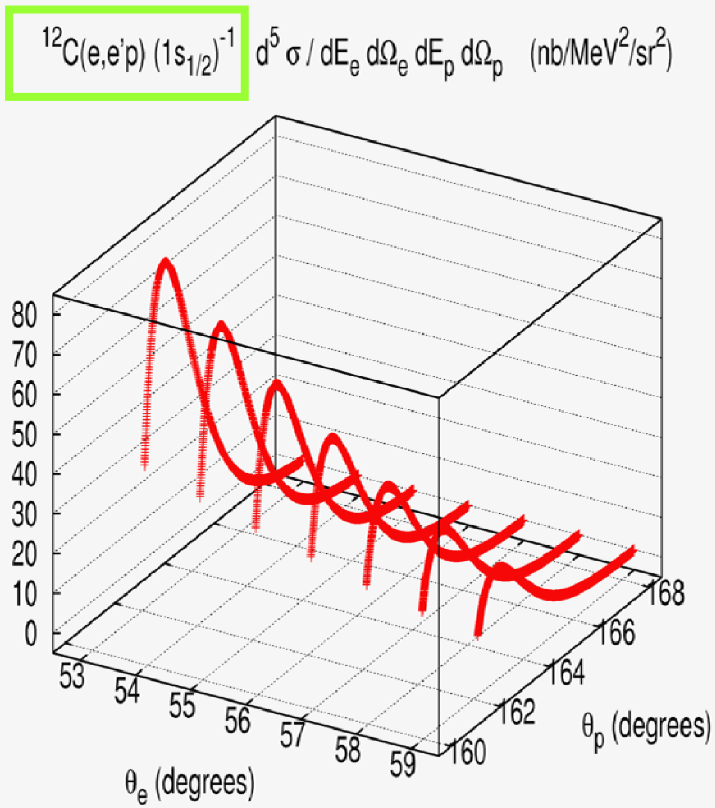
ω = 135 MeV
x = 1 +-15%

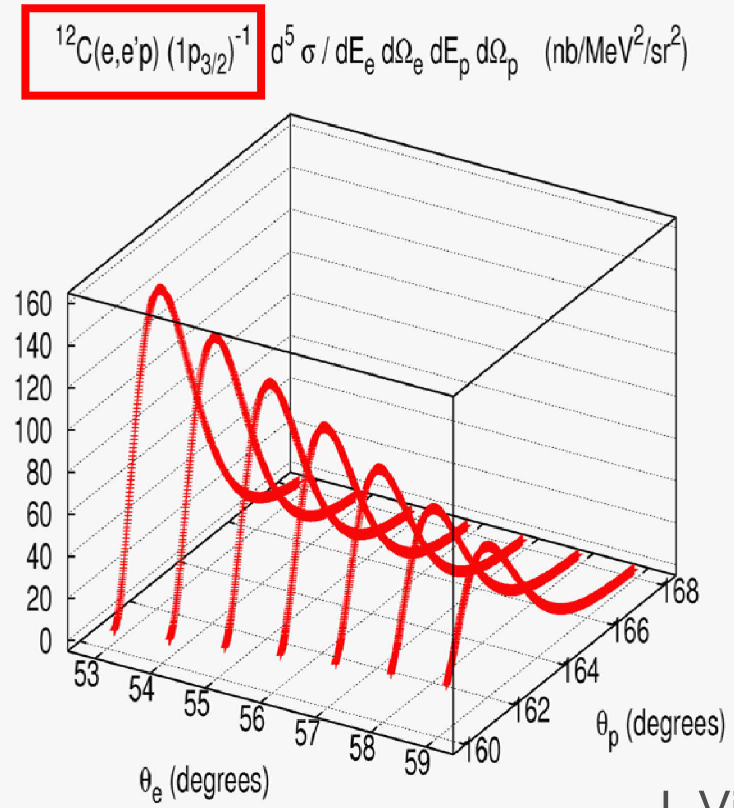
→electron angular range 56+-3°



J. Vignote

Cross section





J. Vignote

➔ proton detection [160,164]°

Reaction kinematics

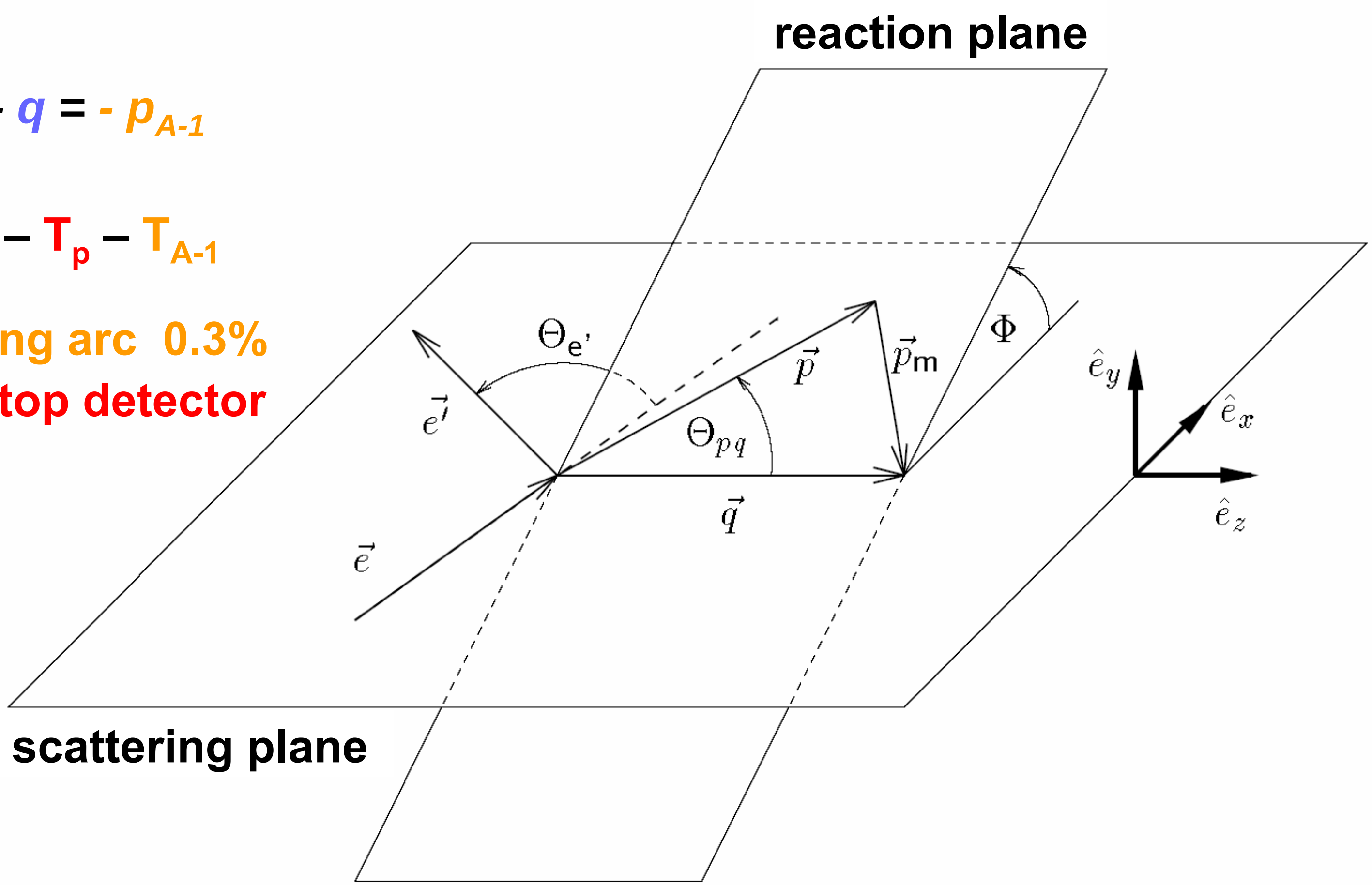
(as seen from the moving target)

$p_m = p - q = -p_{A-1}$

$E_m =$ [illegible] $- T_p - T_{A-1}$

T_{A-1} ring arc 0.3%

T_p stop detector

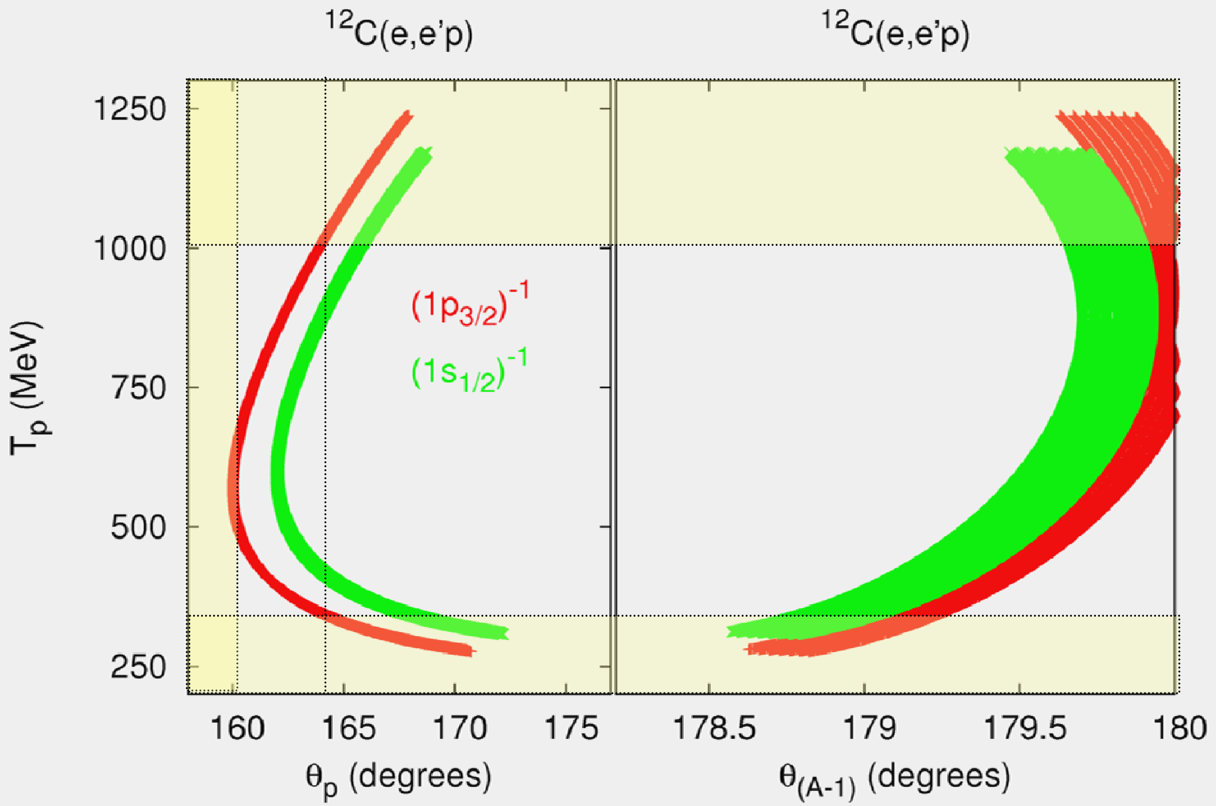


Proton & Fragment emission pattern

- proton angles [160,164]°

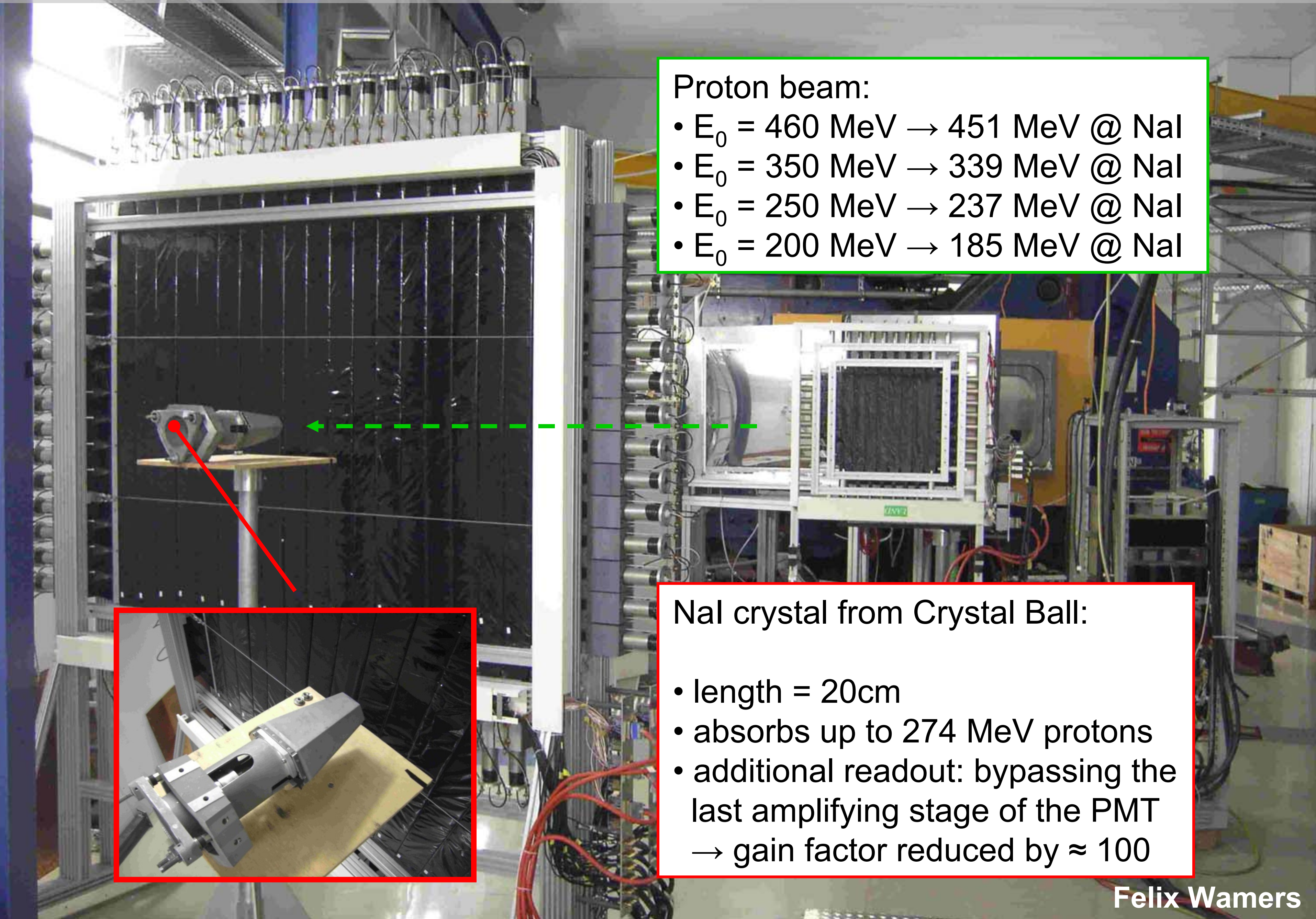
→proton energies [300,1000] MeV

→fragment angles < 25 mrad



J. Vignote

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



Proton beam:

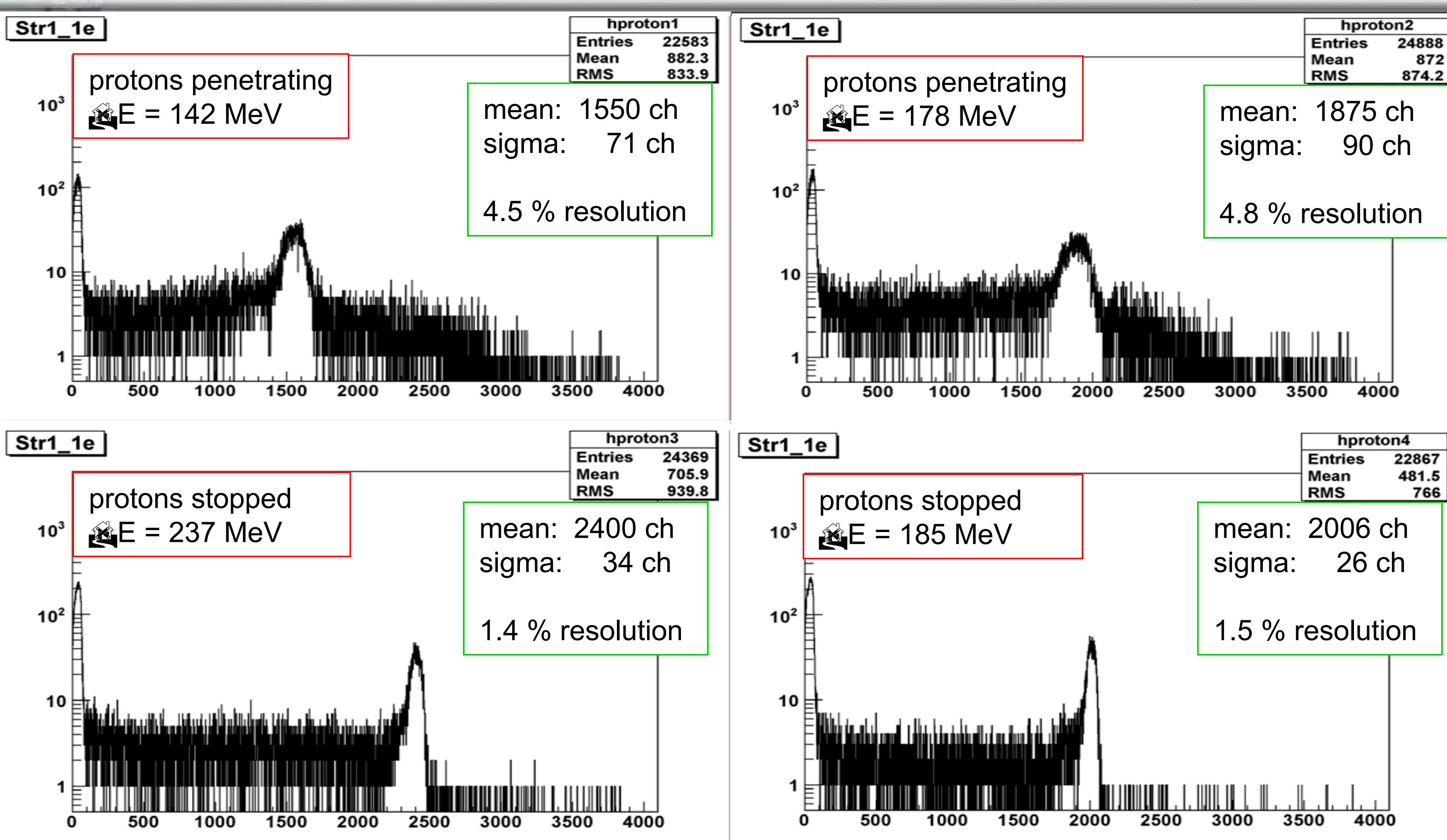
- E_0 = 460 MeV → 451 MeV @ NaI
- E_0 = 350 MeV → 339 MeV @ NaI
- E_0 = 250 MeV → 237 MeV @ NaI
- E_0 = 200 MeV → 185 MeV @ NaI

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

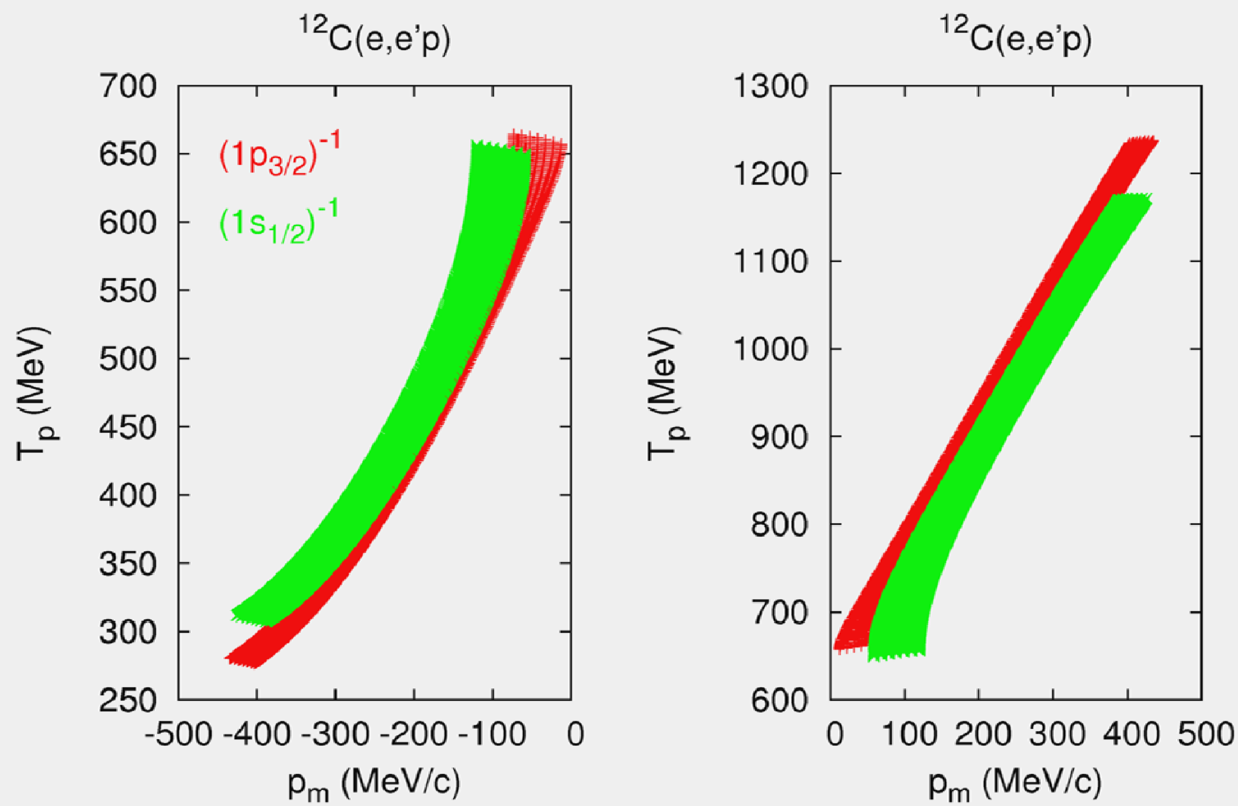


Felix Wamers

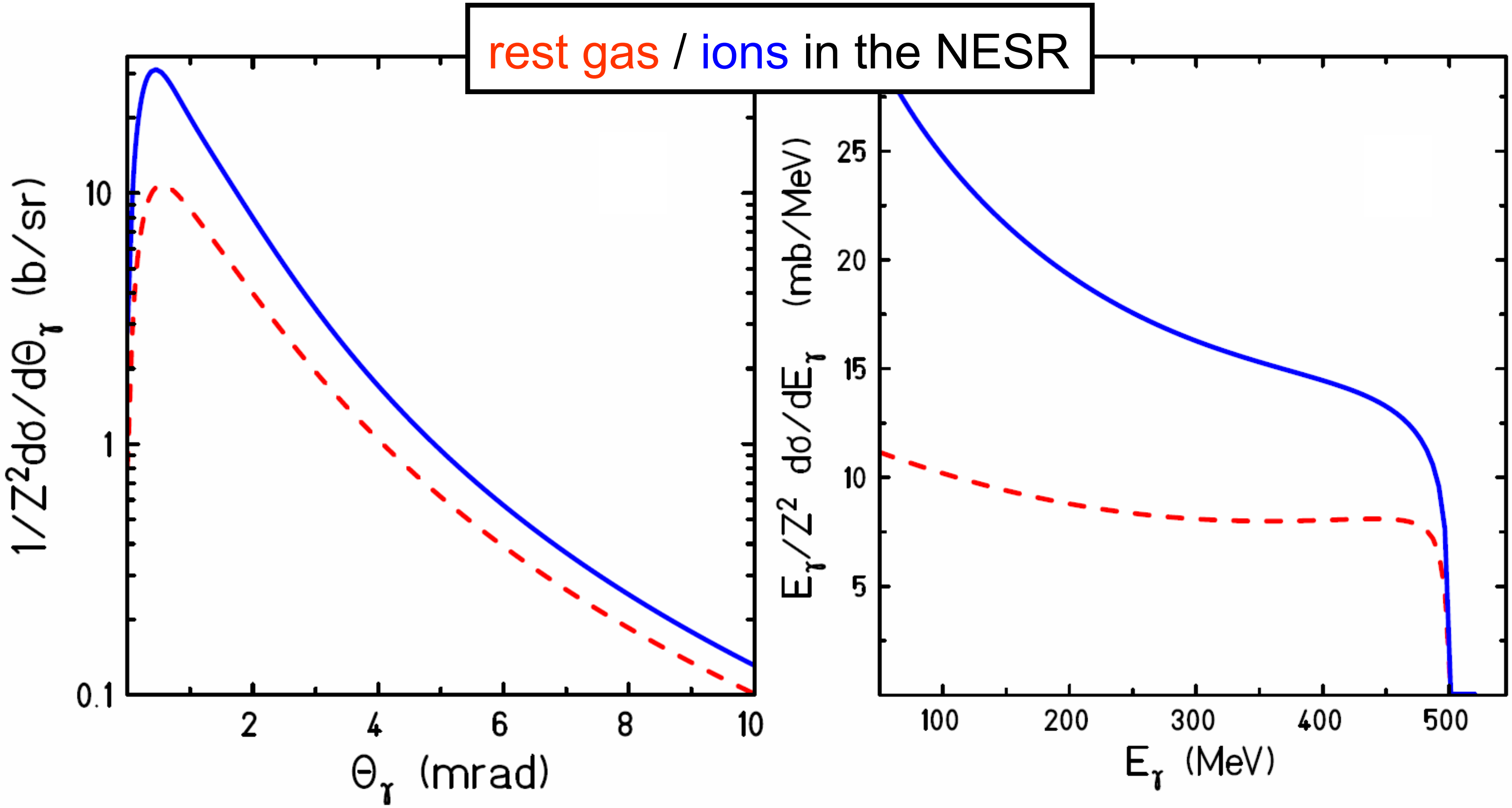
Resolution concerns …

- 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

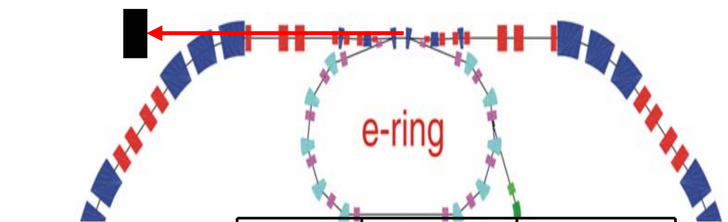


Bremstrahlung: spectrum and angular distribution



Luminosity Monitor via photons: Concept

position sensitive (i)
■-detector



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

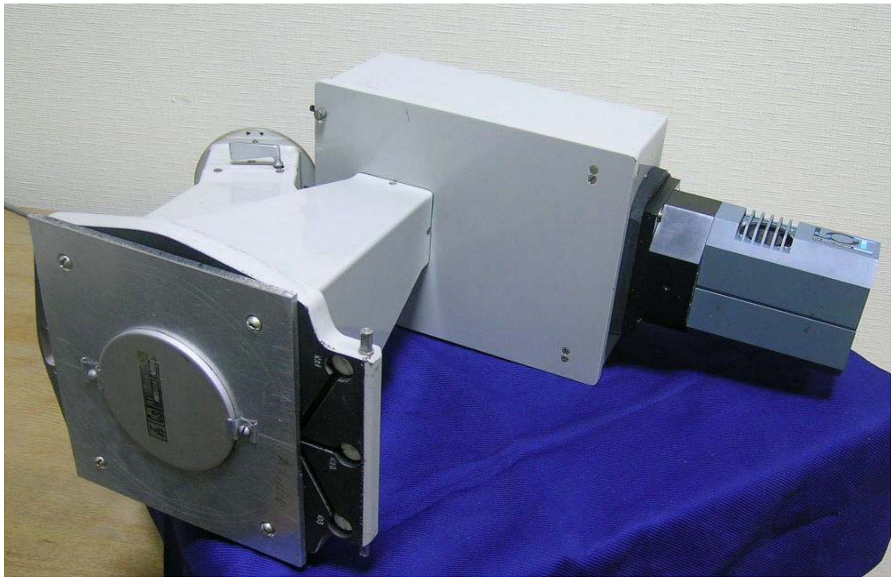
(ii)

	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)

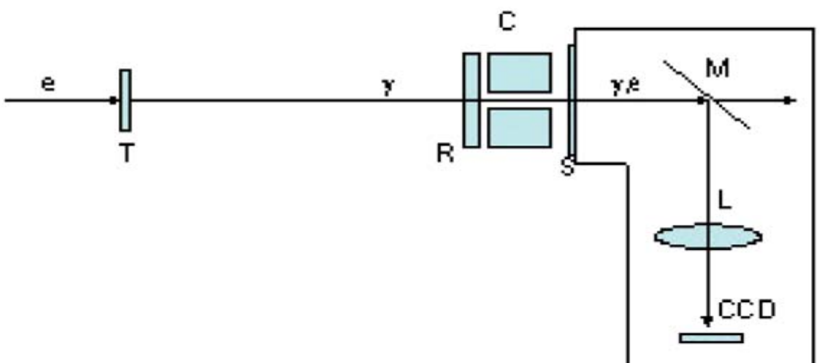
Absolute calibration via small angle scattering:
$q \rightarrow 0 : F(q) \approx 1$ ➔ Pure Mott cross section

Luminosity monitor:
technical realisation/prototypes/simulations



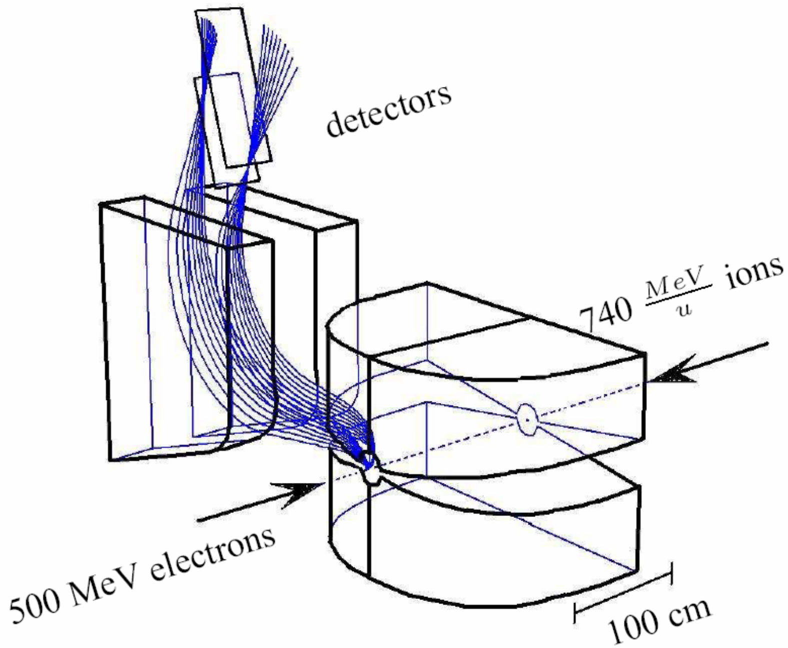
calorimetry
KI Moscow

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



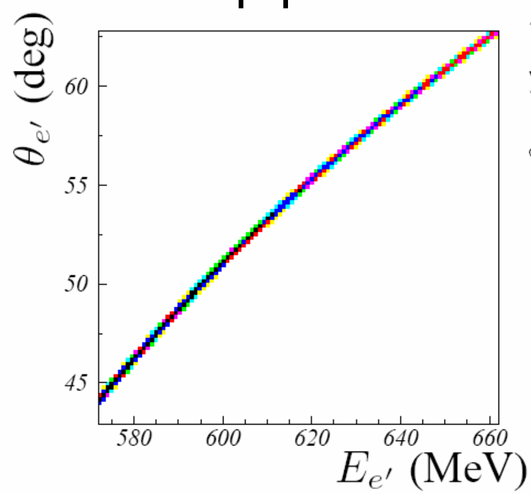
gamma imaging:
INR-RAS Moscow

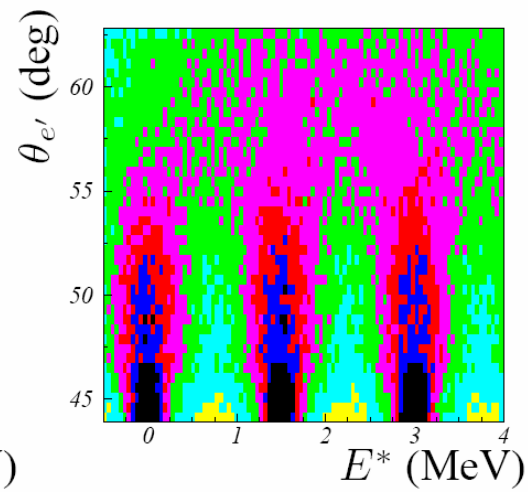
Full 3D simulation calculation
→ Generator vs. Analysis

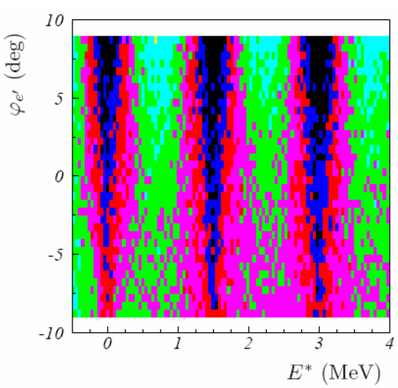


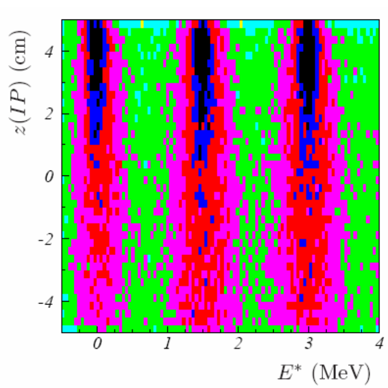
1 mrad angular resolution

10^{-4} $\delta p/p$





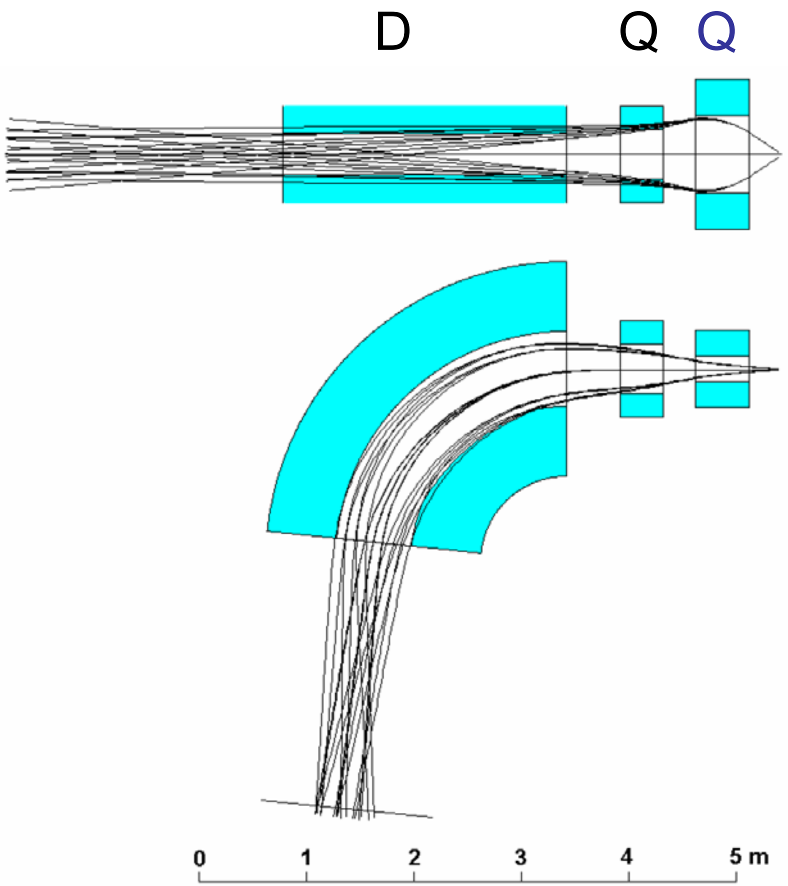


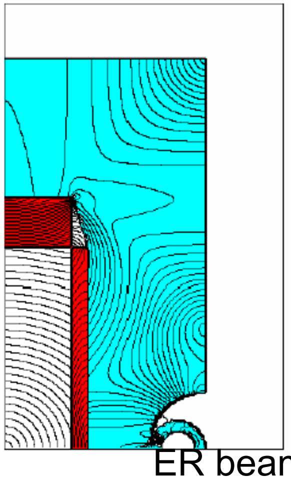


Sufficient resolution can be obtained !

Detection and analysis scheme ok.

Optional: Large angle spectrometer with very high acceptance





¼ Panofsky
s.c. Quadrupole

- very large 1.2 rad vertical
- large 200 mrad horizontal acceptance
- 50-100° scattering angle

S. Kato, Yamagata University

NO CHARGE STATES !

$B\rho$-ΔE-TOF method: Requirements (SuperFRS / ELISe, EXL, HI/DESPEC, R³B)

$B\rho = A/Z\ \beta\ \gamma$ → A/Z, P

TOF=L/β

$\Delta E \sim Z^2/\beta^2$ → Z

Pos res. $\sigma \leq$ 1 mm

Timing res. σ : 50 ps

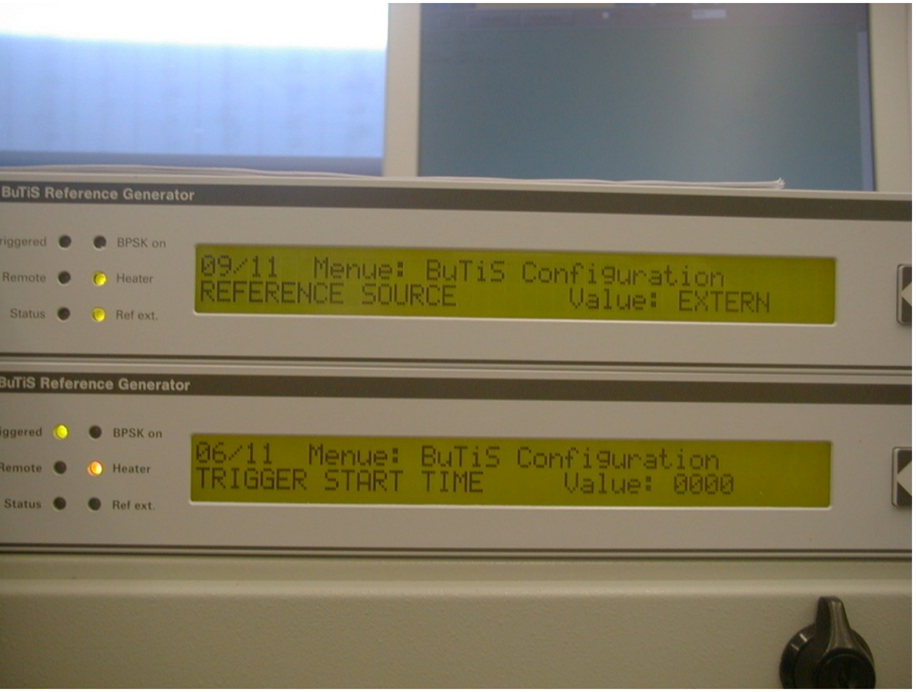
ΔE resolution σ : 1-2 %

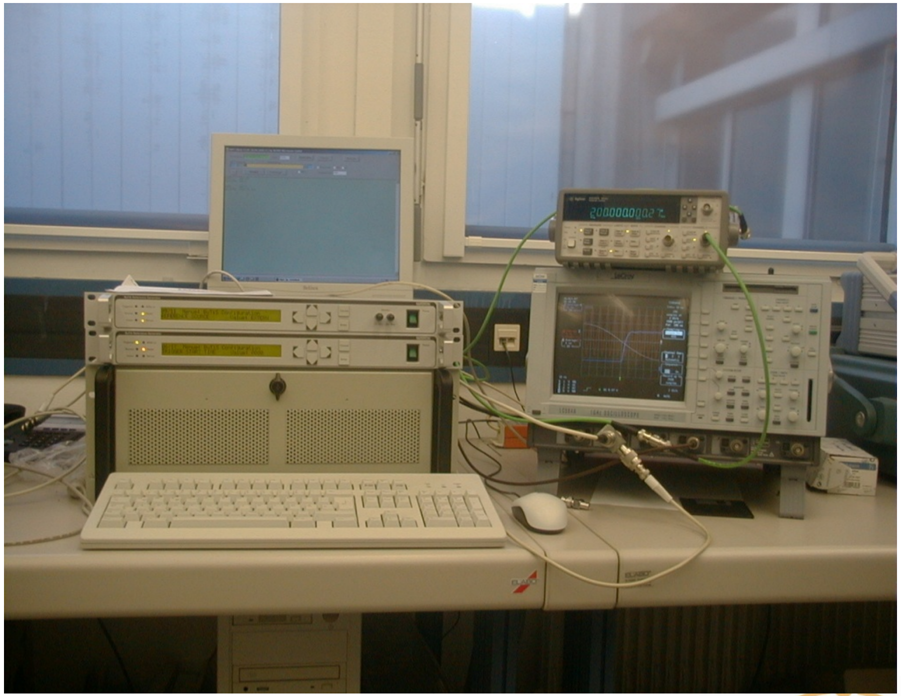
- Position: Wirechambers/Si-strip/Diamond
- ΔE: MUSIC/TEGIC → limit about 1MHz
  rad hard Si/SC Diamond compatible 10MHz
- TOF: Plastic/Diamond

Campus wide time distribution (BuTiS)

P.Moritz/GSI

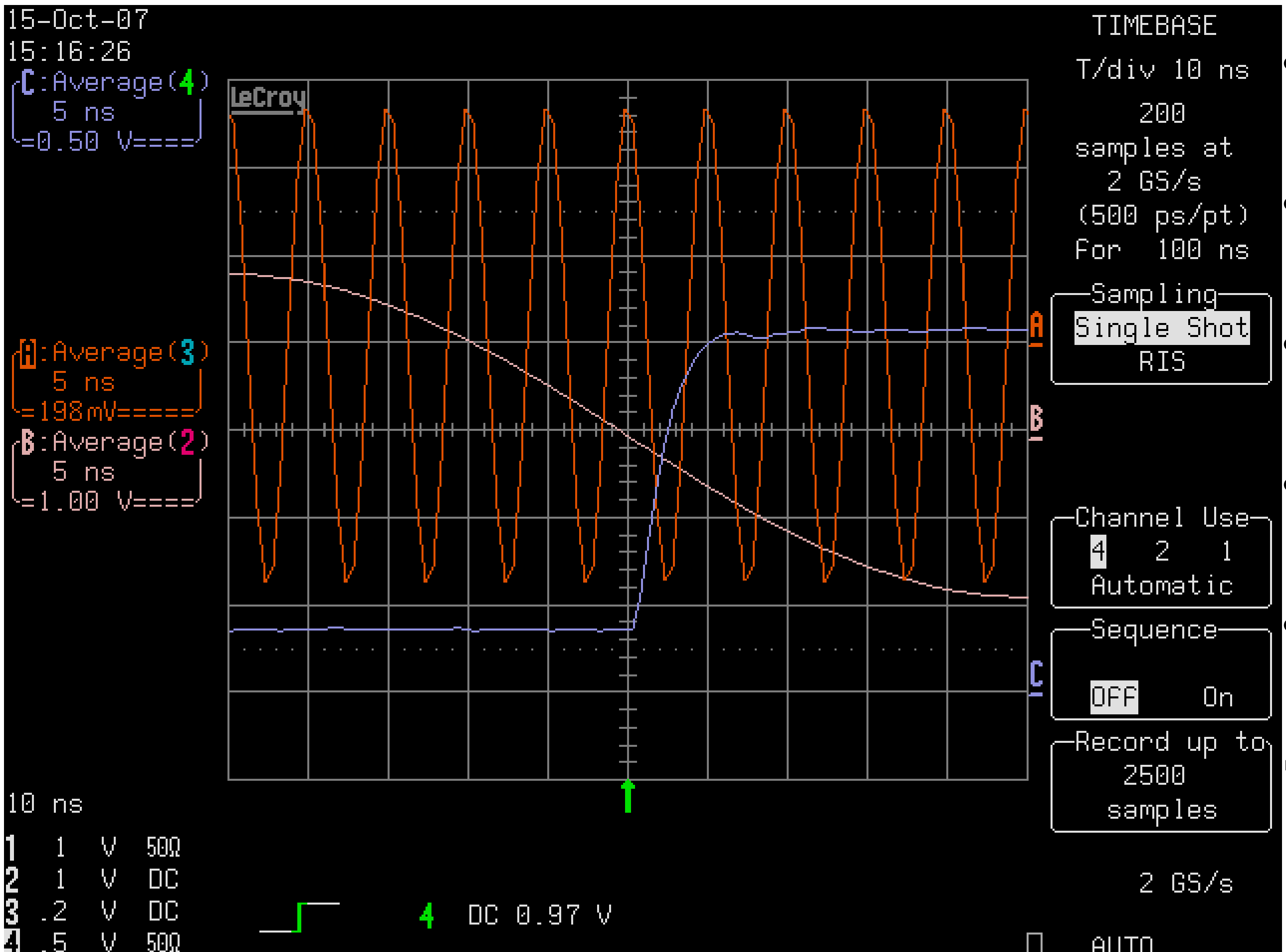
- Campus wide time distribution via fibre optics / local TDS(s)
- Synchronized local oscillators (10kHz, 10Mhz, and e.g. 200, 155 or 76 Mhz) with +/-100ps/km absolute uncertainty and << 10ps oscillator jitter





BuTiS at work (20071015)

P.Moritz/GSI



- 10, 200 MHz sine waves (adj. phase)
- T0 pulse for sync. every 100µs
- very good phase stability
- BuTiS oscillator can run standalone
- about 10k€/system

➔Test of BuTiS generators BNC coupled

BuTiS fibre distribution test bench (09/2009 succesful test of 4th channel < 100ps/km) P. Moritz

BuTiS Master

↓ 0.01, 10, e.g. 200 MHz copper

LASER + AM modulator

↓ opt. fibre (4 * 200GHz bands)

passive splitter distribution 1..2 km

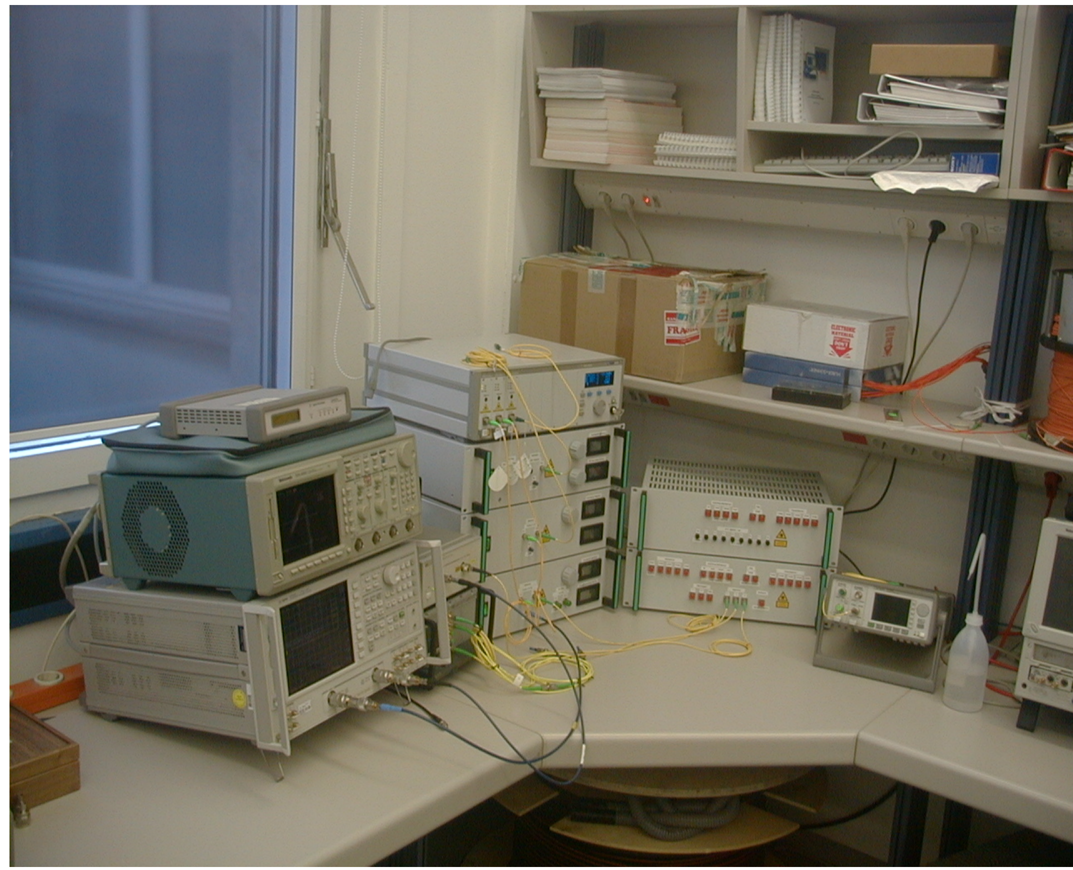
↓

Demodulator + reflector (4th ch)

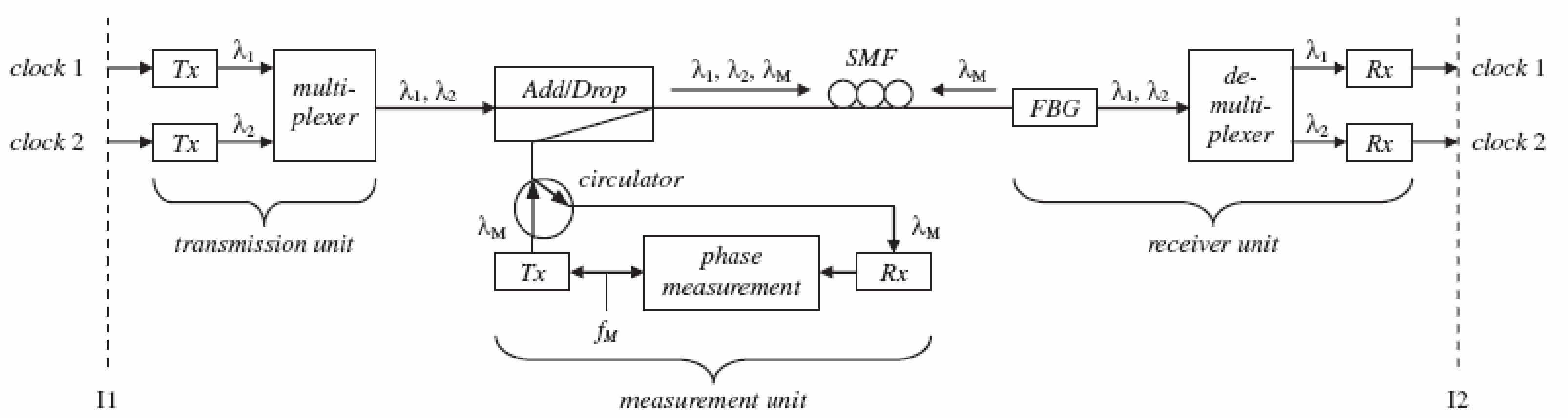
↓ 0.01, 10 MHz copper

BuTiS Slave osc.

↘ 0.01, 10, e.g. 200 MHz copper → **(local TDS) ?**



Detailed view on the LASER distribution system



Dense wavelength division multiplex

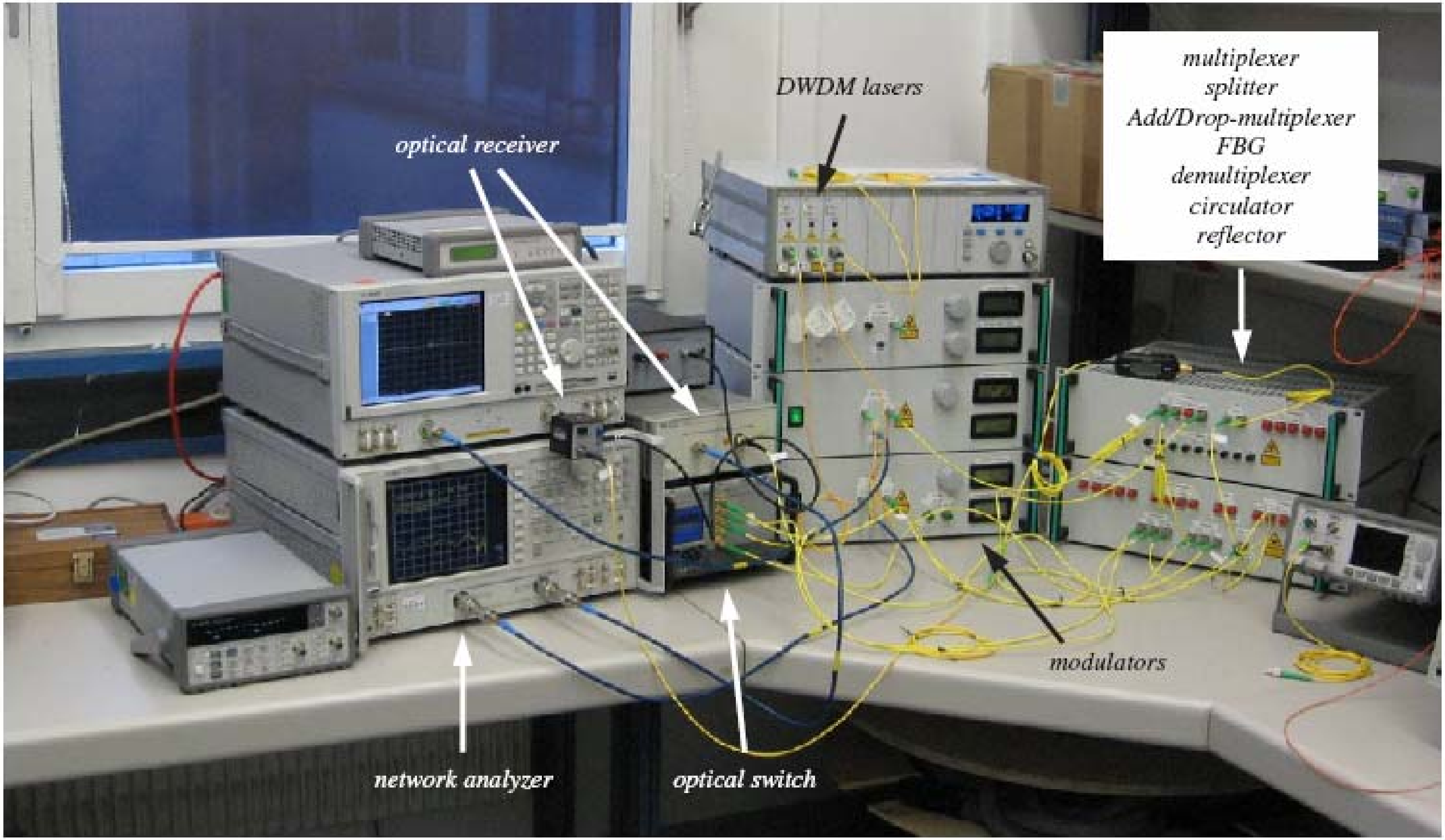
Standard single mode fibres

- Passive splitter
- Erbium-doped fiber amplifier

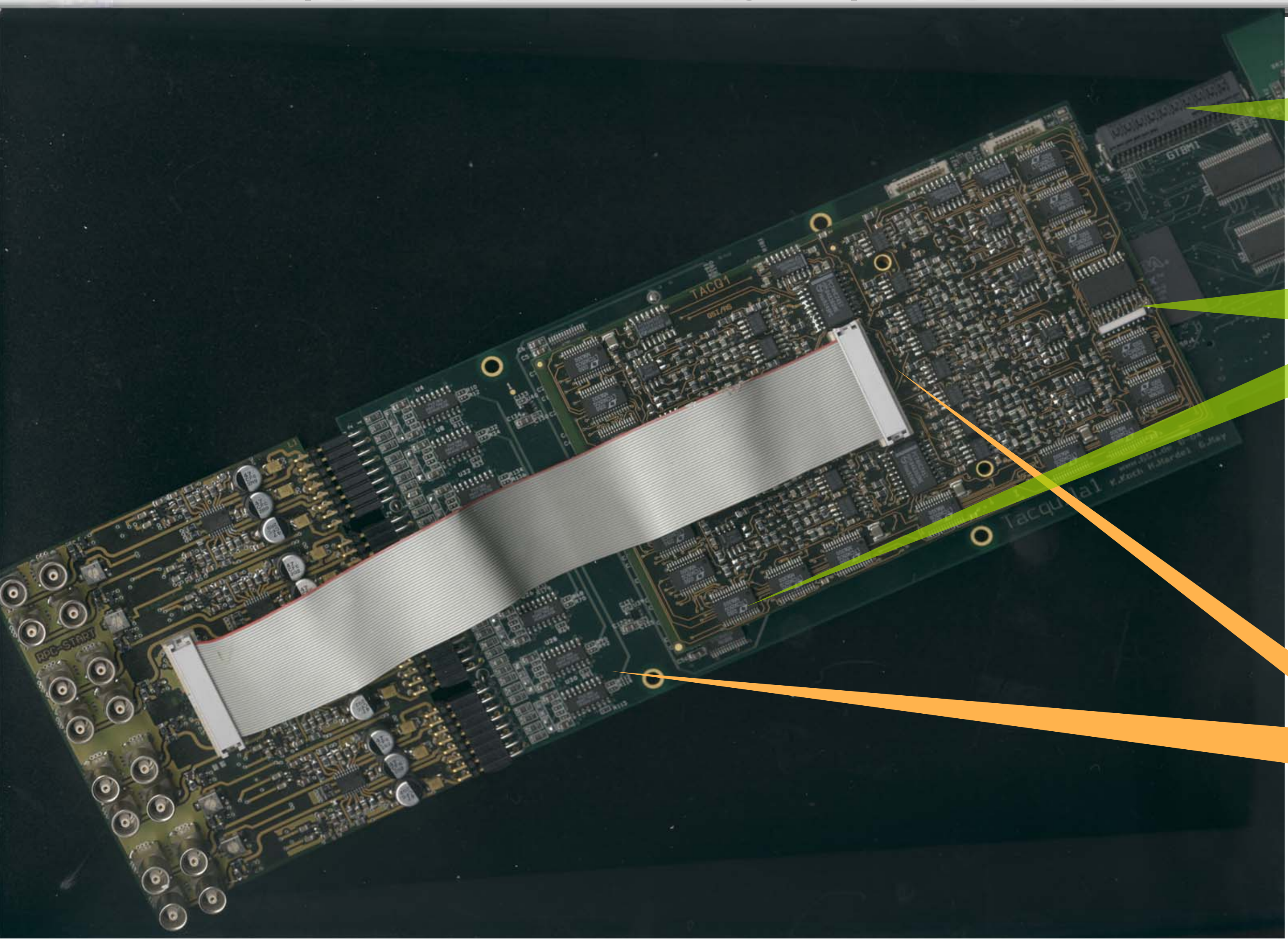
	Channel (ITU norm)	Optical frequency ν [THz]	Optical wavelength λ [nm]
λ_1	32	193.2	1551.721
λ_2	34	193.4	1550.116
λ_M	36	193.6	1548.515

As seen in the laboratory

PR Spec. Top. Acc. Beams 12, 042801 (2009)

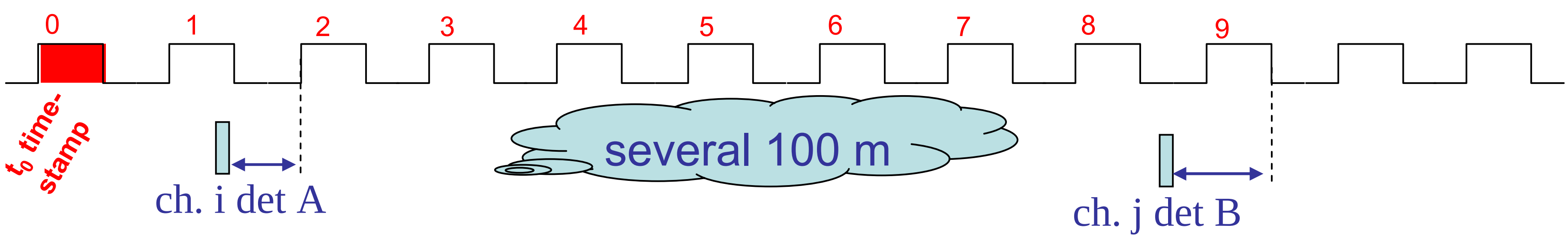


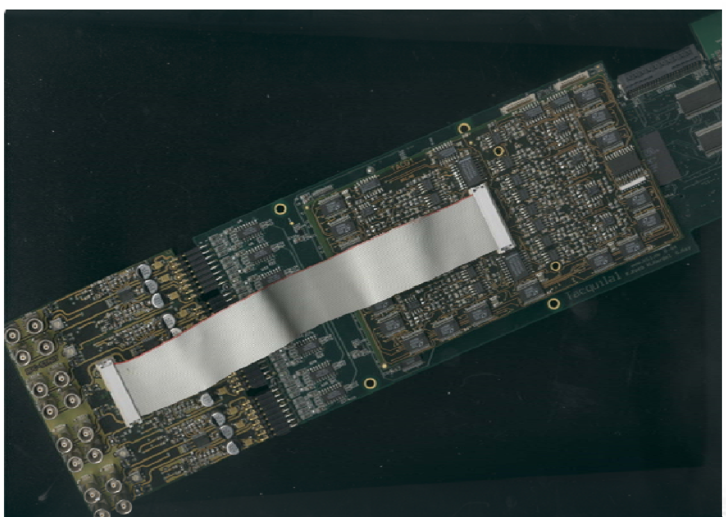
Field test: Precision timing system
Tacquila (R^{3}B: FE prototype) - FOPI/GSI

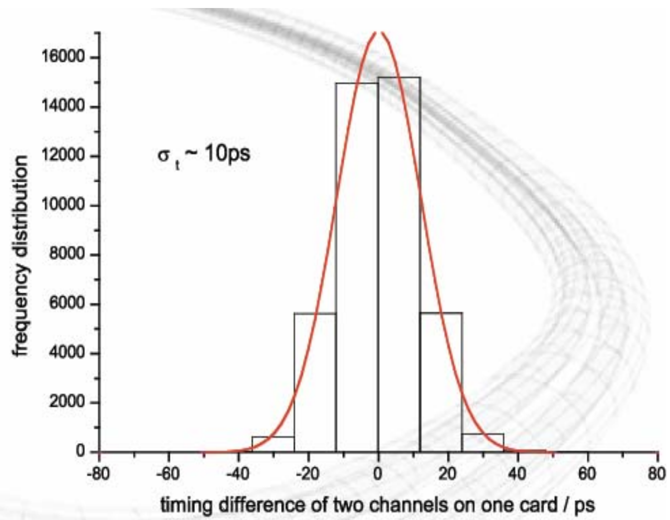


Precision timing (<50ps) vs. Campus Clock

FOPI collaboration/Tacquila – K. Koch







Timing FEEs:

Tacquila system (ASIC FhG/GSI) all existing chips in house

New systems (ASIC dev. GSI

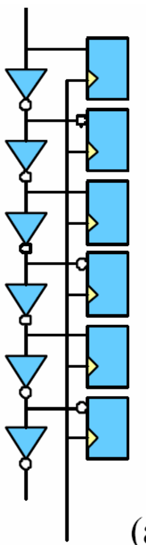
FPGA TDC

The 10-ps Wave Union TDC:

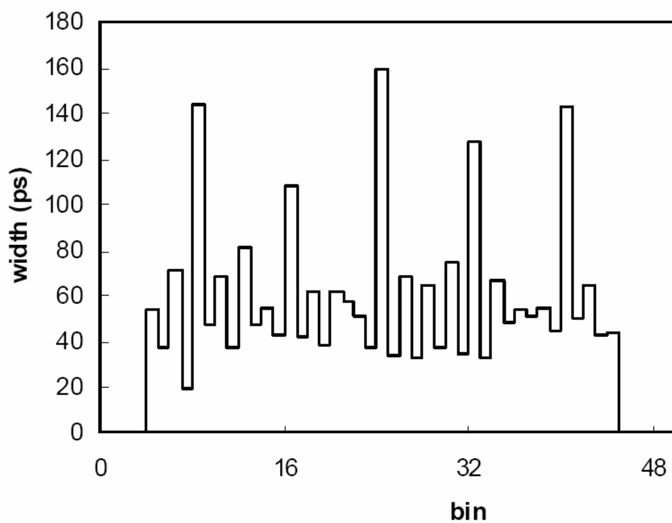
Improving FPGA TDC Resolution beyond Its Cell Delay

Jinyuan Wu and Zonghan Shi

IEEE Nuclear Science Symposium Conference Record, 2008. NSS '08.



(a)



Project at GSI:

M. Traxler / N. Kurz

TABLE I

PARAMETERS OF SEVERAL TDC SCHEMES

Device: EP2C8T144C6, Price: $28 (April 2008)

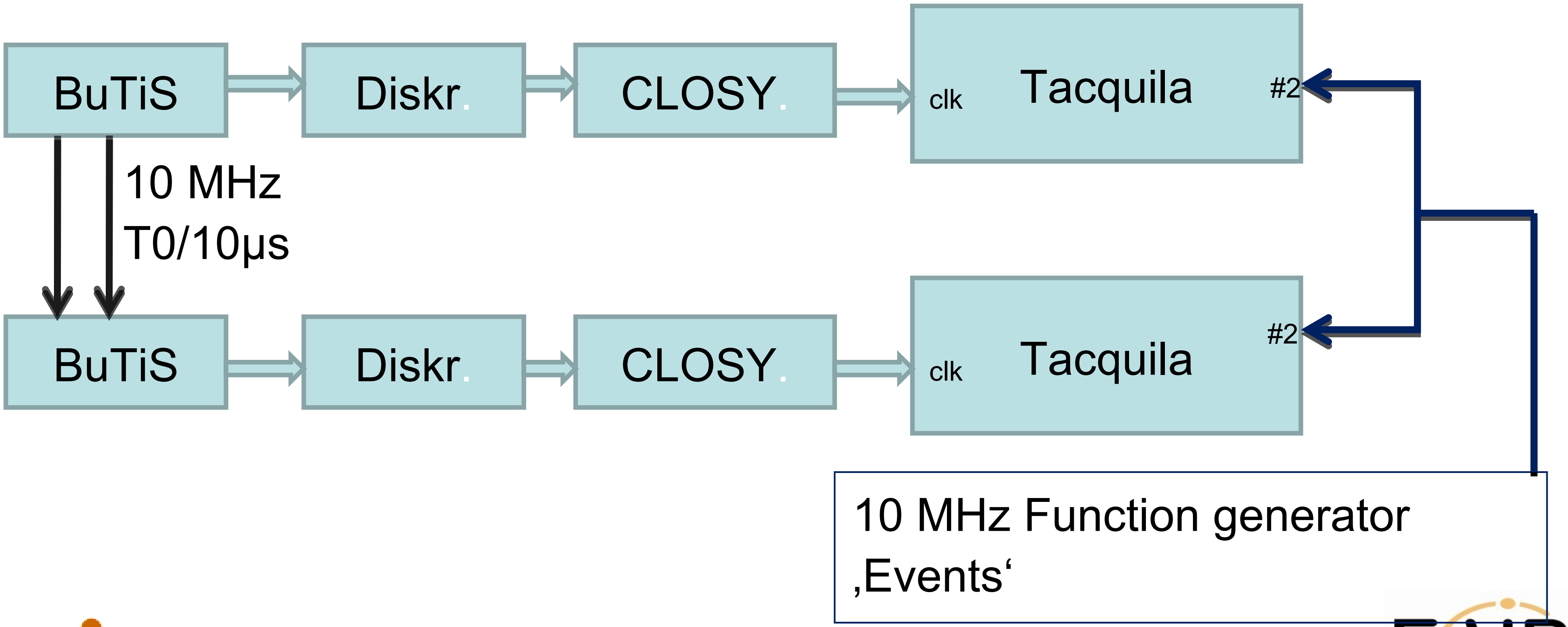
Operating Frequency: 400MHz, Total Logic Elements: 8256

	Max bin width	Av bin width	ΔT RMS error	Dead Time	Delay Chain Length	Logic Element Usage
Un-calibrated TDC	165ps	60ps	58ps	2.5ns	64	1621 (20%)
Plain TDC	165ps	60ps	40ps	2.5ns		
Wave Union TDC A	65ps	30ps	25ps	5ns		
Wave Union TDC B			10ps	45ns		6851 (83%) 8 CH

Altera Cyclone II device (EP2C8T144C6)

Test Bench 20091208 (schematic)

- Demonstration of BuTiS capabilities
- Two Tacquila systems at two coupled BuTiS generators
- Schematic View:



Less schematic

2 * CLOSY and Tacquila

2 BuTiS generators
master & slave

CLOSY (modified CBM prototype)

- PLL based clock divider
- input range limited
➔ CPLD stage

- Butis: division/5
➔ 200 MHz to 40 MHz for Tacquila

Discriminator:

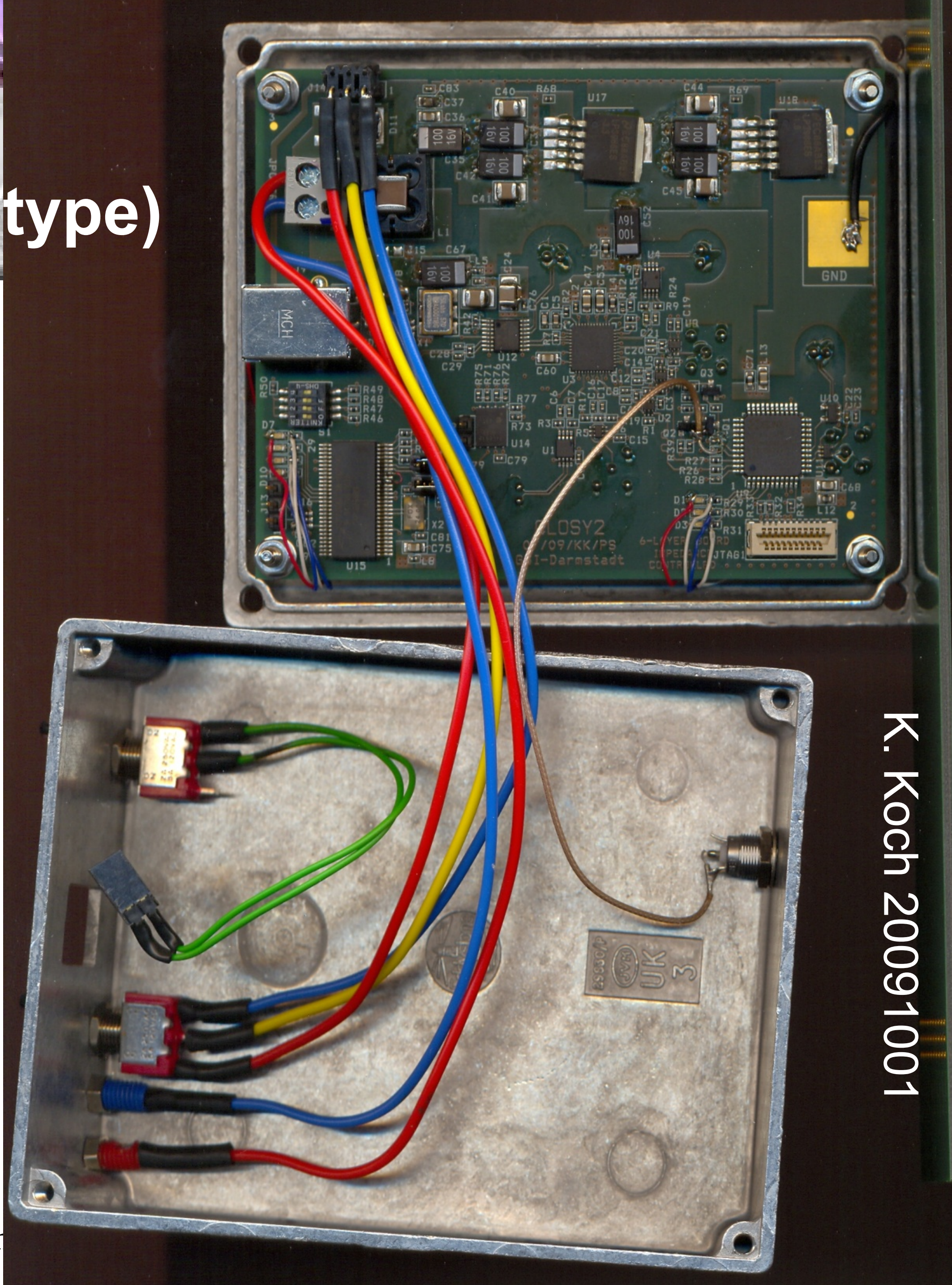
NB4N316M

3.3 V AnyLevel™ Receiver to CML Driver/Translator with Input Hysteresis

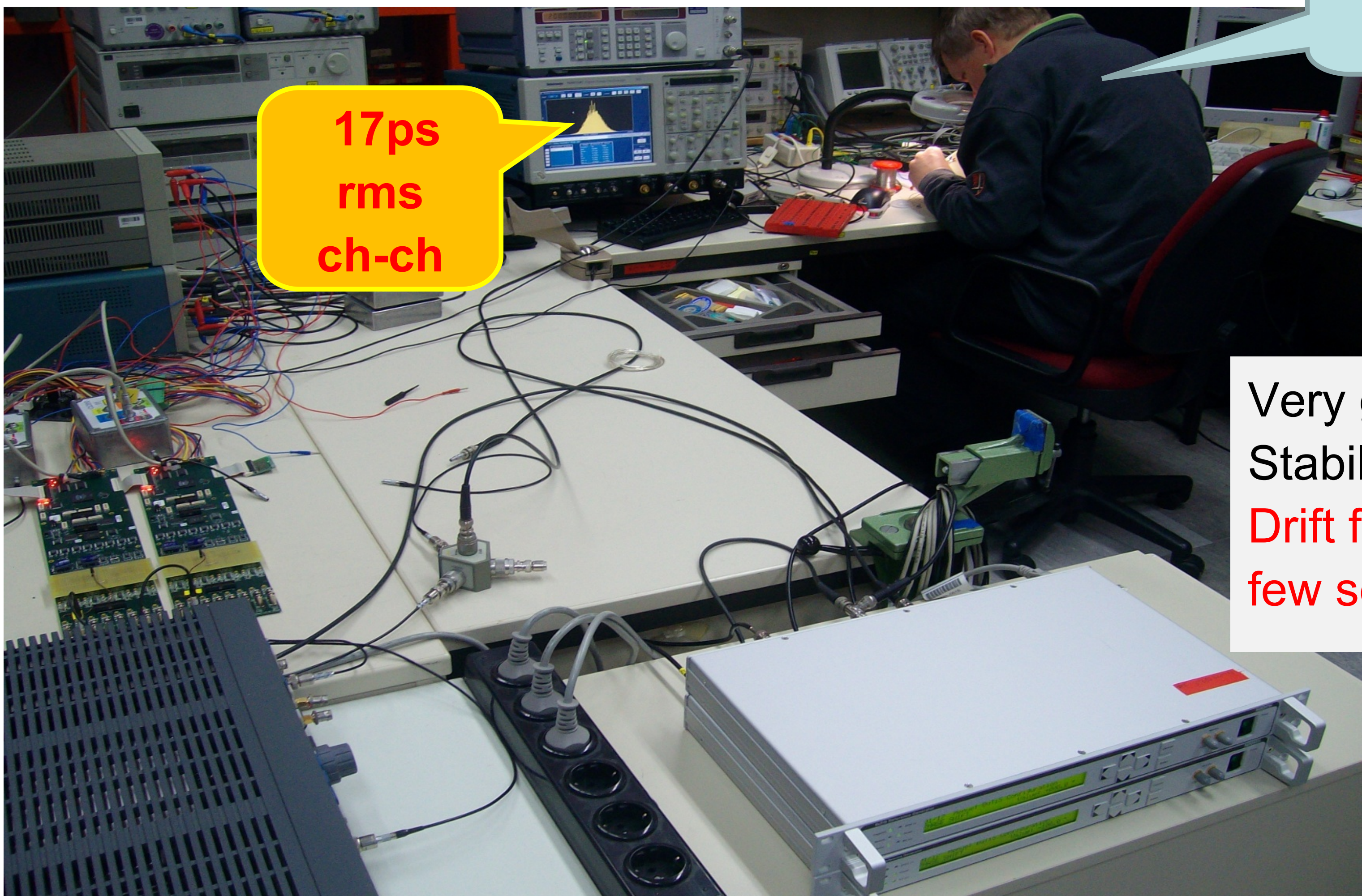
2.0 GHz Clock / 2.5 Gb/s Data

ON Semiconductor®

http://onsemi.com



Result: Test Bench 20091208



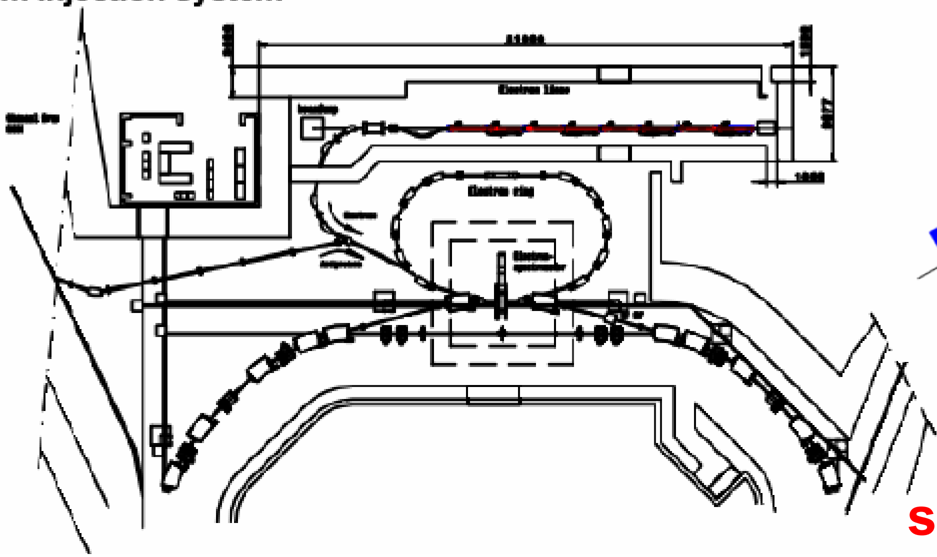
Karsten
Koch

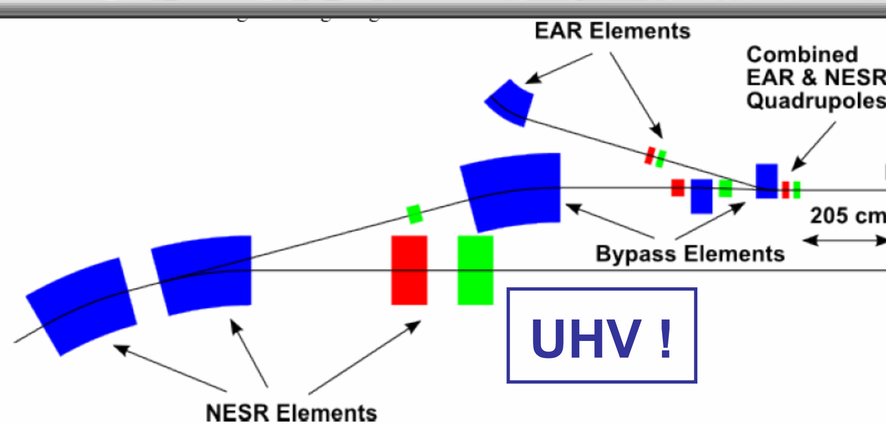
Very good
Stability !
Drift few ps/
few seconds

Does it fit into the hall …

… and even work with the accelerator ?

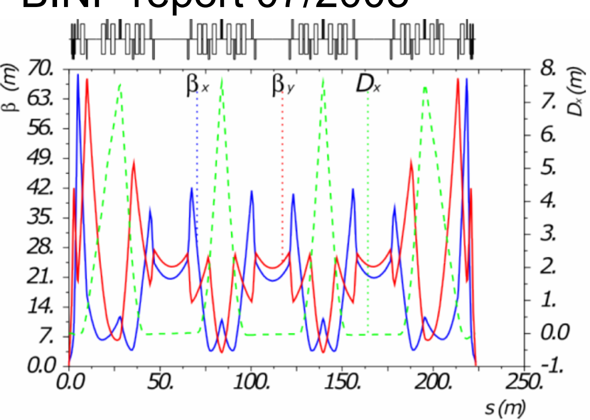
Beam injection system

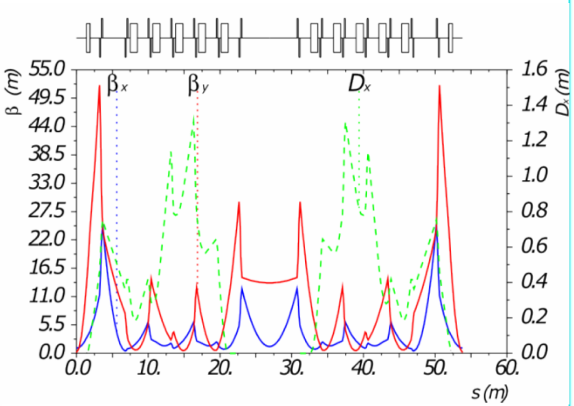


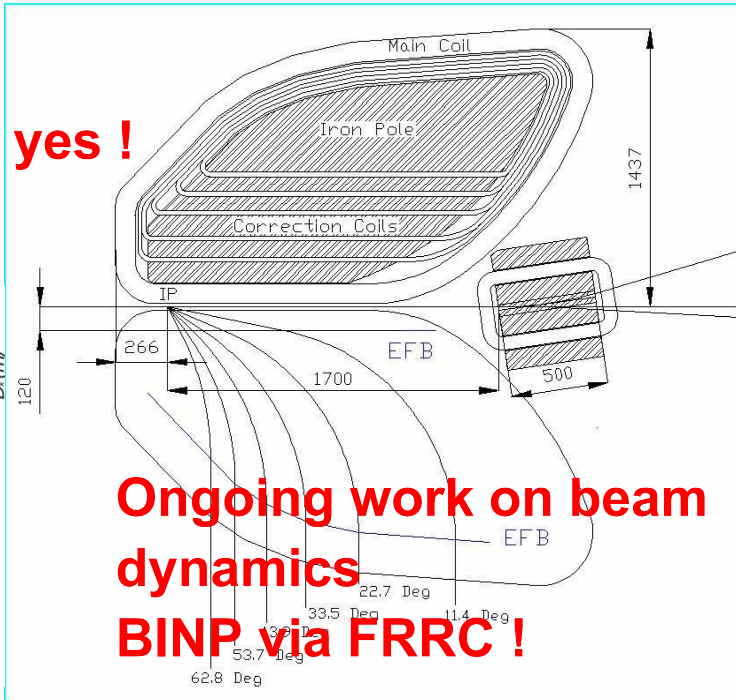


seems yes !

I.A. Koop, Yu.M. Shatunov, P.Yu. Shatunov, D.B. Shwartz
BINP report 07/2008







Ongoing work on beam dynamics
BINP via FRRC !