Experimental projects for eA colliders

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

Manuscript Number: NIMA-D-09-00758R3

*INRNE-BAS Sofia – **Bulgaria**, CENBG,CEA,GANIL, IPN – **France**,*
*TU Darmstadt, GSI, Uni-Mainz, Drezden, Cologne, Giessen – **Germany,***
*RCNP Osaka, RIKEN , Yamagata University – **Japan**, KVI - The **Netherlands,***
*JIN A, University of Notre Dame , Texas A&M ,Yale University , **USA,***
*BINP , RRC KI , INR RAS , JINR , IPPE – **Russia ,***
*Rhodes University **South Africa,** CSIC Madrid , Granada , Seville – **Spain,***
*Lund University – **Sweden**, University of Basel – **Switzerland,***
*Surrey , York , Daresbury, Liverpool , Manchester University - **United Kingdom***

Motivations

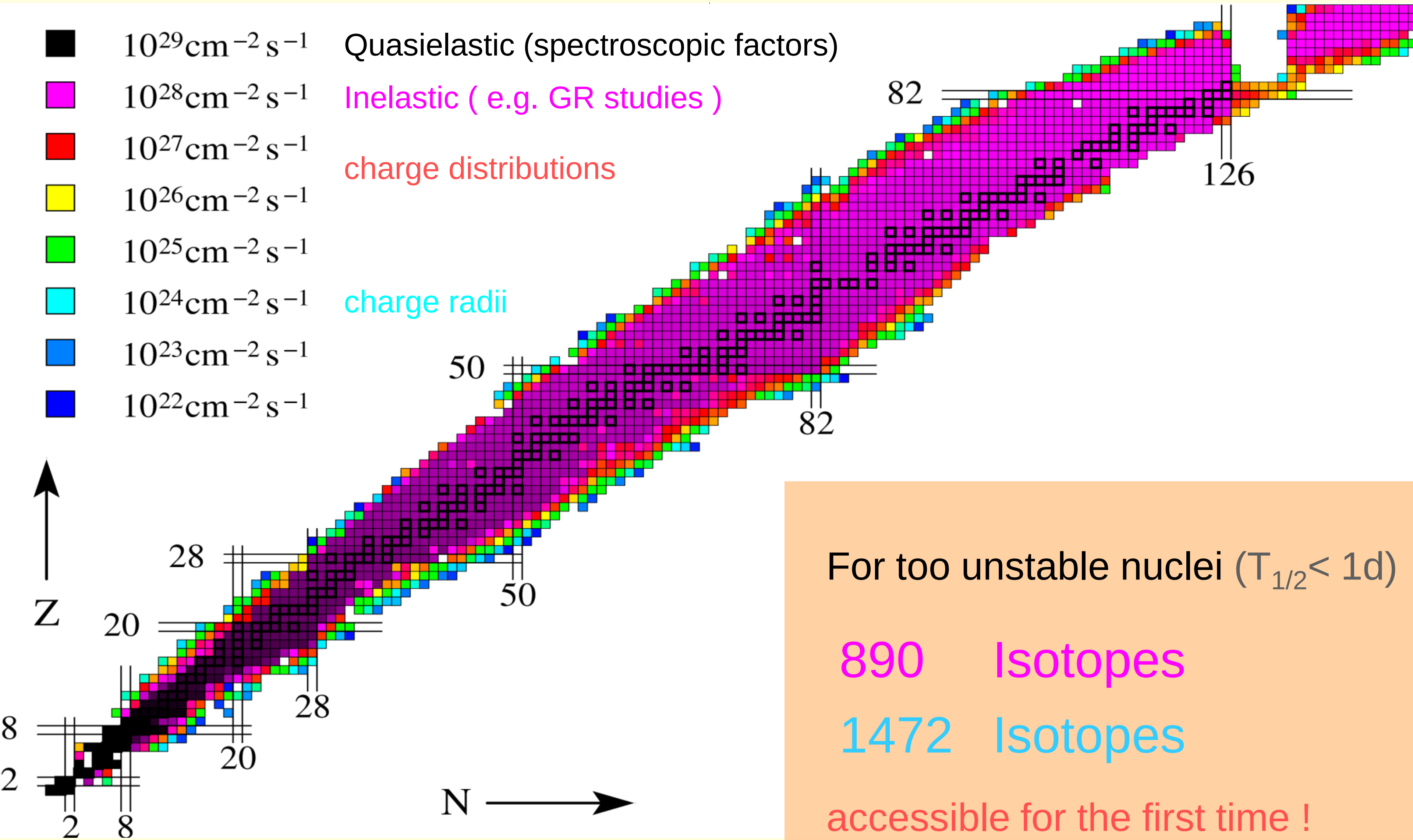
- Unstable short living isotopes

  Polarized beams

- Relativistic nuclear physics

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 !

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}

Competing project: SCRIT

Self-Confining RI Target for RARF

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

- **First Demonstration of Electron Scattering Using a Novel Target Developed for Short-Lived Nuclei.** T. Suda *et al.* **Phys.Rev.Lett.102:102501,2009**.

Internal deuteron tensor polarized target

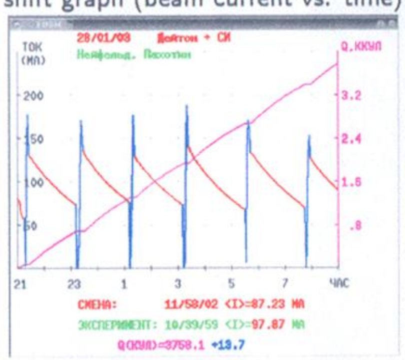
VEPP–3

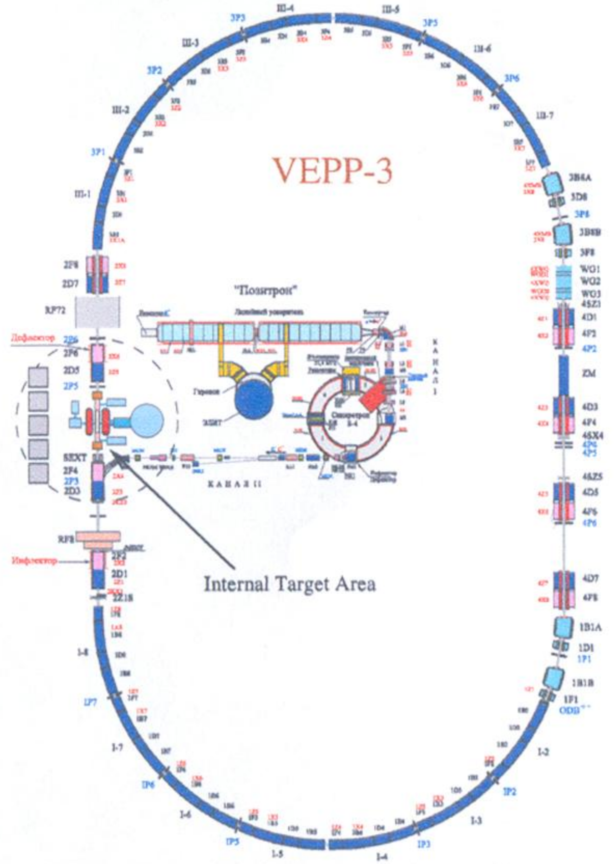
VEPP–3 parameters

Electron energy	E_0	2 GeV
Mean beam current	I_0	150 mA
Energy spread	$\Delta E/E$	0.05%
RF HV magnitude	U_{72}	0.8 MV
revolution period	T	248.14 ns
bunch length	σ_L	15 cm
vertical beam size*	σ_z	0.5 mm
horizontal beam size*	σ_x	2.0 mm
vert. β-function*	β_z	2 m
horiz. β-function*	β_x	6 m
Injection beam energy	E_{inj}	350 MeV
Injection rate	$\dot{I}_{inj}$	$1.5\cdot 10^9$ s^{-1}

* *parameters in the center of 2nd straight section*

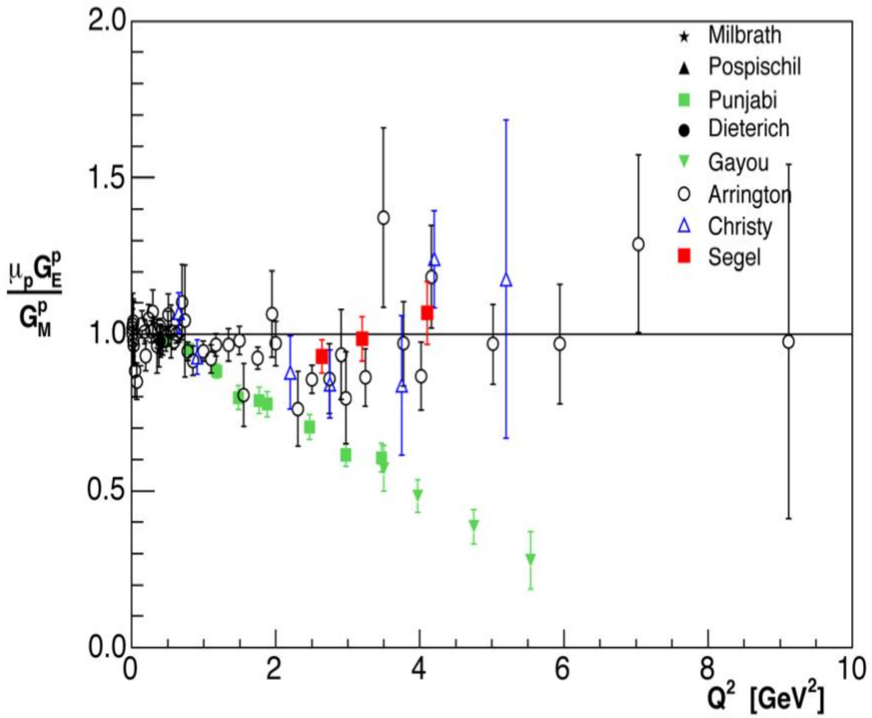
shift graph (beam current vs. time)





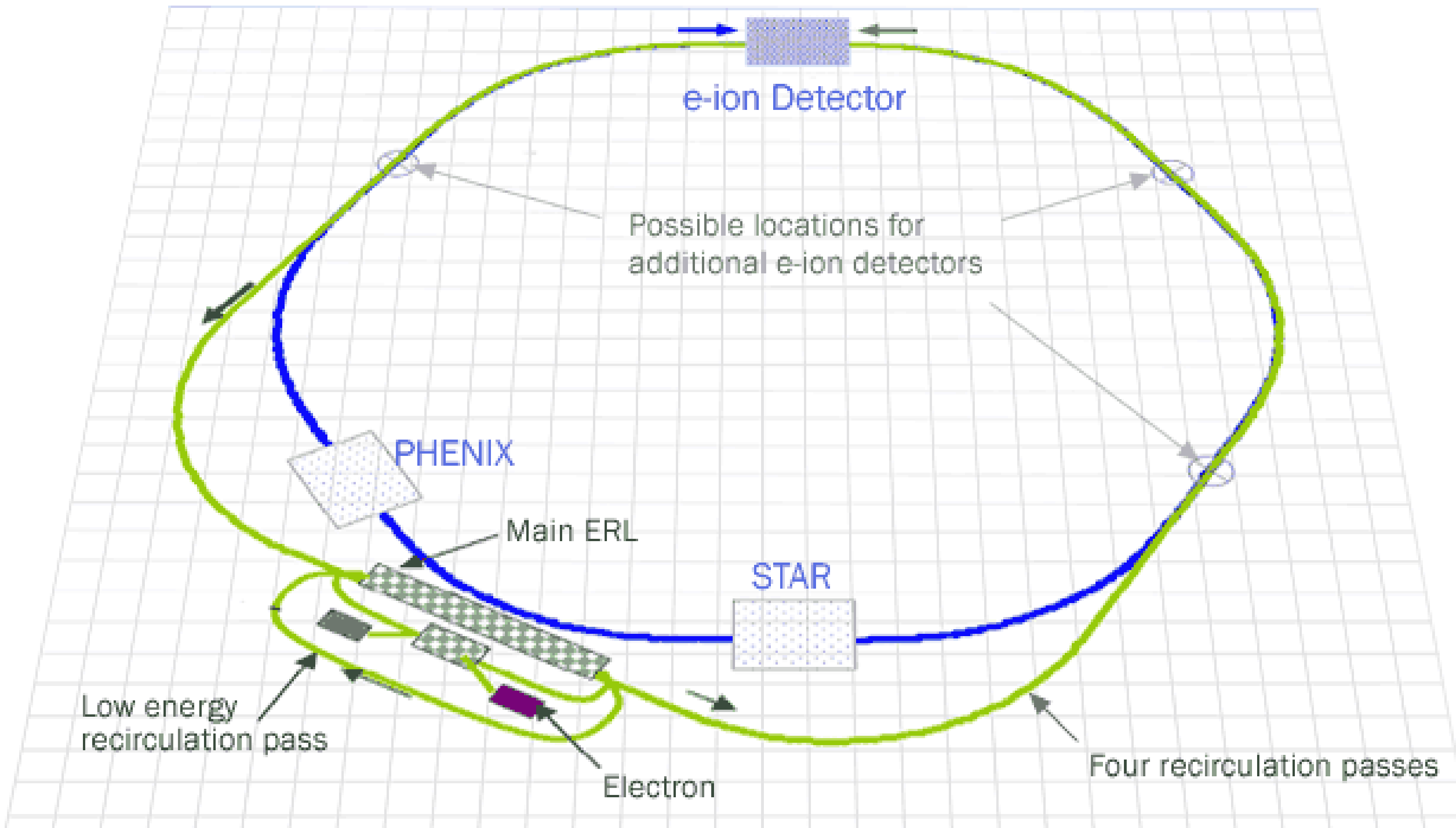
Relativistic nuclear physics

OLYMPUS at the DORIS accelerator (DESY) ep - collider



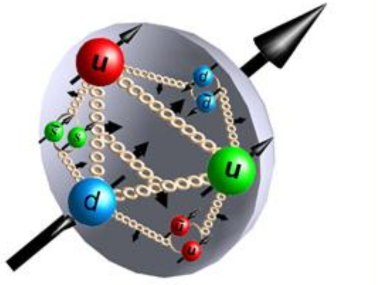
Ratio of the proton electric and magnetic form-factors

Brookhaven Facility Upgrades: RHIC-II and eRHIC



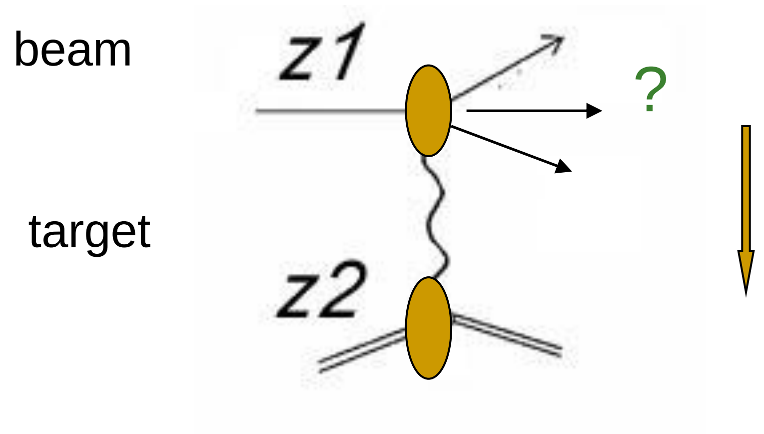
eRHIC goals:

Electron scattering provides the best microscope to unveil the distribution of gluons, a counter-intuitive fact since electrons interact directly only with electrically charged particles, while the gluons are neutral. When the electrons collide with **heavy nuclei**, they can probe the color glass condensate regime at much lower energies than would be required for electron-proton collisions. Thus, **eRHIC would be the world's foremost facility for the study of gluon-dominated matter**, illuminating the conditions just before the RHIC collisions that create the nearly "perfect“ liquid.



Constructing eRHIC requires technological advances in the acceleration of high-current electron beams, advances being pursued in ongoing research and development at RHIC. By **polarizing the electron beams** (arranging the spins of the electrons to point in a preferred direction), and allowing them to scatter off RHIC's **polarized proton beams**, the study of the proton's substructure can be greatly advanced. The ongoing RHIC search for the proton's “missing” spin (the roughly 70% unaccounted for by the orientation of quark and antiquark spins within the proton) can be extended to the contributions from the dominant gluons in the color glass condensate region.

Кулоновская диссоциация



$b\ >\ b_{min} = R_i + R_t$ (incident + target)

Поток виртуальных фотонов

$$F = \frac{Z^2\alpha}{\pi^2 b^2}\frac{1}{\omega}$$

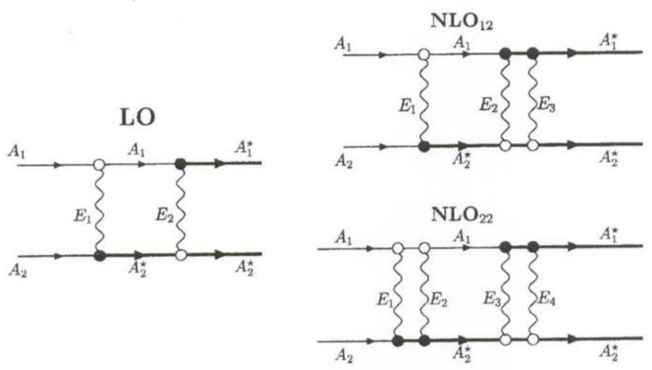
Спектр виртуальных фотонов (интегрированный по b), $Z = Z_t$

$$\frac{dn(\omega)}{d\omega} \approx \frac{z^2\alpha}{\pi}\frac{1}{\omega} f\left(\frac{\omega b_{\min}}{\gamma}\right)$$

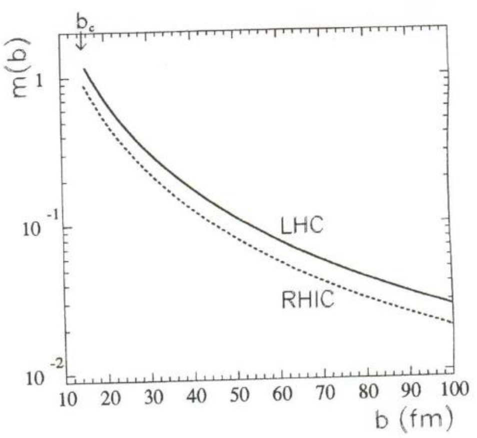
[X.Artru e.a. PL 40B (1972) 43]

Кулоновская диссоциация релятивистских ядер

Многочастичная фрагментация



Многофотонные обмены



Спектры виртуальных фотонов

Деление ядер – актинидов с малой передачей энергии и импульса
Диаграммы КЭД высокого порядка

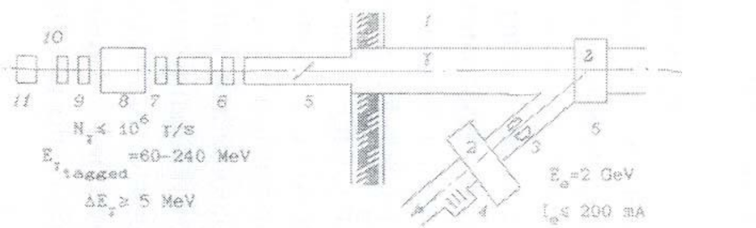


Fig.1. The experimental lay-out and parameters of the storage ring VEPP-3: 1 - vacuum chamber of VEPP-3; 2 - dipole magnets of VEPP-3; 3 - quadruple lens; 4 - tagging system , 5 - mirror; 6 - clearing magnet; 7 - plastic counter "veto"; 8 - fission fragment detector (FD), 9 - second plastic counter, 10 - coordinate sensitive MWPCs; 11 - total photoabsorption γ-spectrometer; (see in detail in ref.[6,8]).

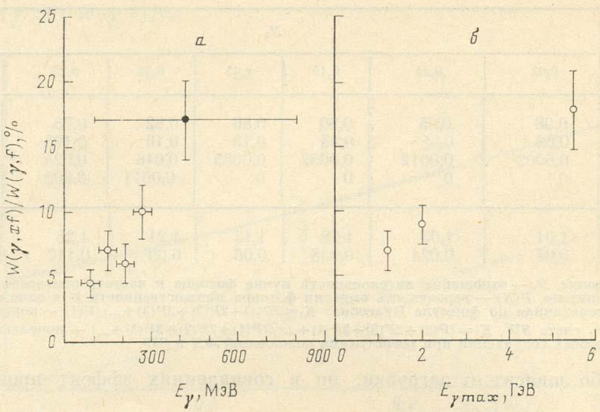


Рис. 4. Вероятность реакции (γ, *xf*) по отношению к полному выходу (γ, *f*): *а* – как функция энергии меченых фотонов, усредненная по ядрам ^{238}U и ^{237}Np(○), точка ● относится к измерениям на ВЭПП-4 с обратно рассеянными комптоновскими квантами [4]; *б* – как функция максимальной энергии тормозного спектра $E_{\gamma\,max}$, точка при энергии 5,5 ГэВ взята из работы [4]

- Д.И.Иванов, Г.Я.Кезерашвили, А.И.Львов и др. Деление ядер ^{237}Np и ^{238}U -квантами средних энергий с малой передачей энергии и импульса. ЯФ 55, 1 (11993) 3.

Nonlinear quantum electrodynamics:

Compton scattering and pair production

Intensity 10^{30} W/cm^2

Electric field 10^{16} V/cm

Nonlinear Compton scattering

Inelastic scattering of light on light

SLAC experiment

Новая программа исследований и новые методы

- Необходим комплексный подход к изучению новых (нелинейных) эффектов в физике электромагнитных взаимодействий ядер :

- - AA и eA коллайдер
- - внутренние мишени на коллайдере
- - фемптосекундные тераваттные лазеры
- - традиционные эксперименты на выведенных пучках

- Совет по электромагнитным взаимодействия ядер   ОИЯИ -2009

NICA JINR

→ eNICA

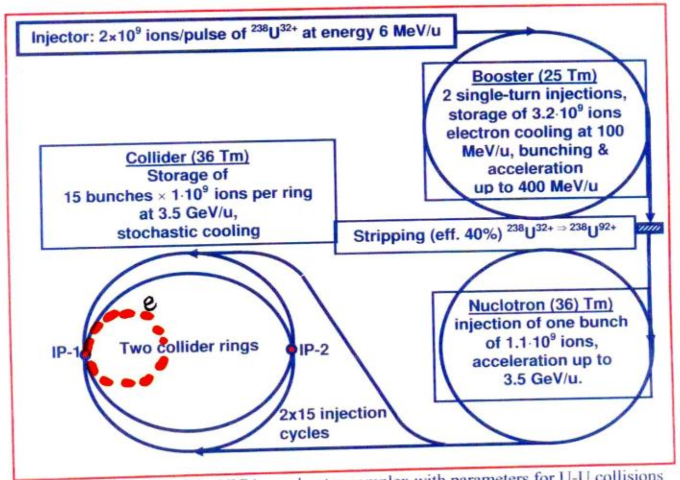


Fig. 1.4. Schematics of the NICA accelerator complex with parameters for U-U collisions

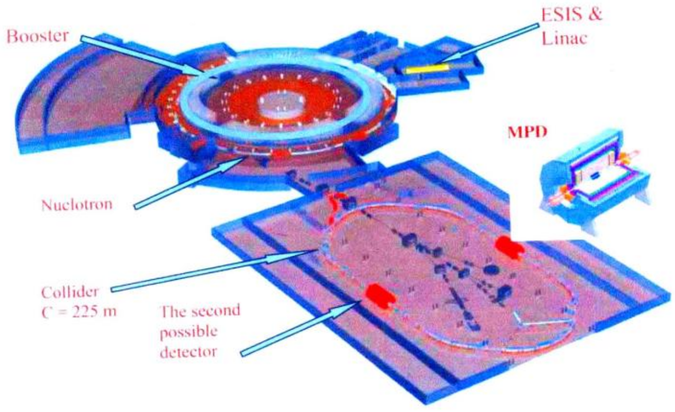


Fig. 1.5. NICA location in the existing buildings.

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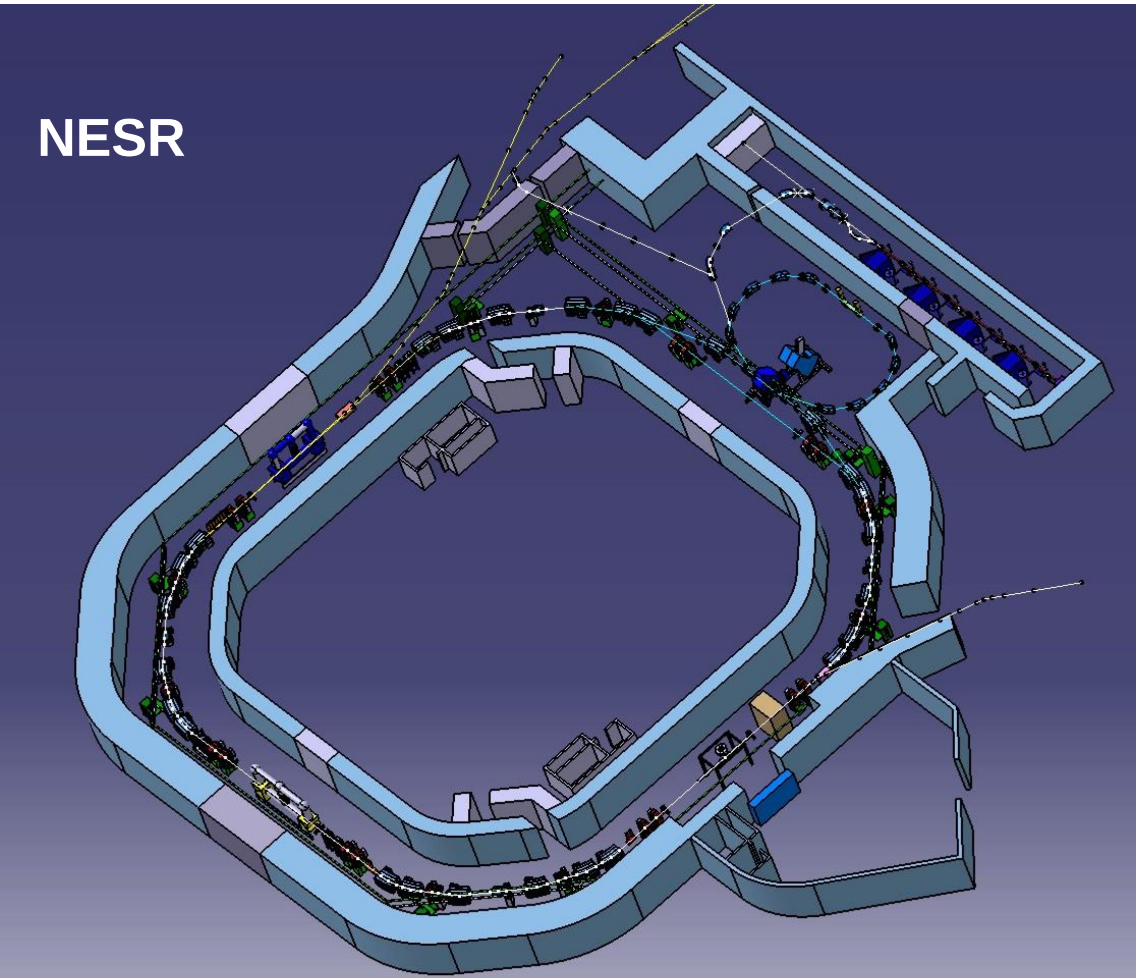
News on the Electron-Ion Scattering-Experiment at FAIR

The NUSTAR/**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

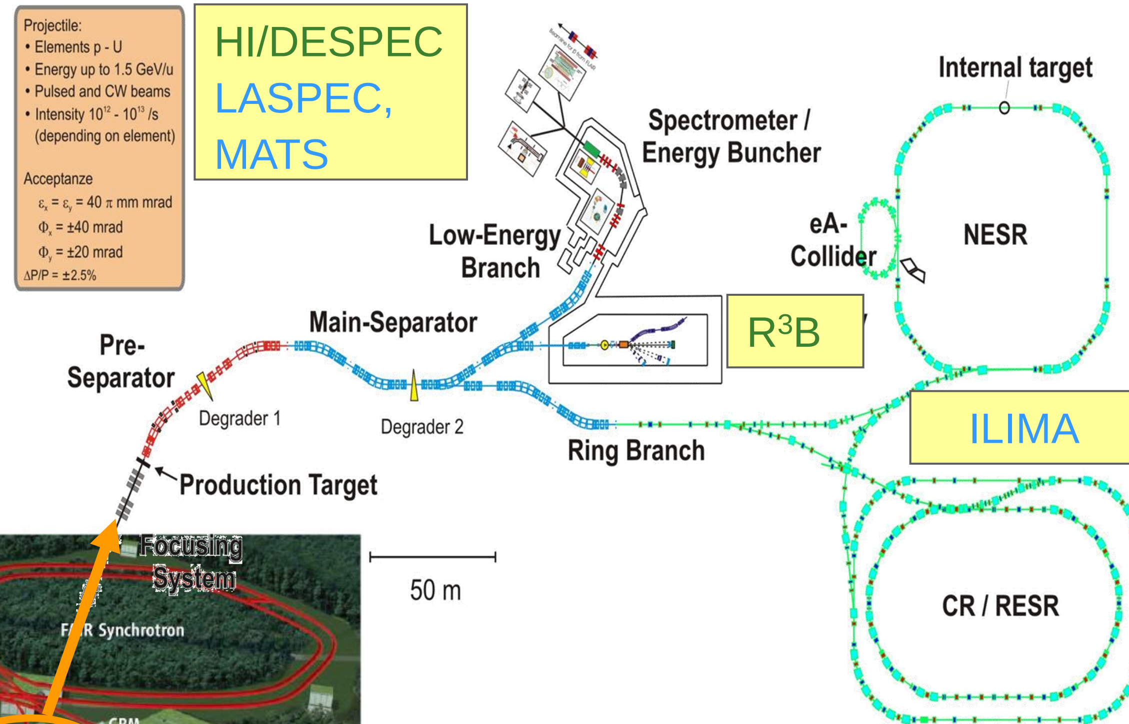
RIB Intensity increase up to a factor 10‘000

NUSTAR Experiments

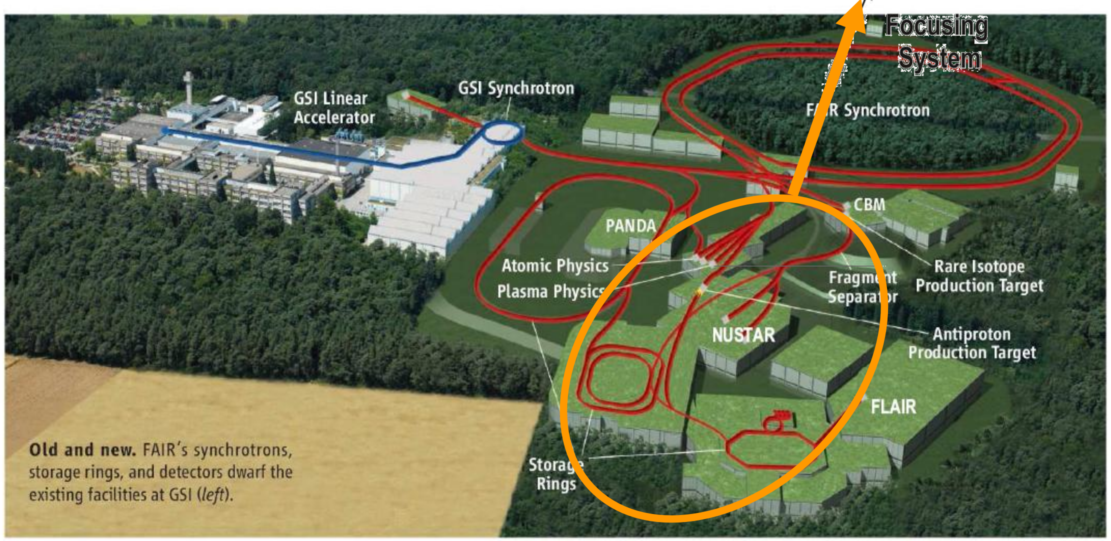
(NUclear STructure Astrophysics and Reactions)

Exotic Nuclei

- Spectroscopy
- Reactions
- Mass/gs. prop.



schematic

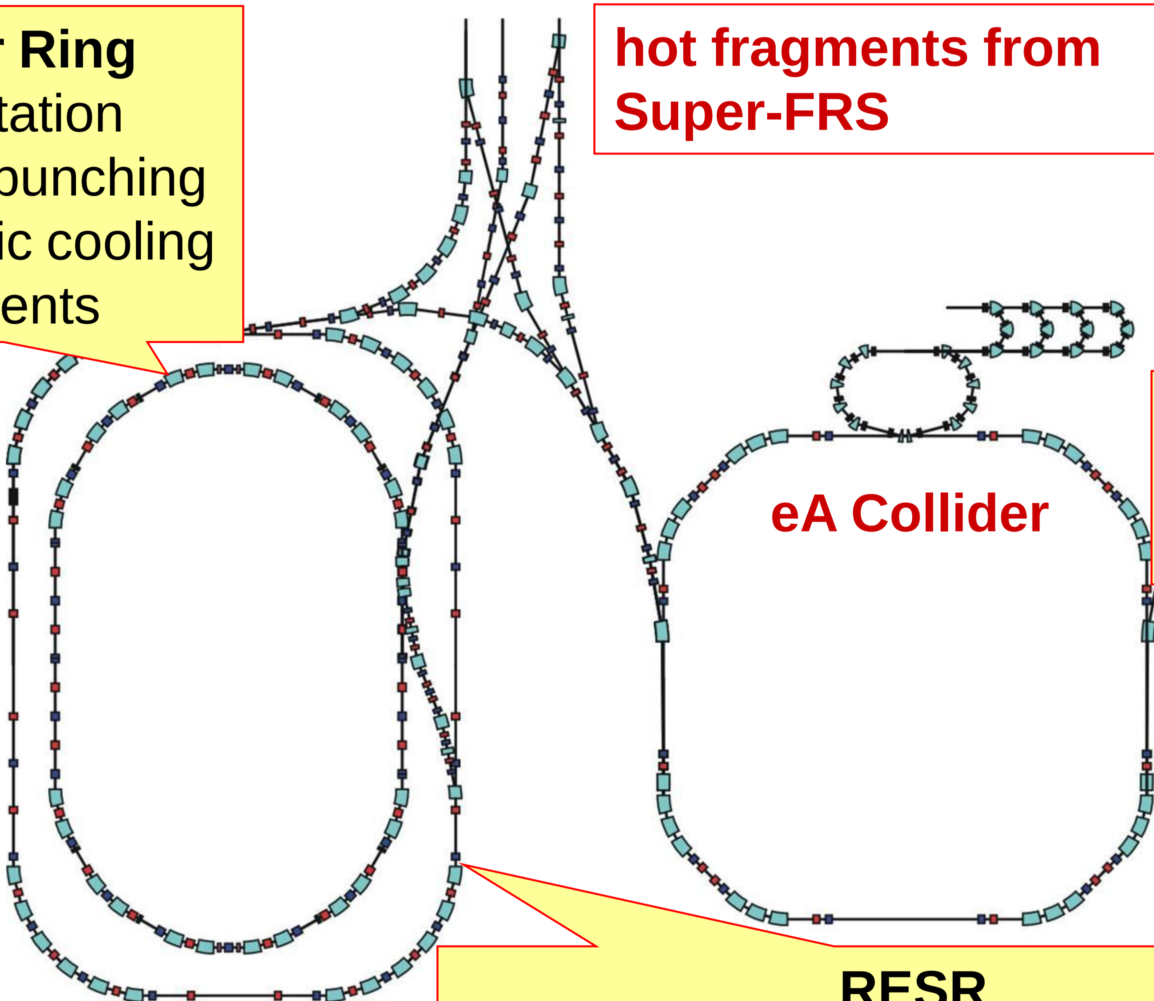


Old and new. FAIR's synchrotrons, storage rings, and detectors dwarf the existing facilities at GSI (*left*).

2 NOVEMBER 2007 VOL 318 SCIENCE www.sciencemag.org

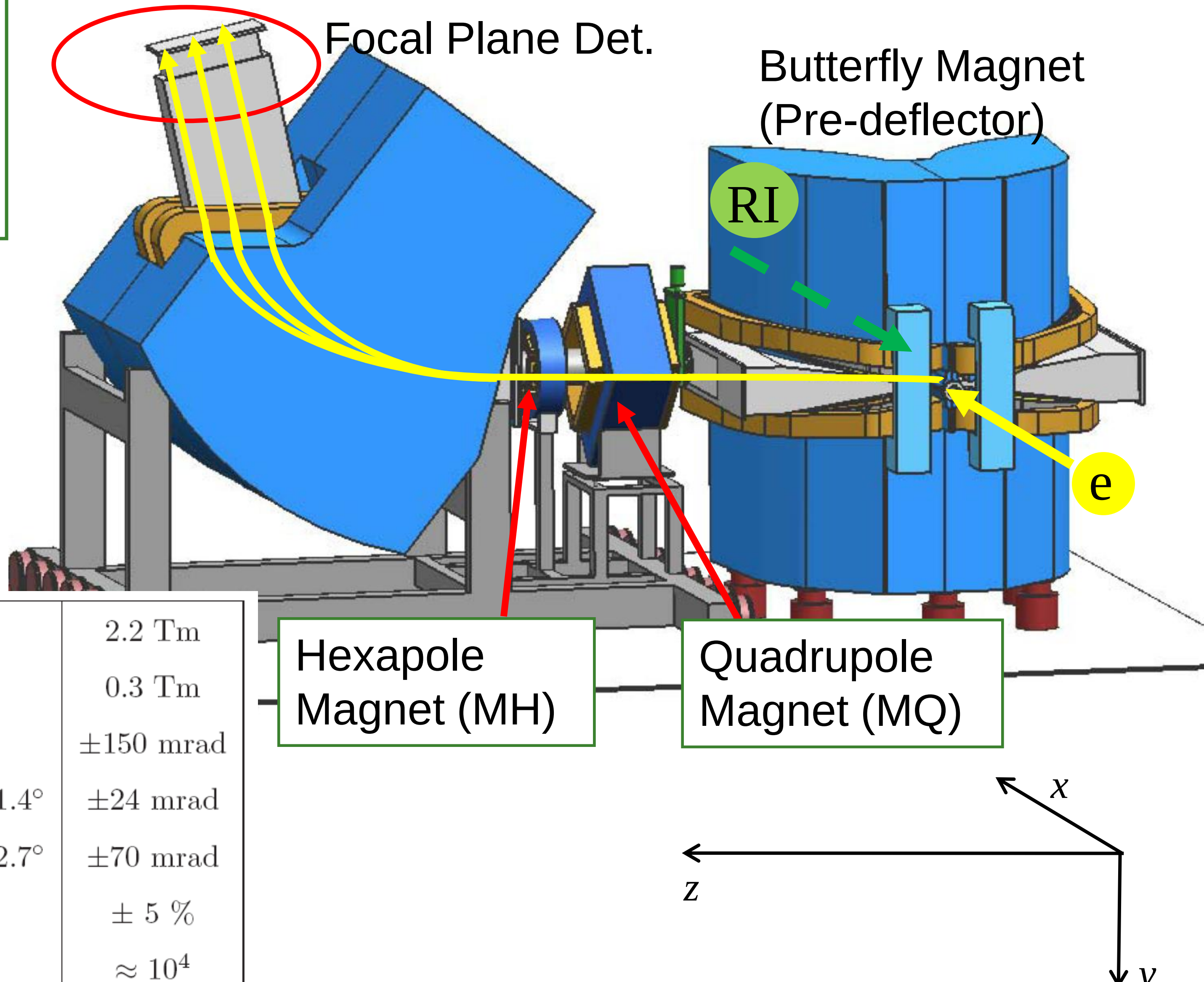
EXL : hadron scattering
ELISe : electron scattering
AIC : antiproton scattering

The Ring Branch



P.Beller †, A. Dolinskii, B. Franzke, M. Steck

Towards a High Resolution Large Acceptance Spectrometer

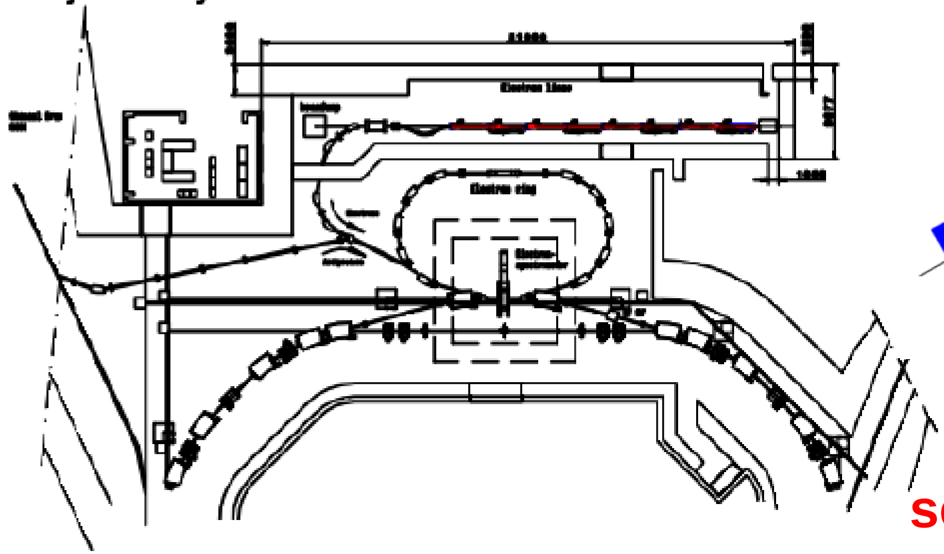


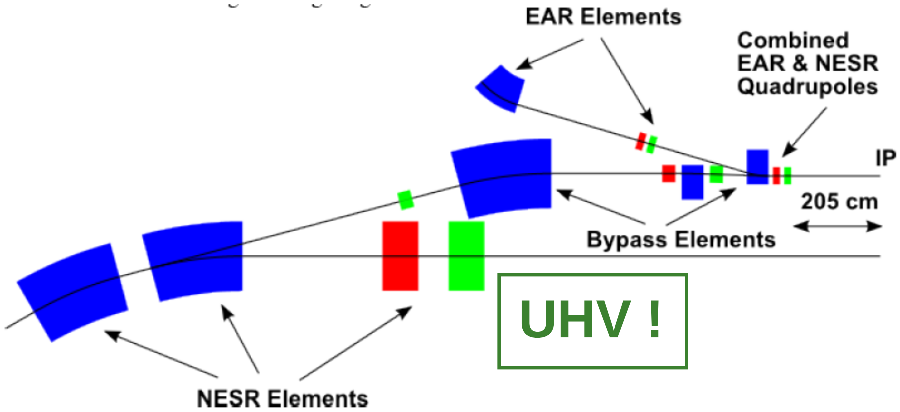
KVI/BINP/GSI NIM paper in preparation

Maximum rigidity Bρ	2.2 Tm
Minimum rigidity Bρ	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

Does the experiment fit into the hall … and even work with the accelerator ?

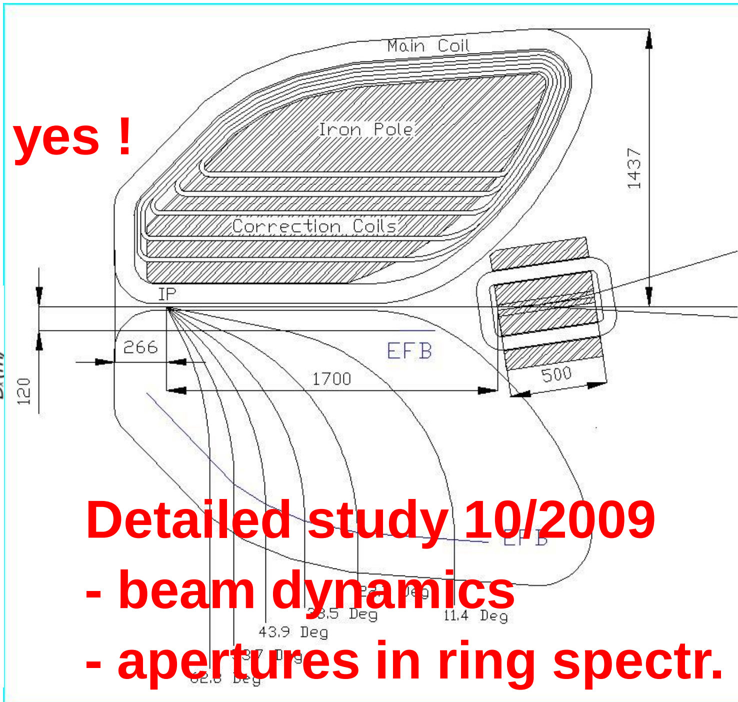
Beam injection system



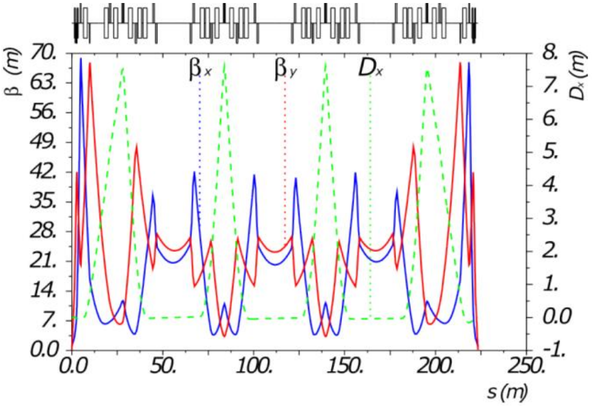


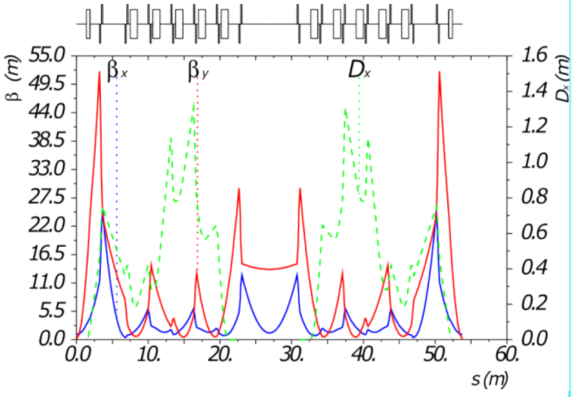
seems yes !

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

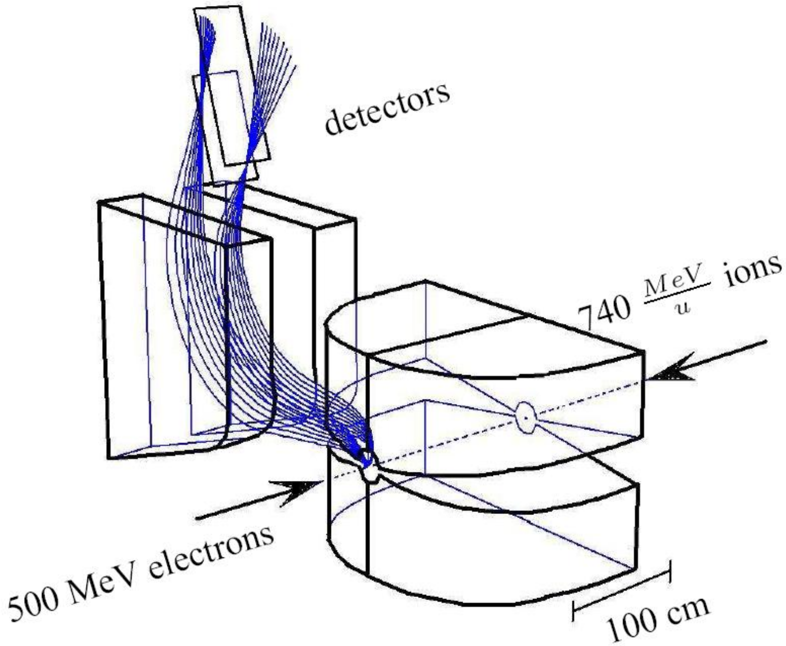


Detailed study 10/2009
- **beam dynamics**
- **apertures in ring spectr.**



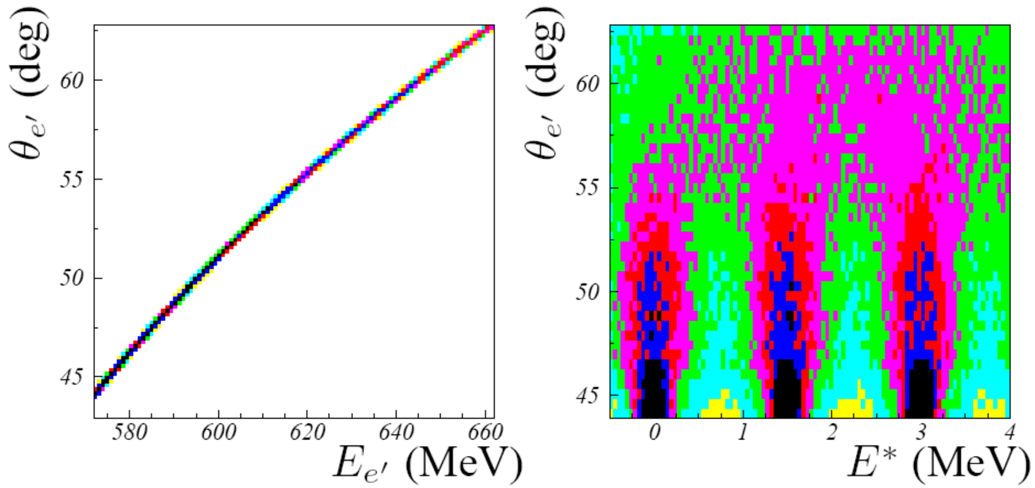


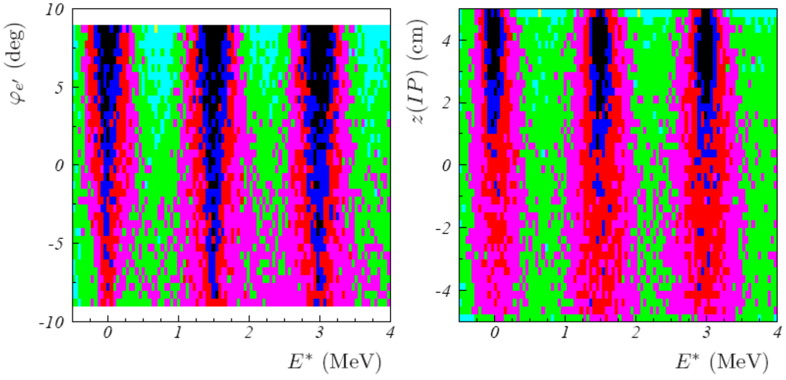
Full 3D simulation calculation
→ Generator vs. Analysis



1 mrad angular resolution

10^{-4} δp/p

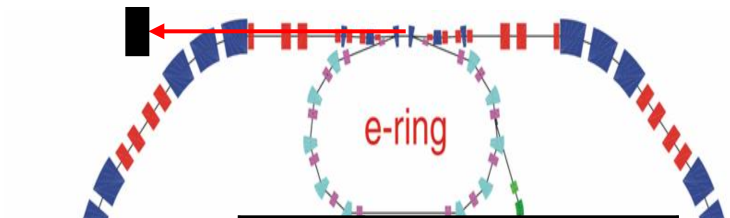




Sufficient resolution can be obtained !
Detection and analysis scheme ok.

Luminosity Monitor via photons: concept

position sensitive (i)
γ-detector



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

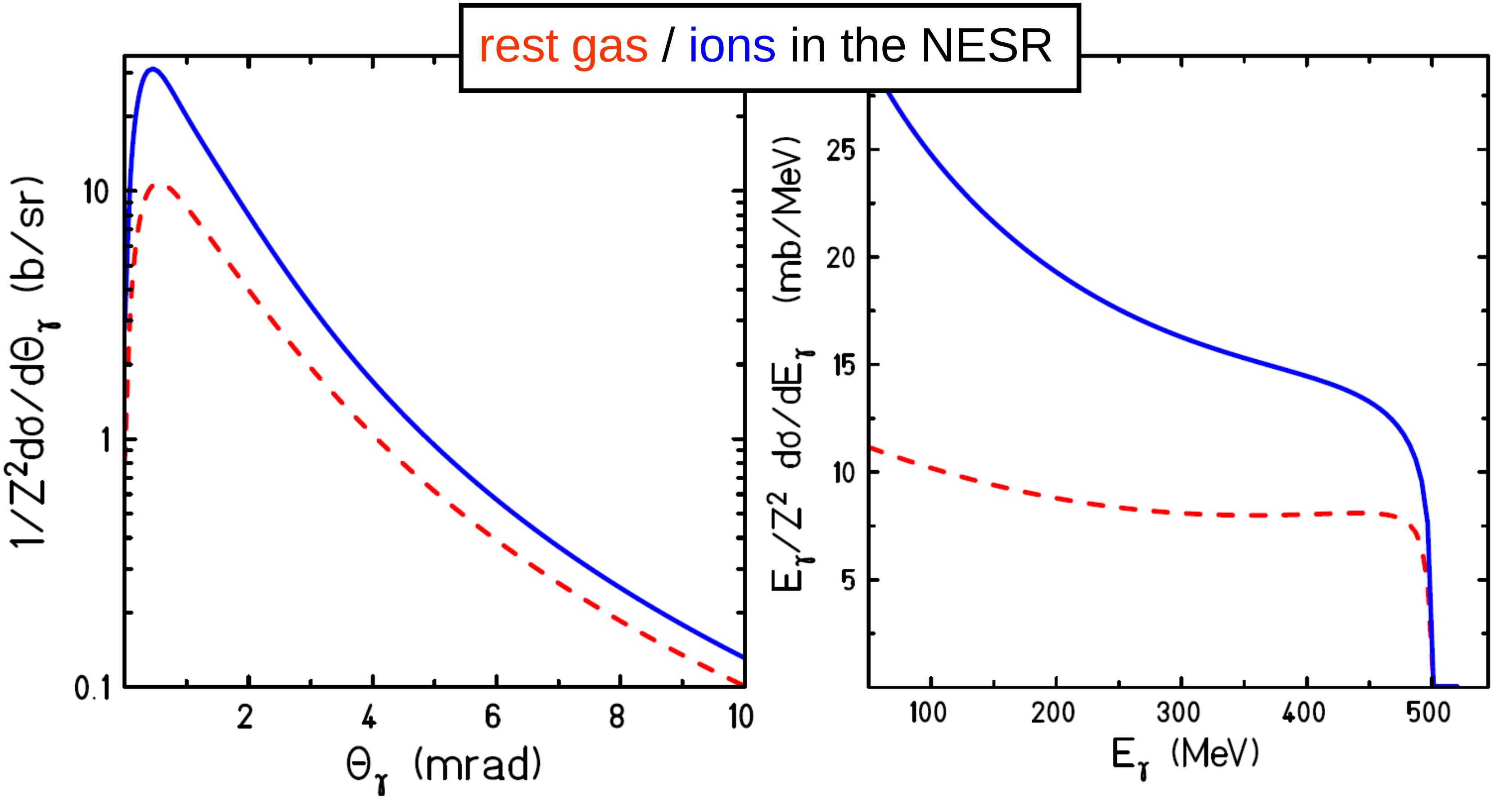
(ii)

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

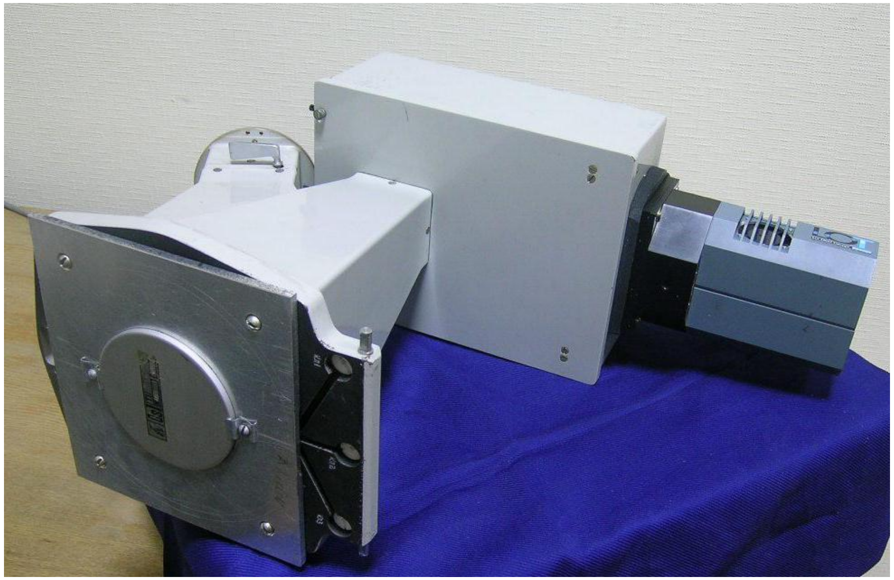
(iii)

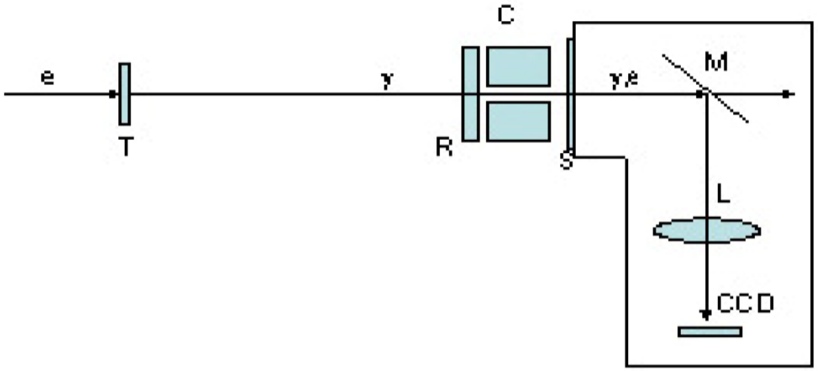
Absolute calibration via small angle scattering:
$q \rightarrow 0 : F(q) \approx 1$ ➔ Pure Mott cross section

Luminosity measurement via Bremstrahlung: spectrum and angular distribution

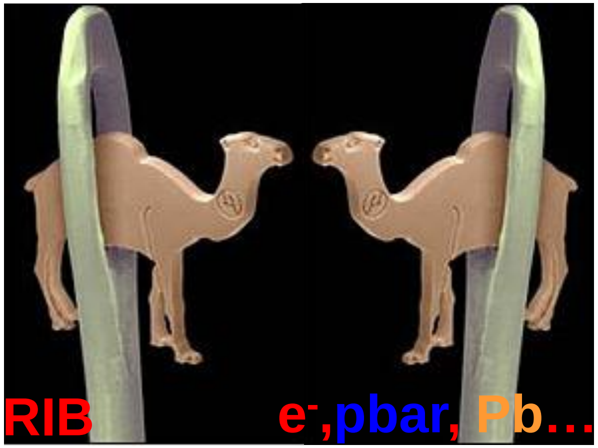


Luminosity monitor:
technical realisation prototypes, simulations





So as far as camels are involved it 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

Presumable Timeline

The Modularised FAIR Start Version 2009

A stepwise approach to the realisation of FAIR

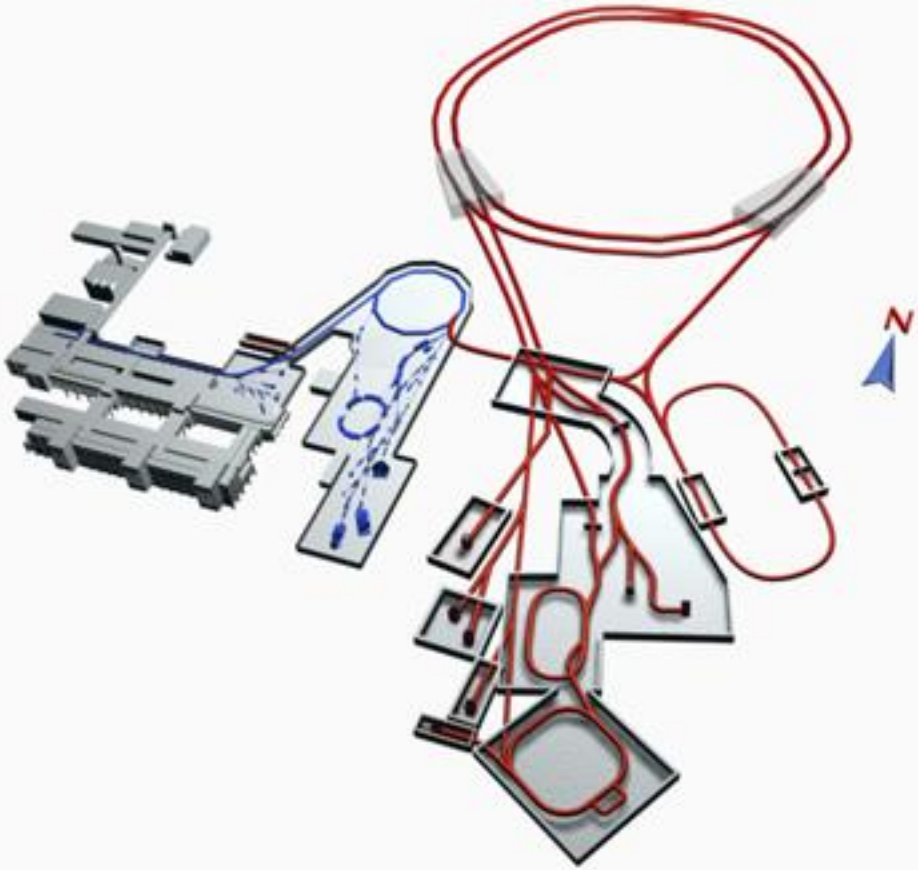
Based on the civil construction and technical infrastructure pre-planning studies for FAIR, carefully documented and with costs evaluated within the German „*Z-Bau*" procedure, and following revised designs of the accelerator complex, documented in the recent Technical Design Reports, new revised up-to-date cost figures were derived for the FAIR start version. These revised cost estimates amount to 1,395 M€ as compared to the original estimate of 955 M€. (All prices cited in 2005 price levels, and including civil construction, accelerator, experiments, and personnel for the FAIR start version.)

Draft Version
FAIR STI meeting 08 July 09

Anticipated project cost 955M€

- 10% cut applied by TAC not feasible
- Cost increases for civil construction
  + 290 M€ (103%) !
- Unfavourable price increases for stainless steel, copper, and equipment.
  + 150 M€ (35%)

The FAIR facility



Primary Beams

- $5\ x10^{11}/s$; 1.5 GeV/u; $^{238}U^{28+}$
- $2(4)x10^{13}/s$ 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

Новая программа исследований и новые методы

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- - AA и eA коллайдер
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- - фемптосекундные тераваттные лазеры
- - традиционные эксперименты на выведенных пучках

- Совет по электромагнитным взаимодействия ядер ОИЯИ -2009