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12 - 16 May 2008

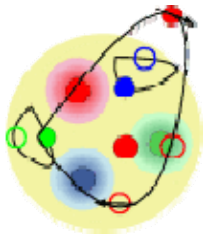
Recent Activities and Perspectives at MAMI.

H.-J. Arends
Institut fuer Kernphysik
Universitaet Mainz
Germany

Recent Activities and Perspectives at MAMI

Hans-Jürgen Arends
Institut für Kernphysik, Universität Mainz

Trieste 2008



SFB 443

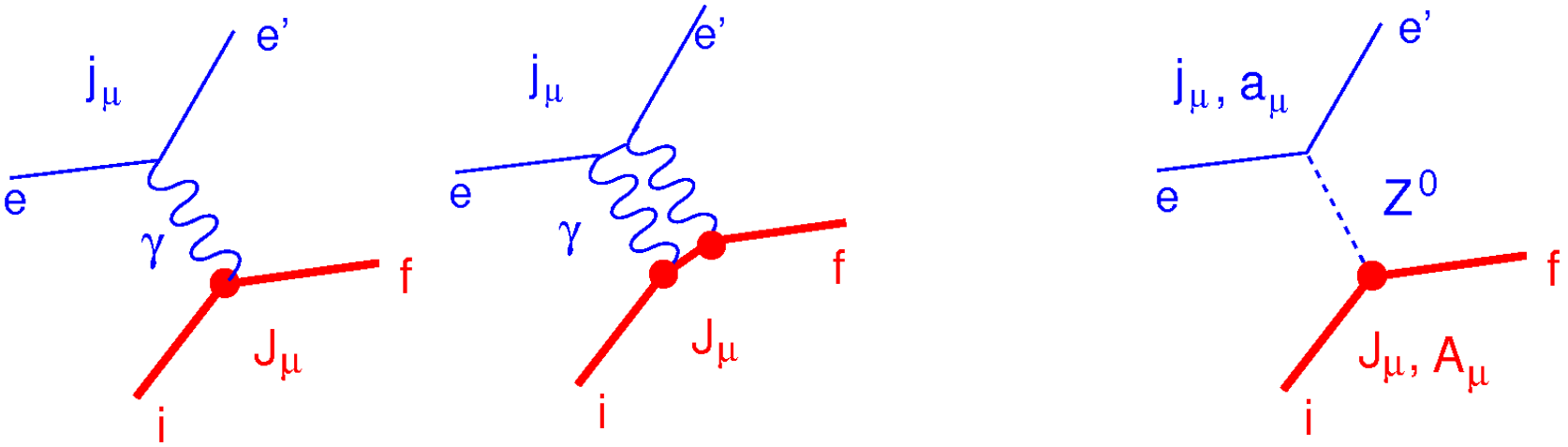
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

MAMI MAINZER MIKROTRON

Overview

- MAMI C (1.5 GeV)
  - Accelerator and experiments
- Selected recent results
- Future perspectives

Electroweak probes

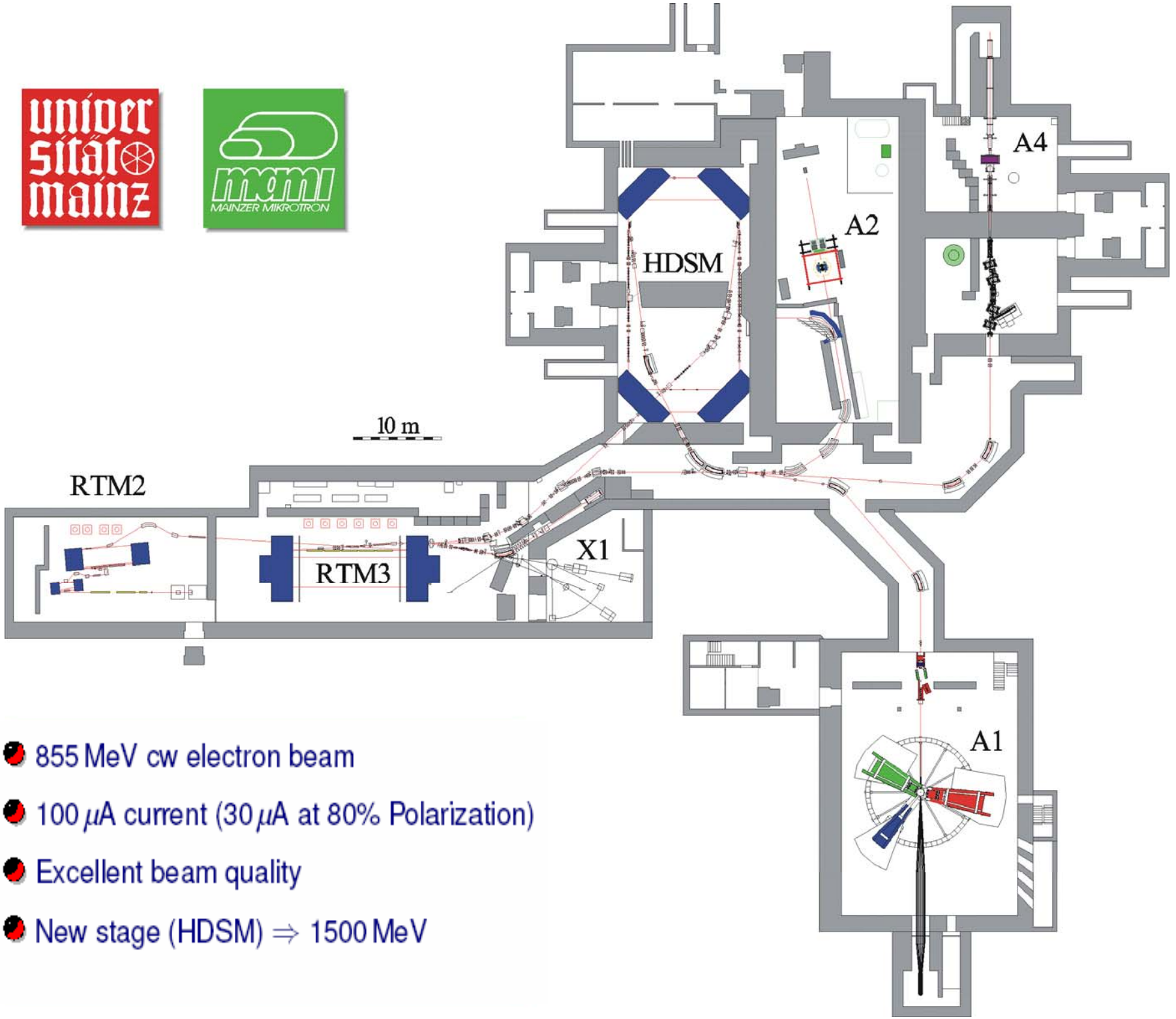


Hadronic vector and axial vector currents

→ Structure functions/ form factors: $F(Q^2, E_{CM})$

MAMI C: $Q^2 \lesssim 1$ GeV/c^2 → long-range structures

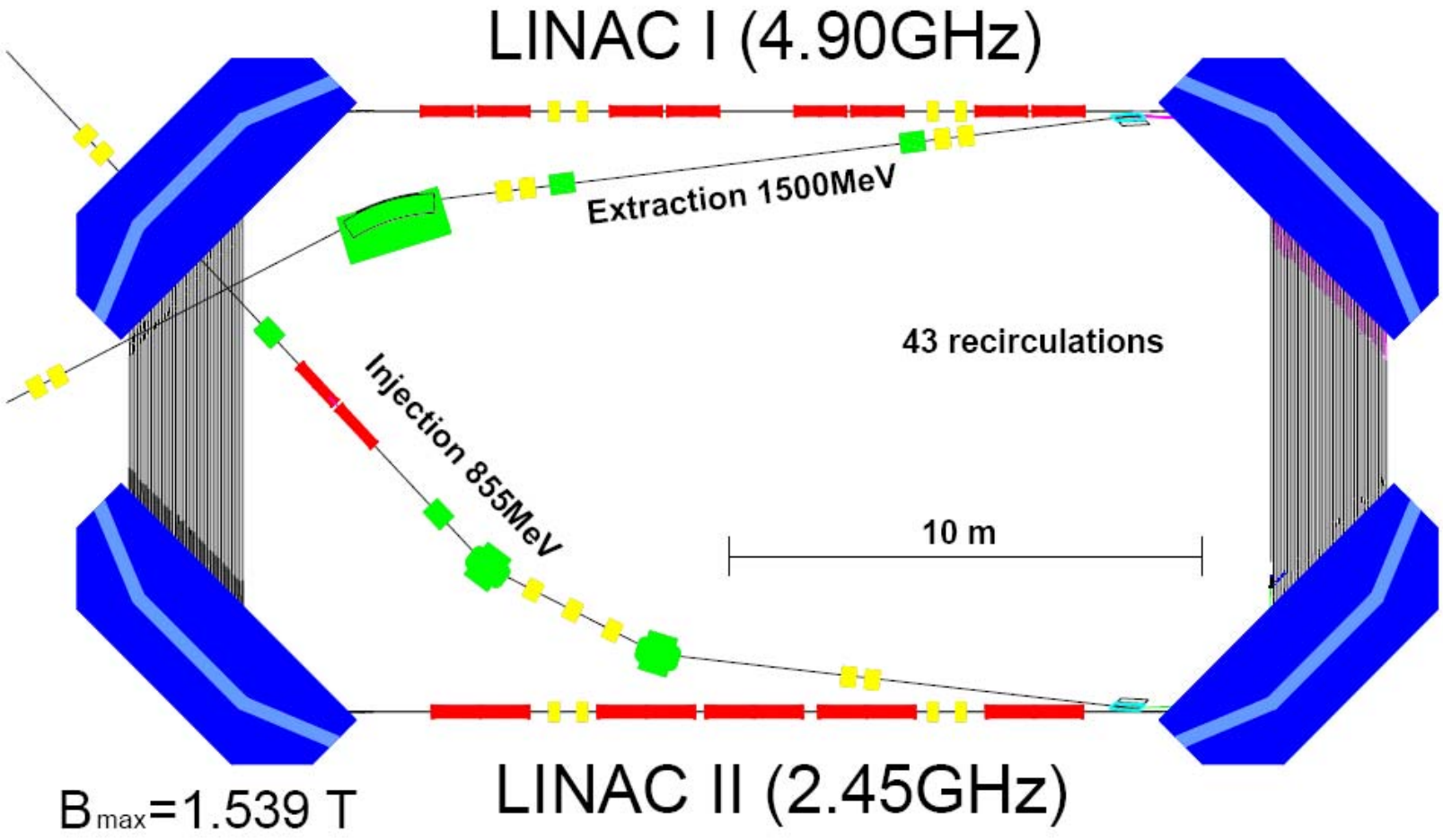
$E_{CM} < 2$ GeV → excitation spectrum



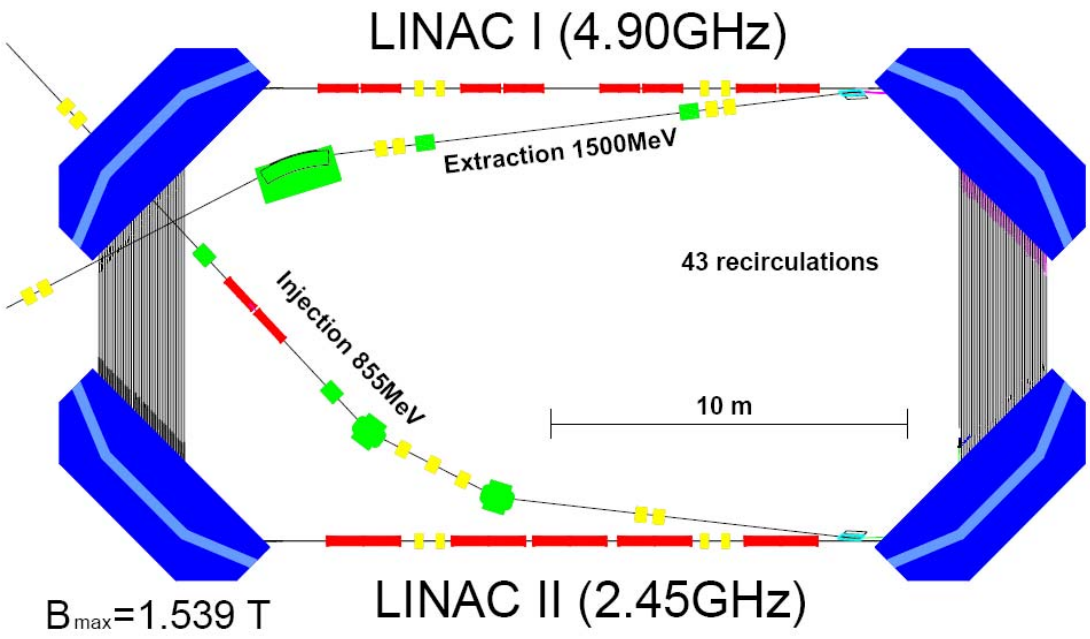
- 855 MeV cw electron beam
- 100 μA current (30 μA at 80% Polarization)
- Excellent beam quality
- New stage (HDSM) $\Rightarrow$ 1500 MeV

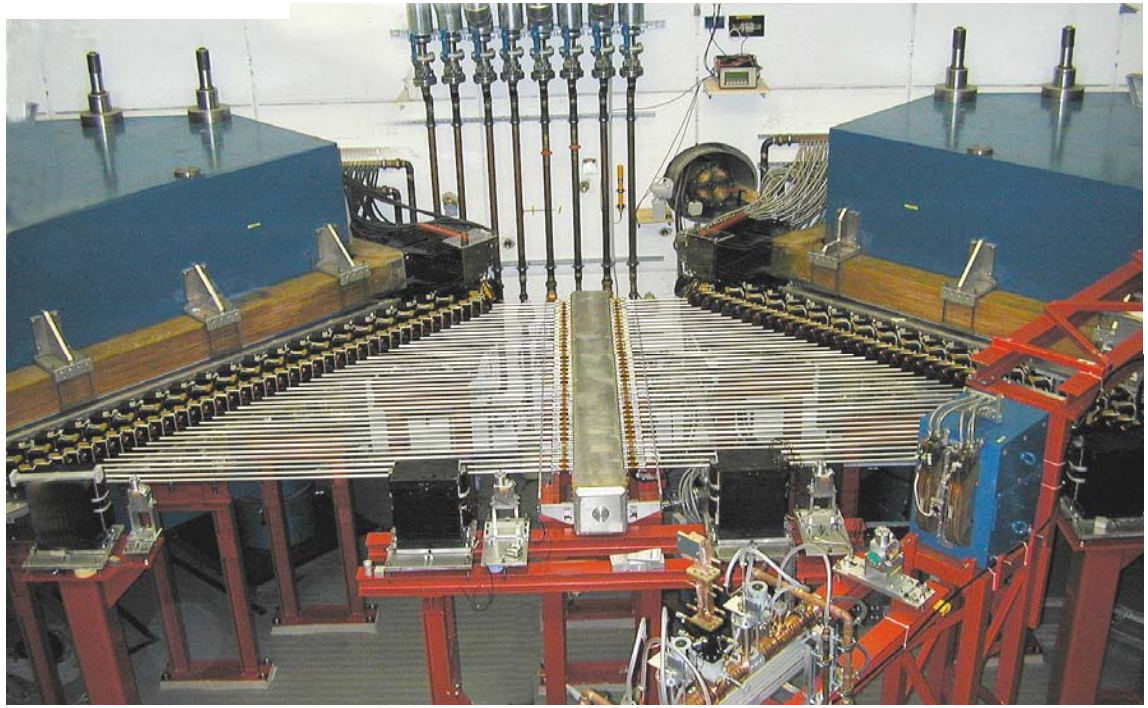
MAMI-C: harmonic double-sided Microtron

K.-H. Kaiser et al., NIM A (2008)

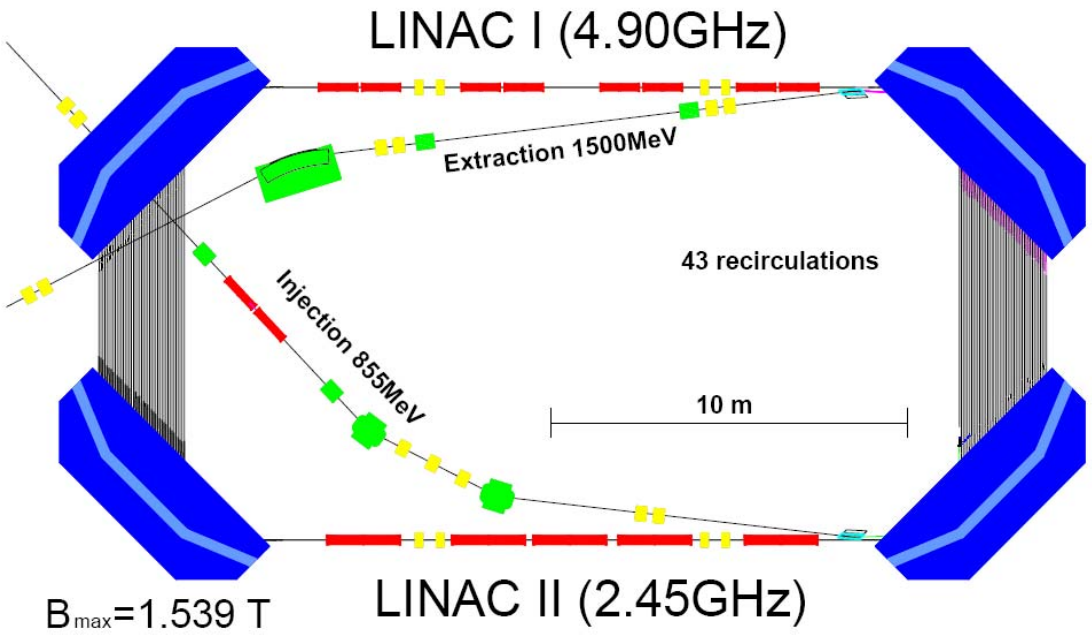


MAMI C: harmonic double-sided Microtron





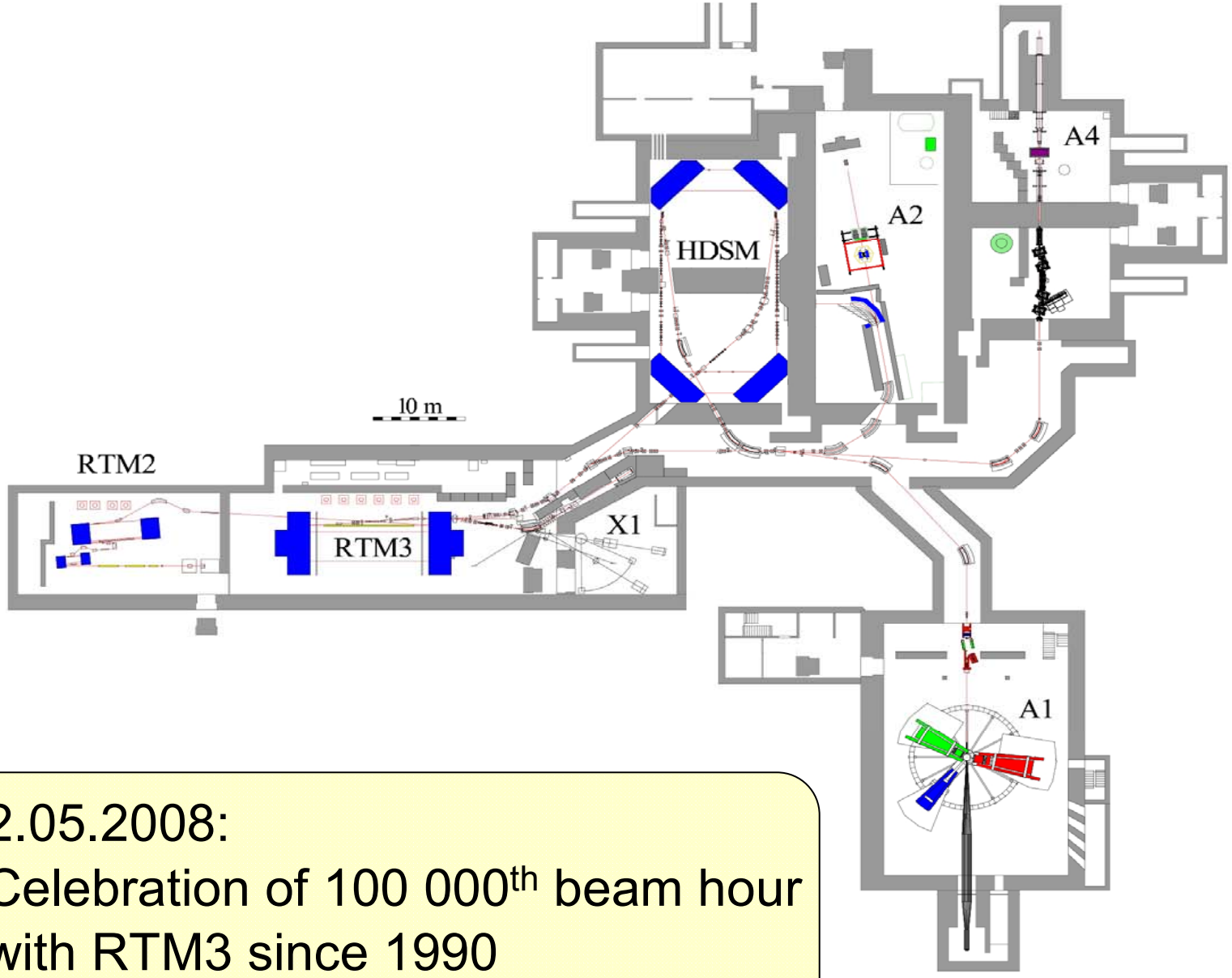
MAMI C: harmonic double-sided Microtron



Dec. 2006 : first beam
Feb. 2007 : routine operation for experiments

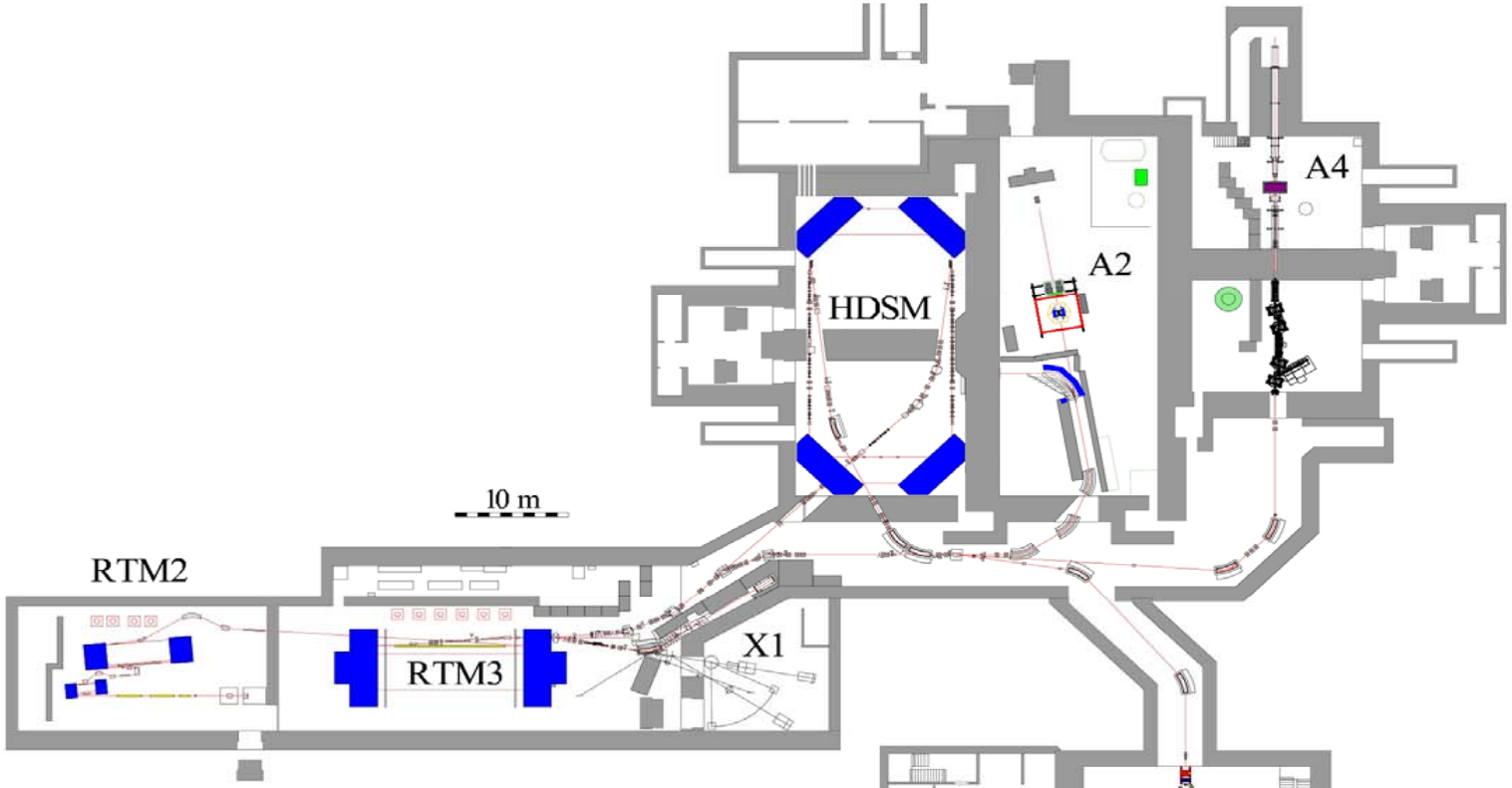
2007 ~7000 total beam hours
~1400 h : machine studies, optimisation
~3200 h : MAMI B (855 MeV)
~2400 h : MAMI C (1500 MeV)

Experiments at MAMI



2.05.2008:
Celebration of 100 000th beam hour with RTM3 since 1990

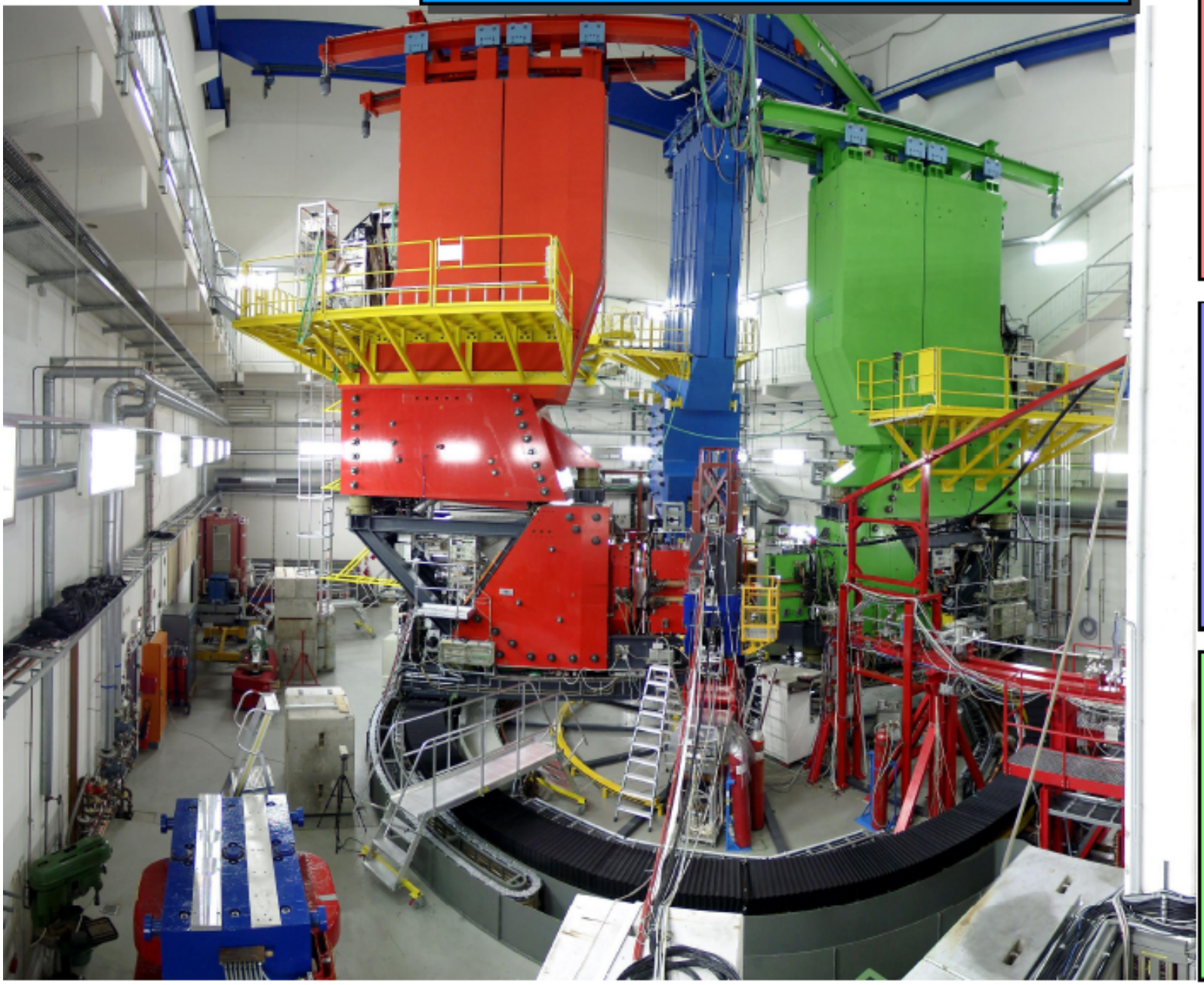
Experiments at MAMI



Electron scattering (A1):

- 3 focusing magnetic spectrometers
- short orbit pion spectrometer
- neutron detectors
- Kaon spectrometer (KAOS/A1)

A1: The »three« spectrometer facility



Spectrometer A:

$$\alpha > 20^\circ$$
$$p < 735\,\frac{\mathrm{MeV}}{c}$$
$$\Delta\Omega = 28\,\mathrm{msr}$$
$$\Delta p/p = 20\%$$

Spectrometer B:

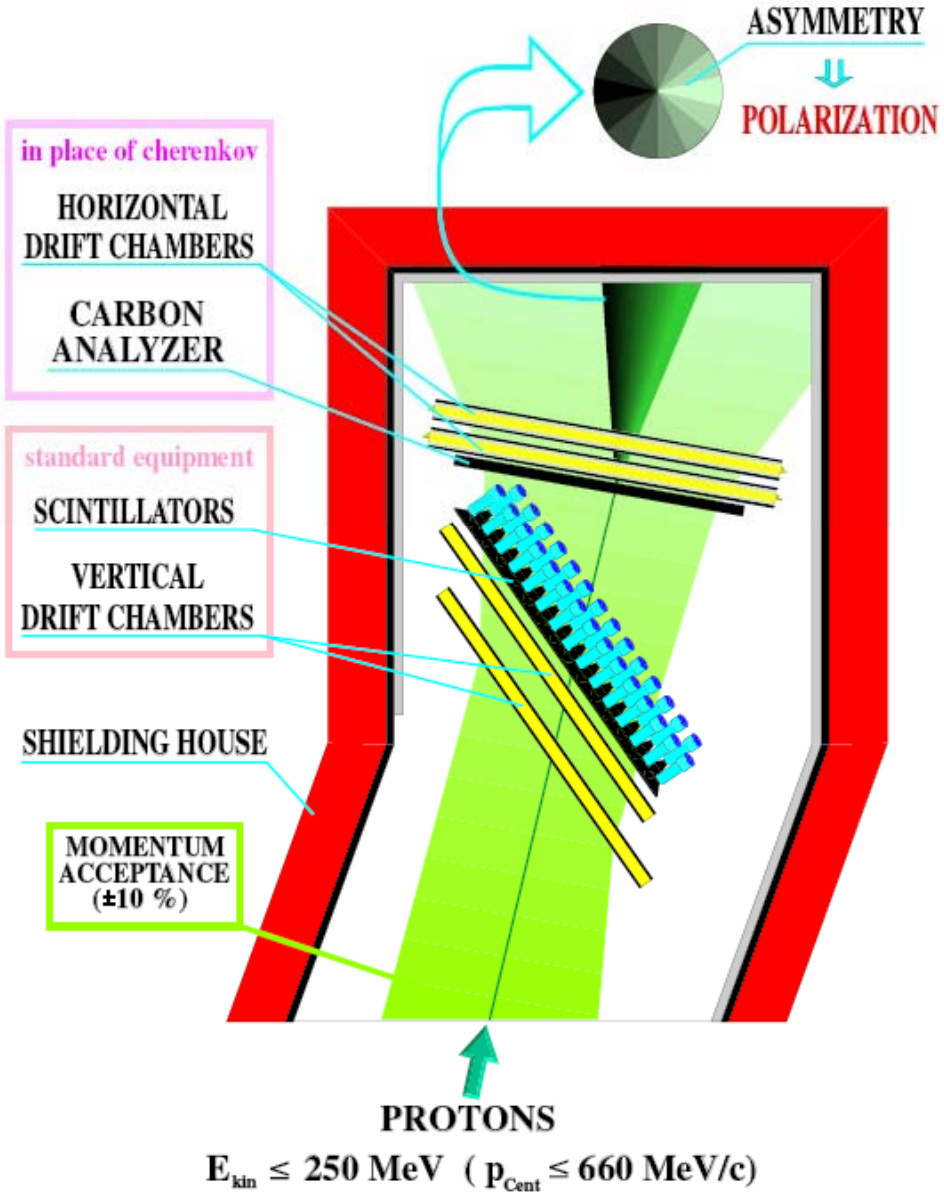
$$\alpha > 8^\circ$$
$$p < 870\,\frac{\mathrm{MeV}}{c}$$
$$\Delta\Omega = 5.6\,\mathrm{msr}$$
$$\Delta p/p = 15\%$$

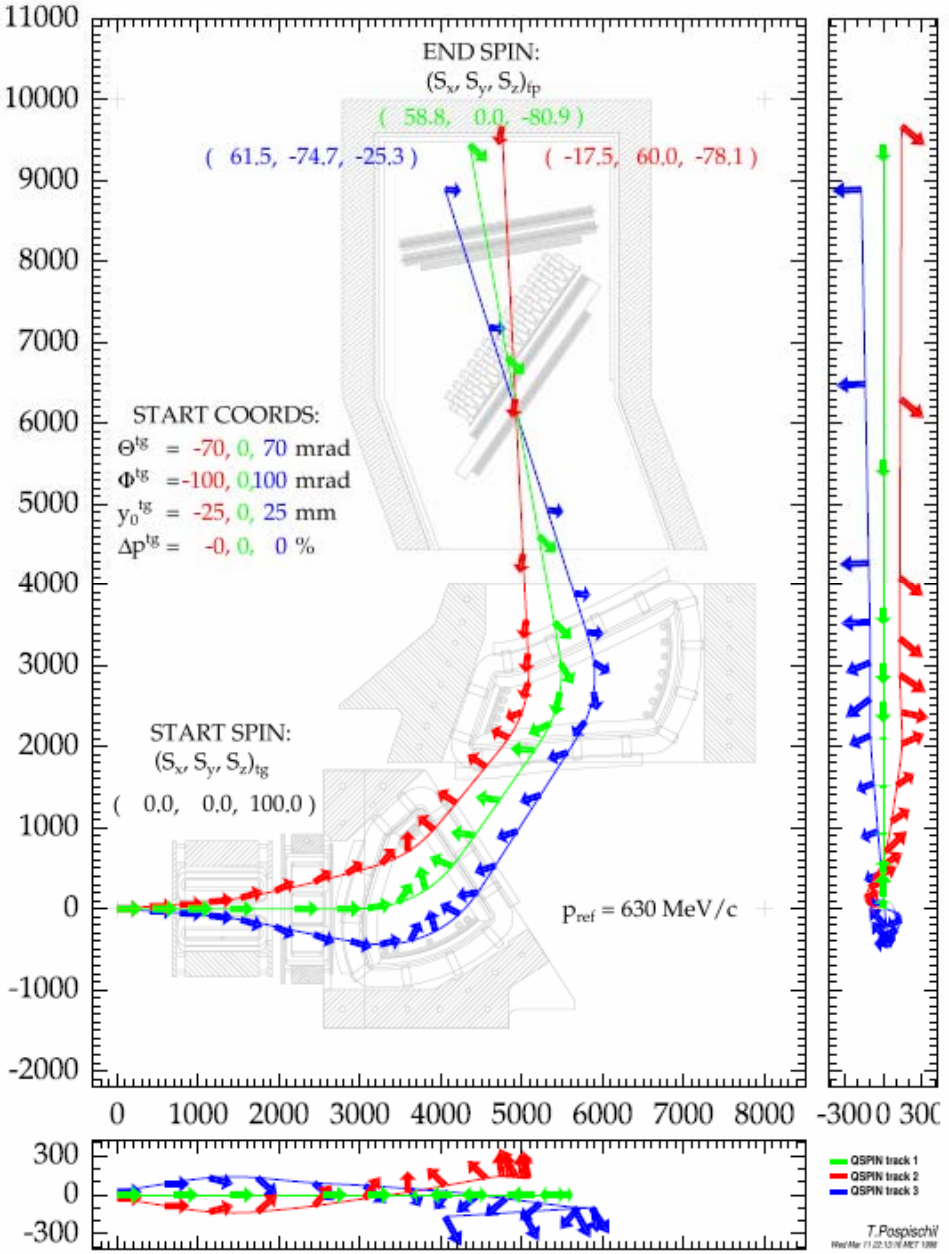
Spectrometer C:

$$\alpha > 55^\circ$$
$$p < 655\,\frac{\mathrm{MeV}}{c}$$
$$\Delta\Omega = 28\,\mathrm{msr}$$
$$\Delta p/p = 25\%$$

Recoil Polarimeter

spectrometer A





Overview on recent experiments

A1- Collaboration

- Elm. form factors (G_{en} via $^3\vec{H}e(\vec{e},é\,n)$)
- Axial form factor $p(e,é\,\pi^+)$
- Generalized polarizabilities of the proton (VCS)
- ^{3}He structure studies $^3\vec{H}e(\vec{e},ép)$, $^3\vec{H}e(\vec{e},ép)pn$, $^3\vec{H}e(\vec{e},ép)d$
- η electroproduction

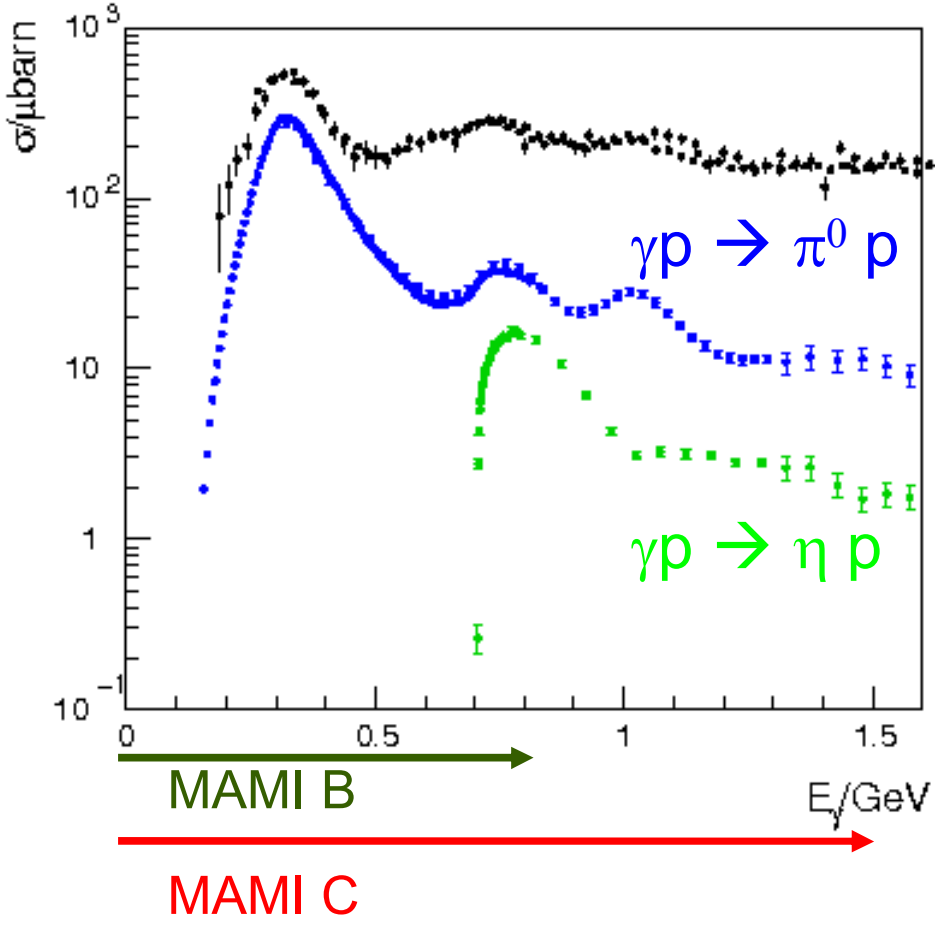
Selected Topics

- Resonances - excitation spectrum

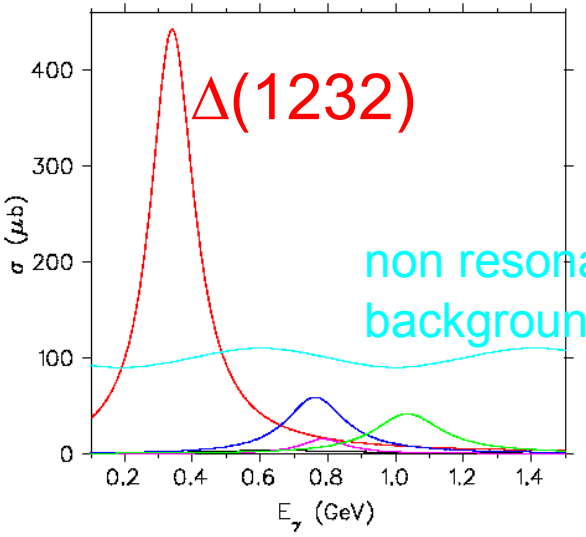
  - $\vec{e}\, p \rightarrow \eta\, \vec{p}$
  - $\gamma\, p \rightarrow \pi^0 \eta\, p$

- Matter distribution in nuclei - coherent and incoherent π^0 production

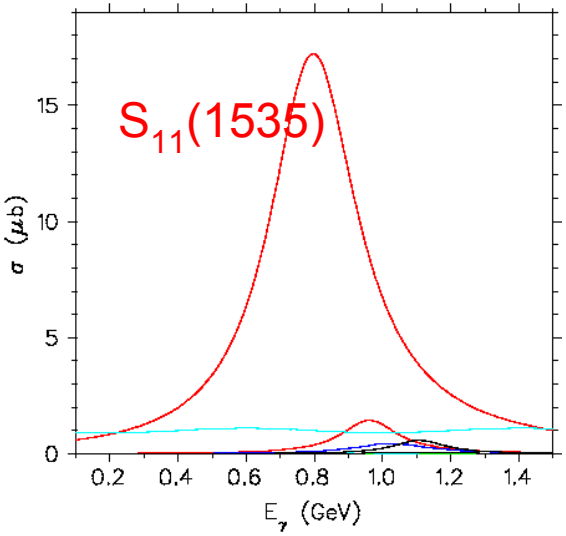
Photoabsorption on the Proton



γp → π^0 p

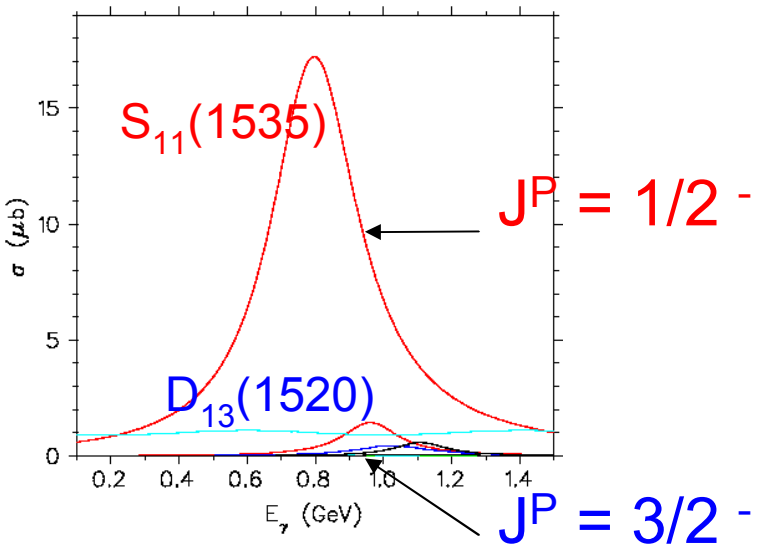


γp → η p



Polarisation observables in $\gamma p \rightarrow \eta p$

$\gamma p \rightarrow \eta p$

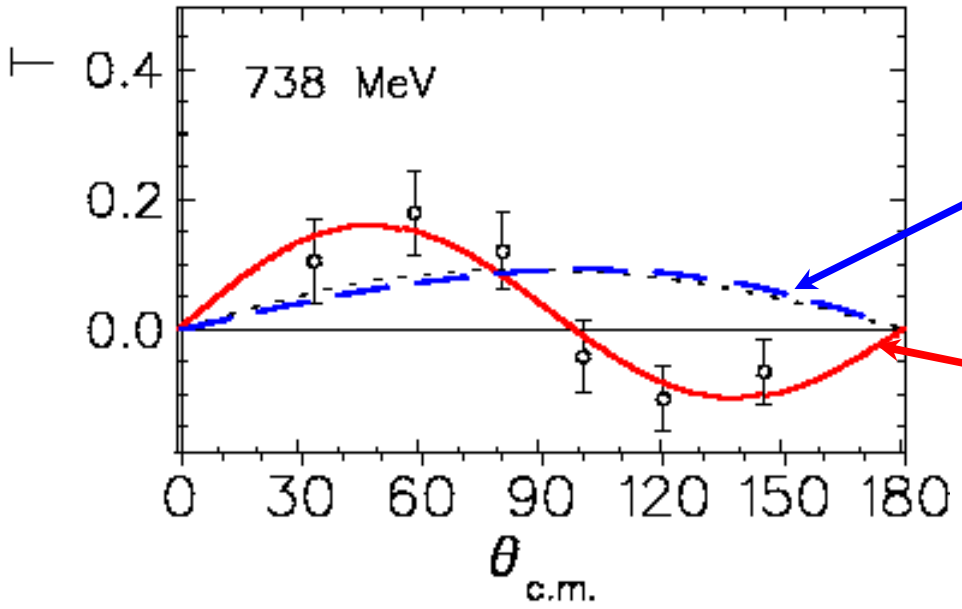


Asymmetry with transverse polarised target: T ~ Im (E_{0+}^{*} (E_{2-} + M_{2-}))

Polarisation of the recoil proton: P_y ~ Im (E_{0+}^{*} (E_{2-} + M_{2-}))

Target asymmetry in $\gamma \vec{p} \to \eta p$

$T \sim \mathrm{Im}\,(E_{0+}^{*}\,(E_{2-} + M_{2-}))$



Breit-Wigner resonances in $J^P = 1/2^-$ and $3/2^+$ partial waves

energy dependent phase shift between $J^P = 1/2^-$ and $3/2^+$ partial wave amplitudes

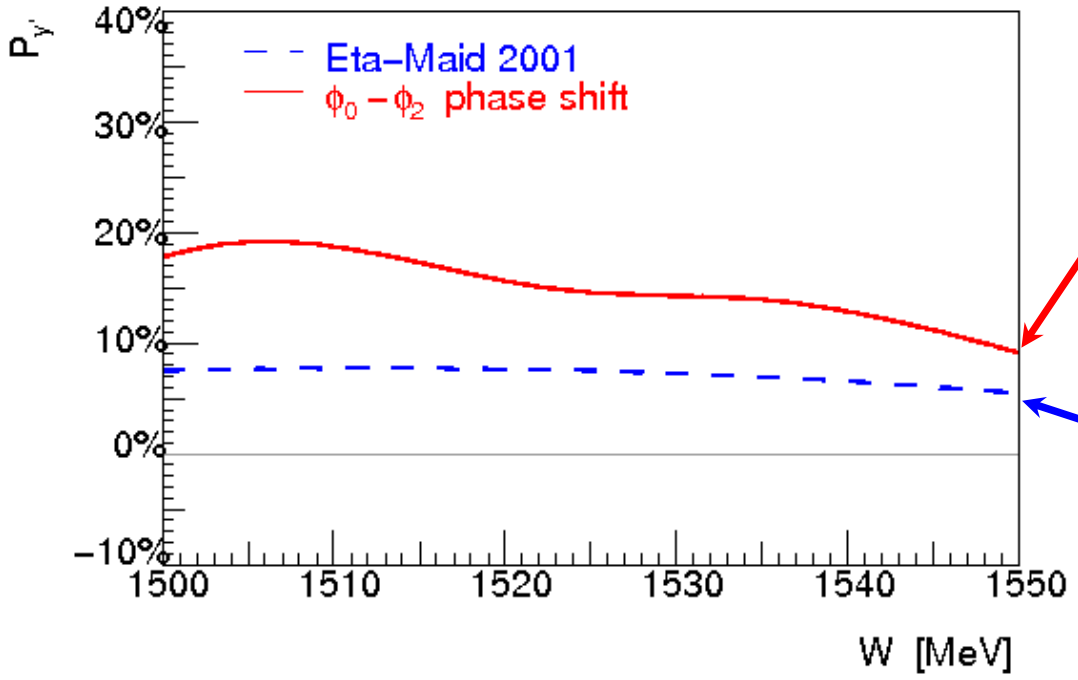
Phoenix/Bonn, A. Bock et al., PRL81(1998)

Recoil proton polarisation: $p(e, e'\vec{p})\eta$

A1 Collaboration:
First experiment with MAMI C and the 3-spectrometer setup

$P_y \sim \mathrm{Im}\,(E_{0+}^{*}\,(E_{2-} + M_{2-})) \sim T$

Merkel et al., PRL 99:132301 (2007)



energy dependent phase shift between $J^P = 1/2^-$ and $3/2^+$ partial wave amplitudes

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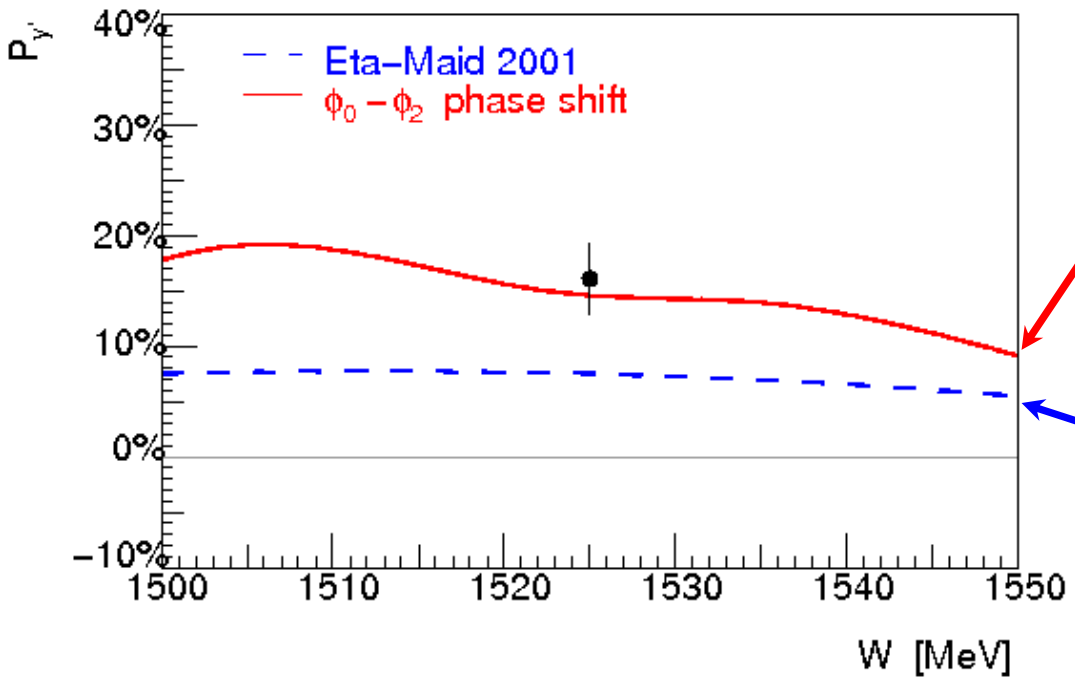
Merkel et al., PRL 99:132301,2007

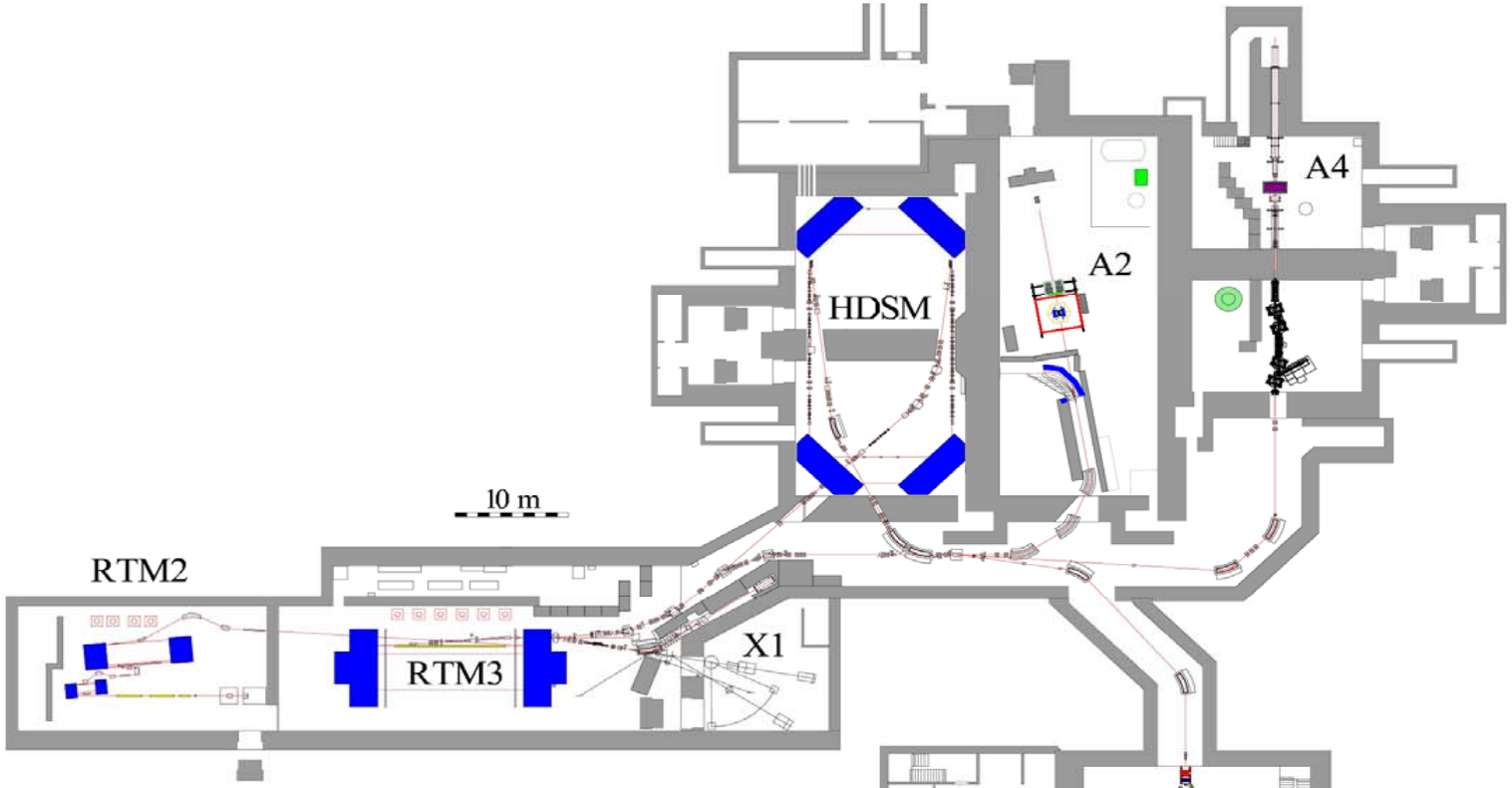


energy dependent phase shift between $J^P = 1/2^-$ and $3/2^+$ partial wave amplitudes

Breit-Wigner resonances in $J^P = 1/2^-$ and $3/2^+$ partial waves

More complete energy- and angular coverage planned

Experiments at MAMI



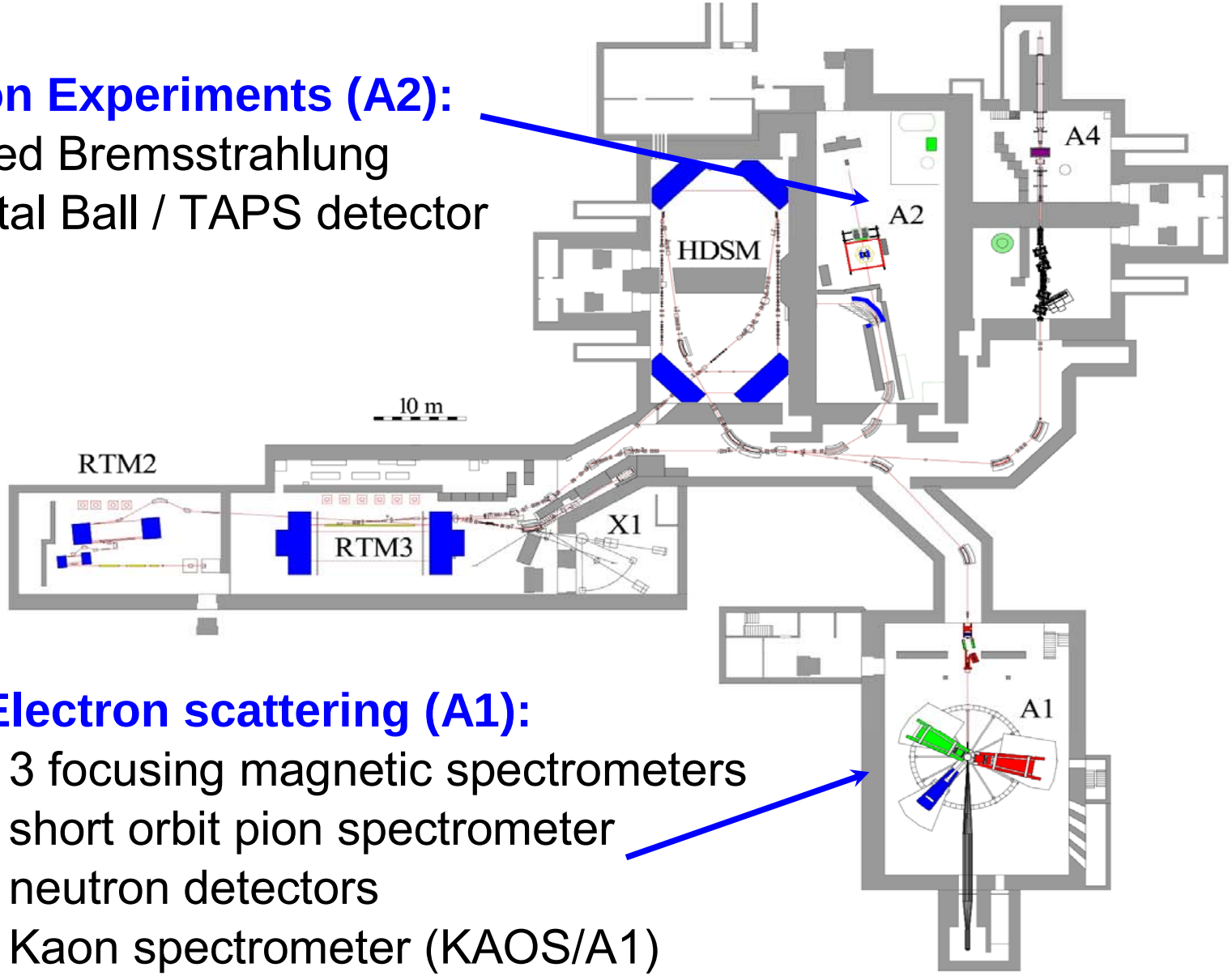
Electron scattering (A1):

- 3 focusing magnetic spectrometers
- short orbit pion spectrometer
- neutron detectors
- Kaon spectrometer (KAOS/A1)

Experiments at MAMI

Photon Experiments (A2):

- tagged Bremsstrahlung
- Crystal Ball / TAPS detector

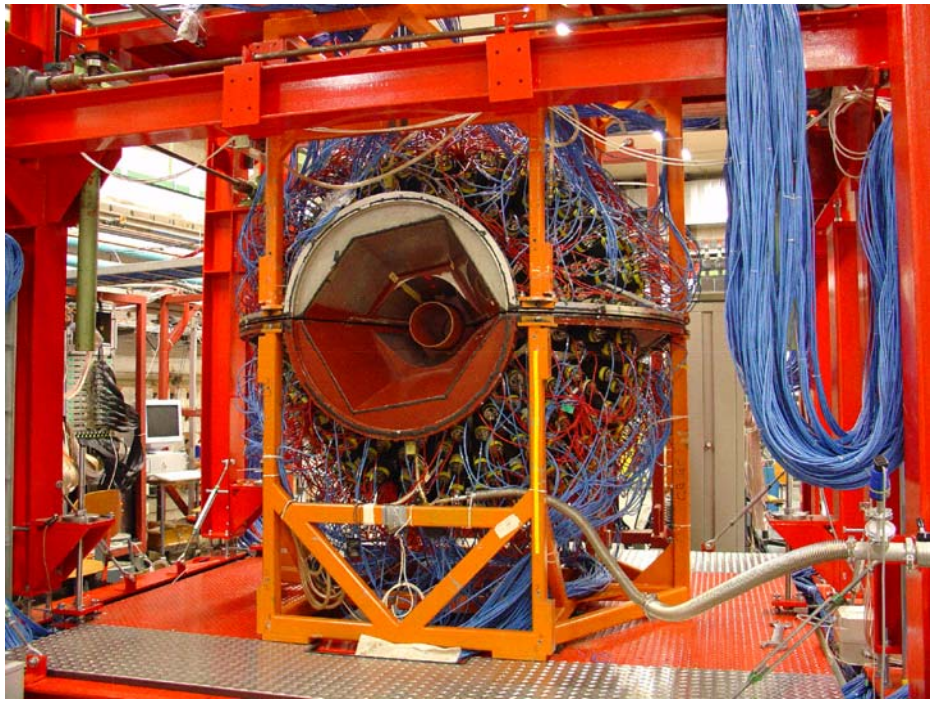


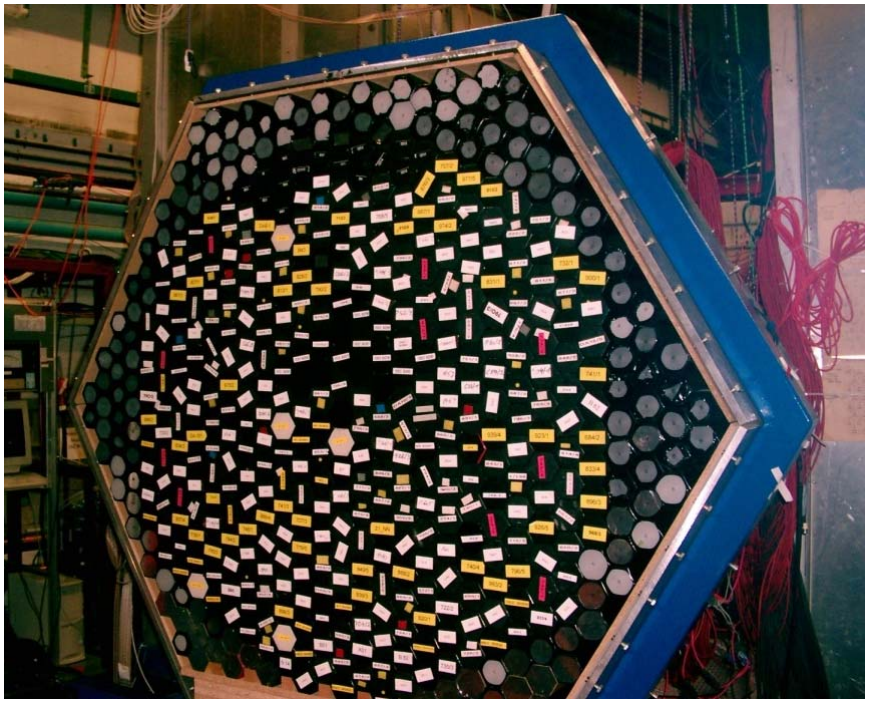
Electron scattering (A1):

- 3 focusing magnetic spectrometers
- short orbit pion spectrometer
- neutron detectors
- Kaon spectrometer (KAOS/A1)

Crystal Ball/TAPS Detector

4π photon spectrometer





Crystal Ball:

672 NaI scintillators (20-160°),

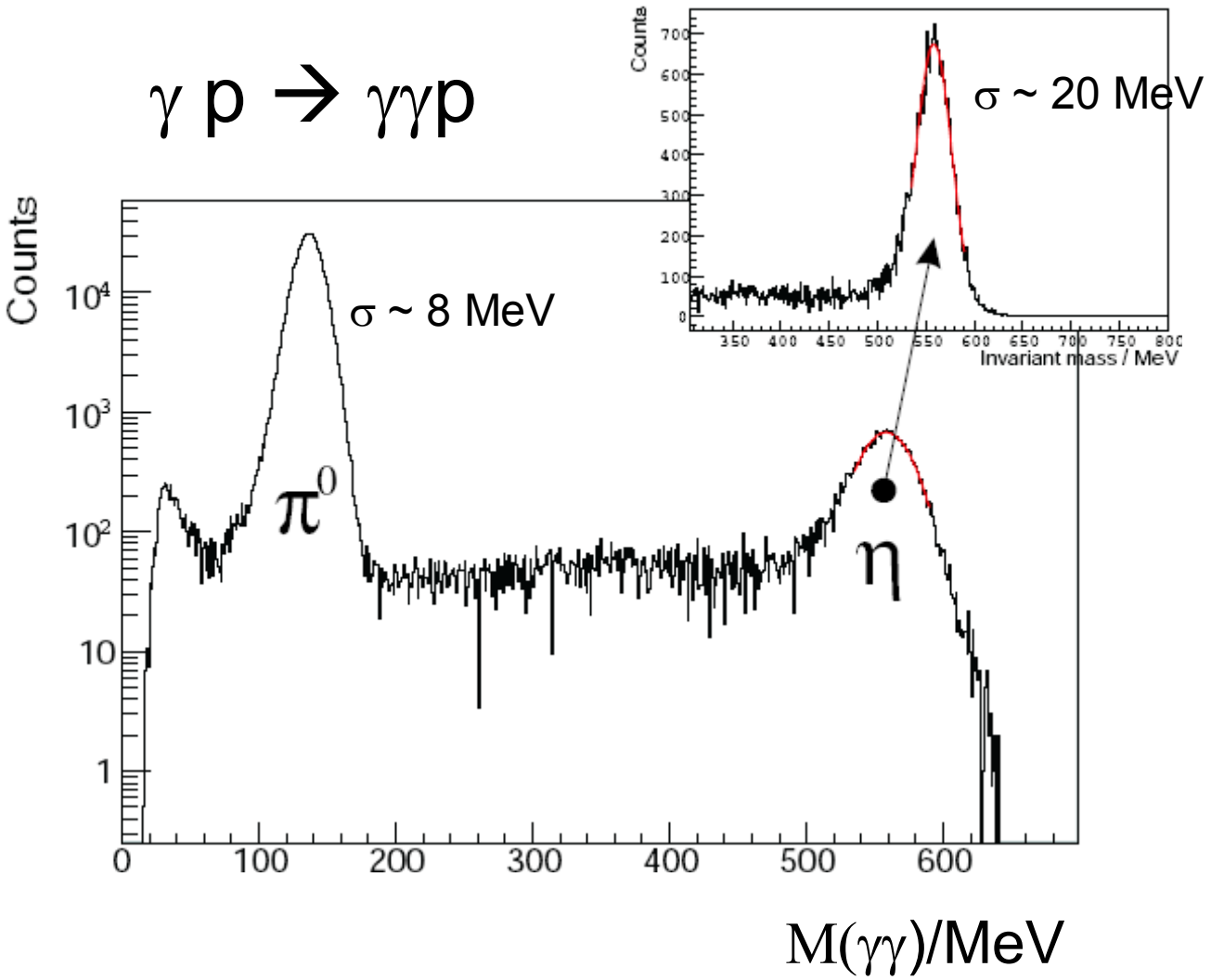
PID + tracking detectors

TAPS:

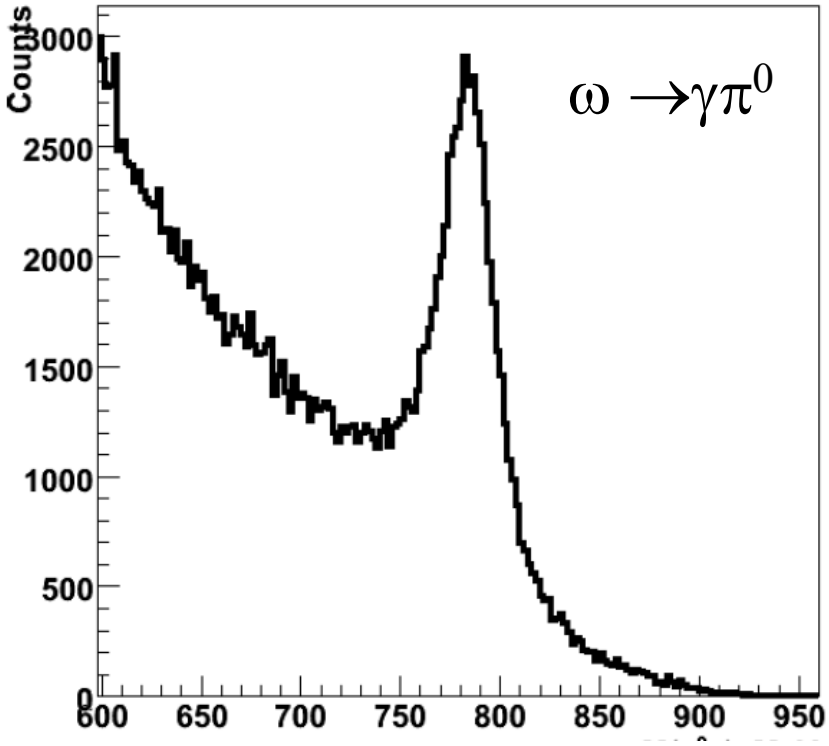
384 BaF_2 scintillators (1-20°),

individual detectors for charged particle ID

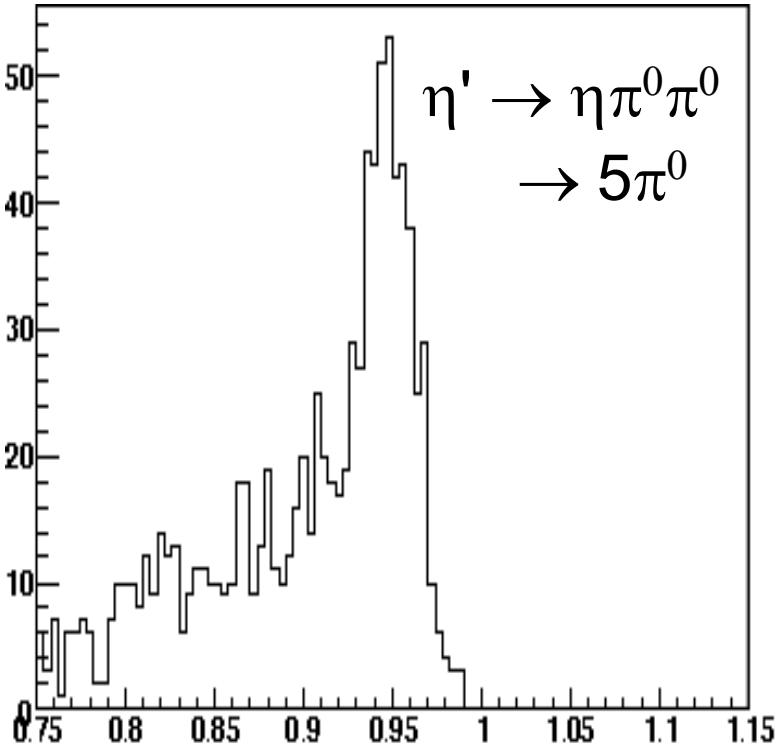
Crystal Ball/TAPS Detector



invariant mass spectra at MAMI C



$M(\gamma\pi^0)$/MeV



$M(10\gamma)$/GeV

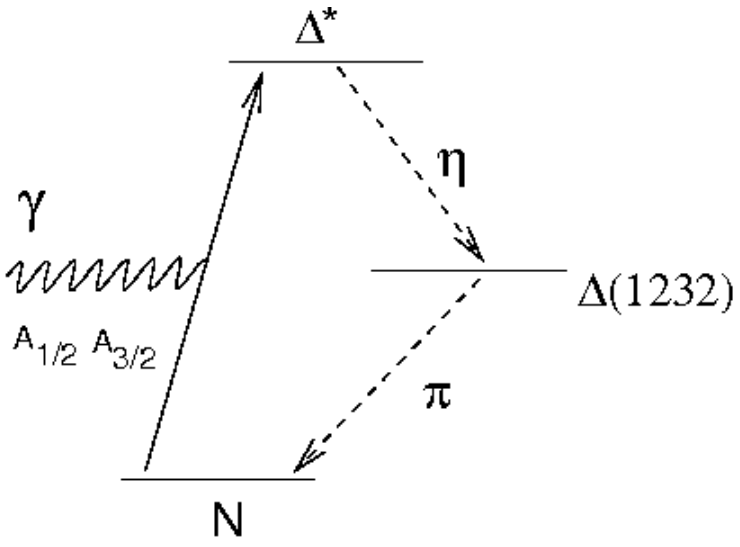
Overview on recent experiments

A2- Collaboration
(real photons, DAPHNE, TAPS, Crystal Ball)

- Helicity structure of γp and γD and GDH sum rule
- π^+ polarizabilities
- Magnetic moment $\mu(\Delta(1232))$ from $\gamma p \to \pi^o \gamma' p$ and $\pi^+ \gamma' n$
- Threshold π^0 production (test of ChPT)
- double pion production
- η production, rare η decays, η mass
- γ p $\to$ $\pi^0\eta$ p

Crystal Ball at MAMI C: $\gamma p \rightarrow p\pi^0\eta$

- reaction mechanism
- nature and properties of resonances



$\Delta^*(1700)$ $(J^P=3/2^-)$

- PDG : $\Delta(1700) \rightarrow N\pi$ 10-20%
  $\rightarrow N\pi\pi$ 80-90%
  $\rightarrow \Delta\pi$ 30-60%

  $A_{3/2}/A_{1/2}$ ~ 0.8-1.5

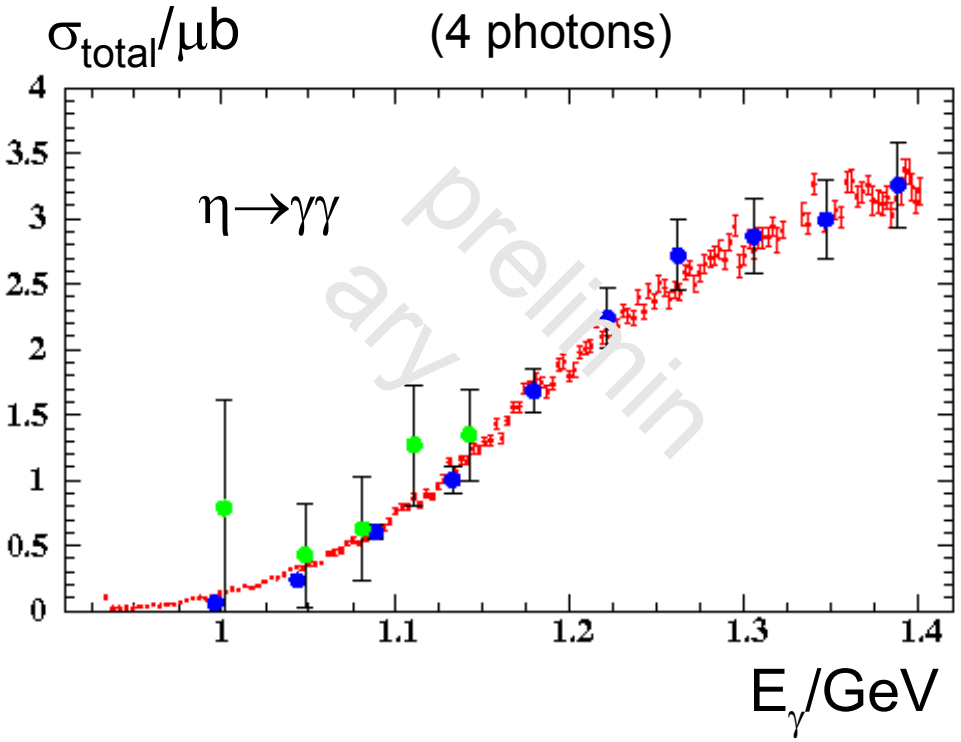
- origin in meson-baryon dynamics ?
  (E. Oset et al., M. Lutz et al., ...)

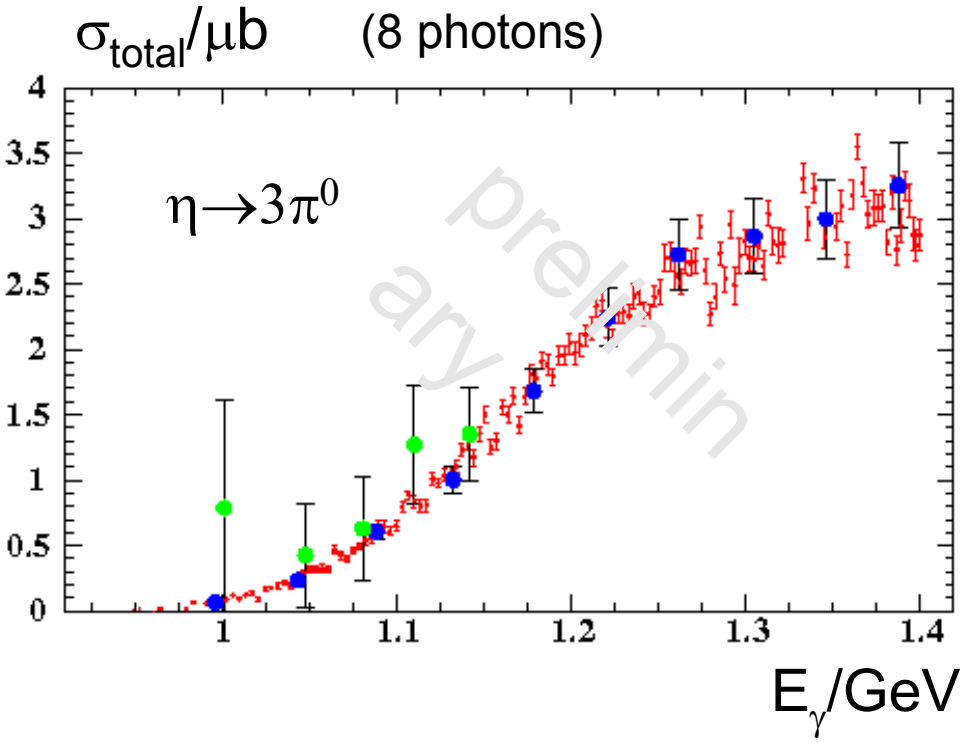
  $\rightarrow$ large branching ratio:
  $\Delta(1700) \rightarrow \eta\, \Delta(1232) \rightarrow \eta\, \pi^o p$

  $\rightarrow \pi^o\, S_{11}(1232) \rightarrow \pi^o\, \eta\, p$

Crystal Ball at MAMI C: $\gamma p \rightarrow p\pi^0\eta$

~ 4 weeks in Juni/July 2007

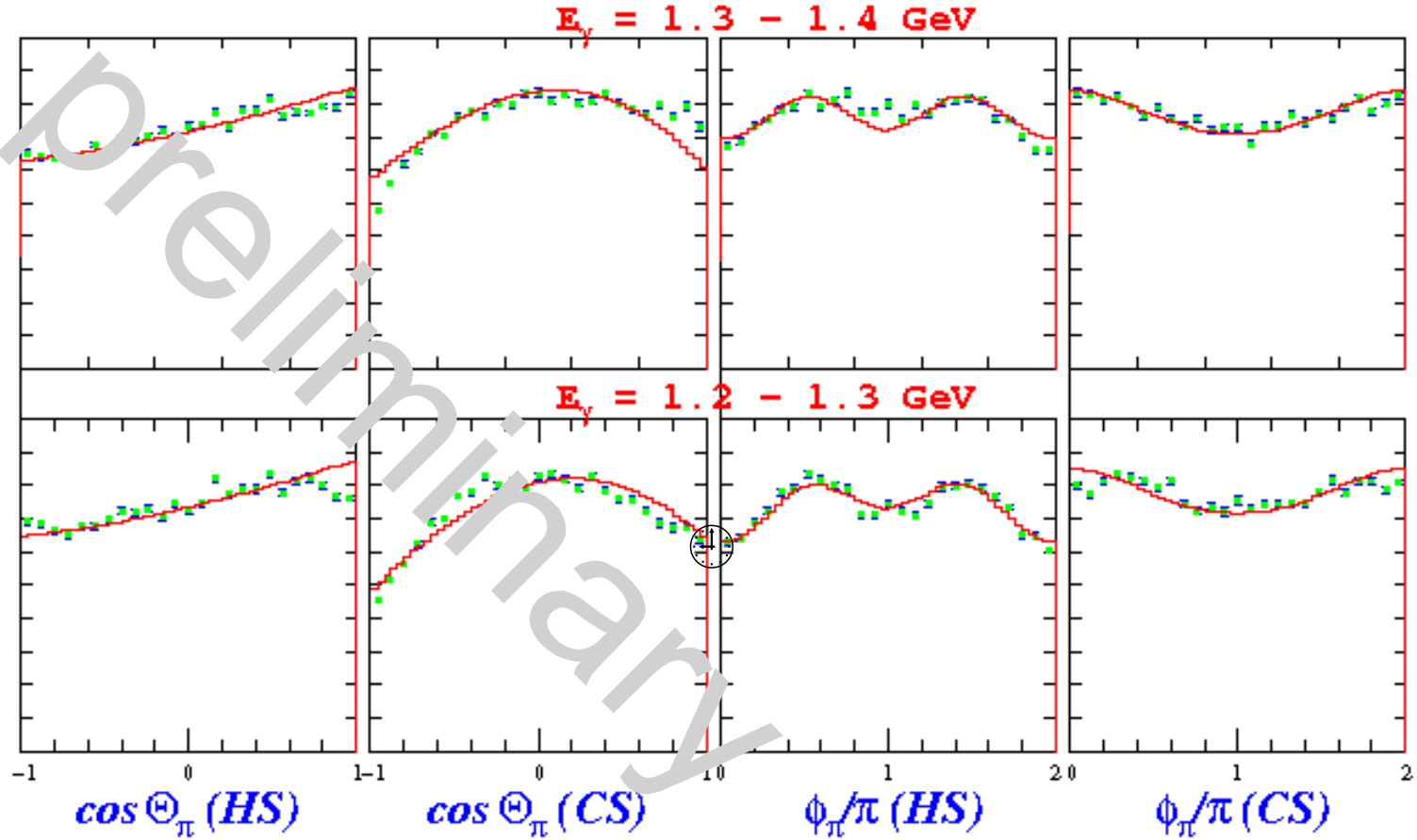


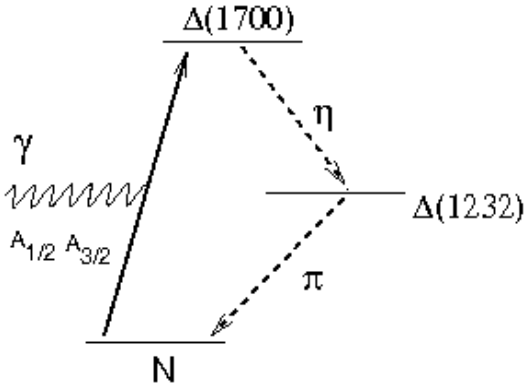


Graal/ESRF: PRL 100 (2008)

LNS/Japan: PRC 74 (2006)

Crystal Ball an MAMI C: $\gamma p \rightarrow p\pi^0\eta$





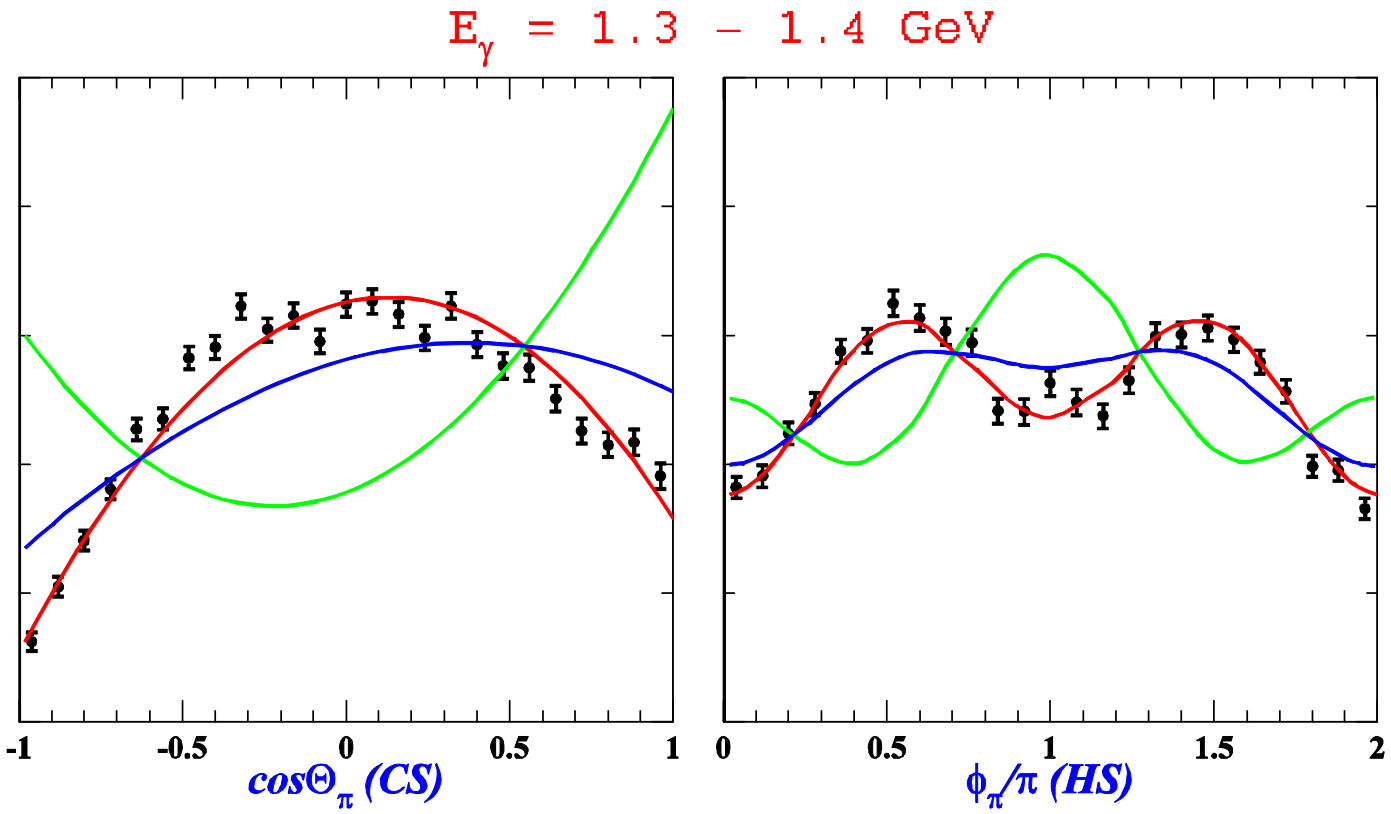
model by A. Fix et al., EPJ A 36 (2008), 61

$\Delta(1700) \rightarrow \eta\Delta(1232)$

and non-resonant amplitudes

Sensitivity to the photon couplings ratio $A_{3/2}$ / $A_{1/2}$

$\gamma p \rightarrow p\pi^0\eta$



$$R = \frac{A_{3/2}}{A_{1/2}}$$

R=0.8

R=1.2

R=1.45 (best fit)

Selected Topics

- Resonances - excitation spectrum

  - $\vec{e}\, p \rightarrow \eta\, \vec{p}$
  - $\gamma\, p \rightarrow \pi^0 \eta\, p$

- Matter distribution in nuclei - coherent and incoherent π^0 production

Matter distribution in nuclei

- elastic electron scattering on nuclei A (e , e') A

$$\frac{d\sigma}{d\Omega} \sim Z^2 F_c^2(q)$$

$F_C(q)$: charge form factor
Fourier-transform of the charge distribution

- coherent π^0 production A (γ , π^0) A

$$\frac{d\sigma}{d\Omega} \sim A^2 F_M^2(q)$$

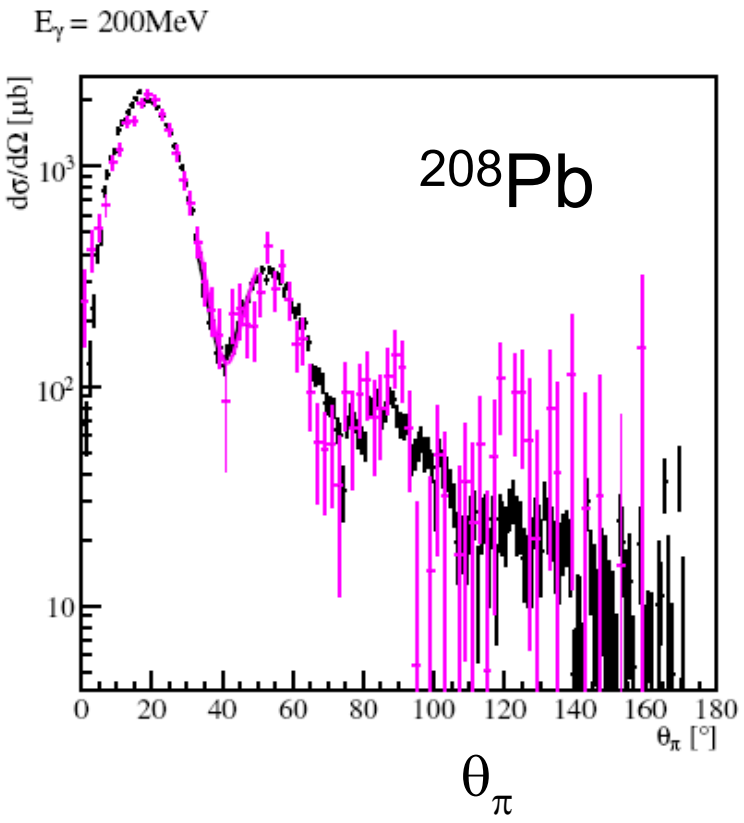
$F_M(q)$: matter form factor

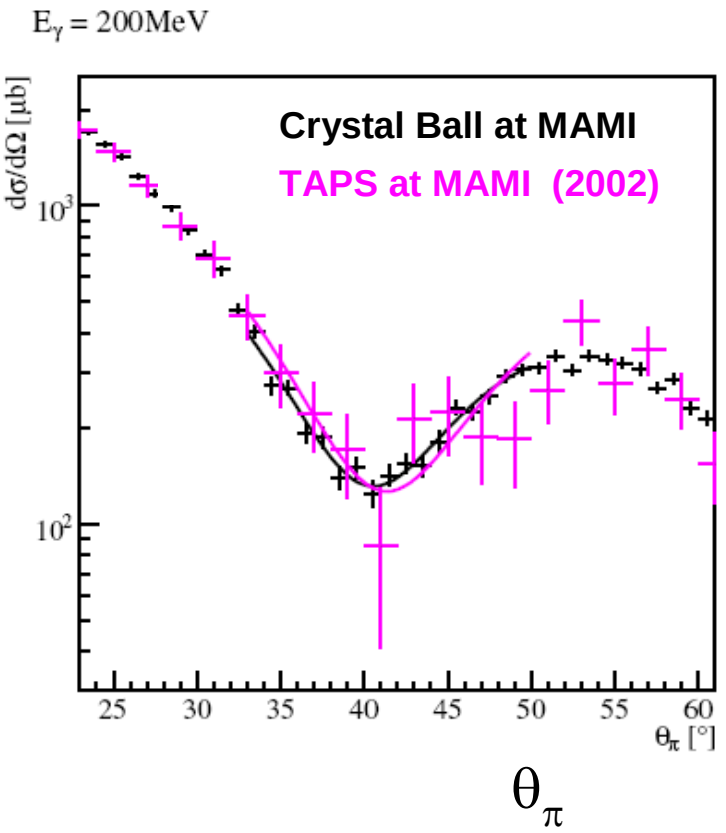
(p (γ, π^0) p $\approx$ n (γ, π^0) n
in the $\Delta(1232)$ resonance region)

$\rightarrow$ Crystal Ball at MAMI

Coherent π^0 production on nuclei

Clear diffraction patterns for ^{208}Pb, ^{40}Ca, ^{16}O, ^{12}C



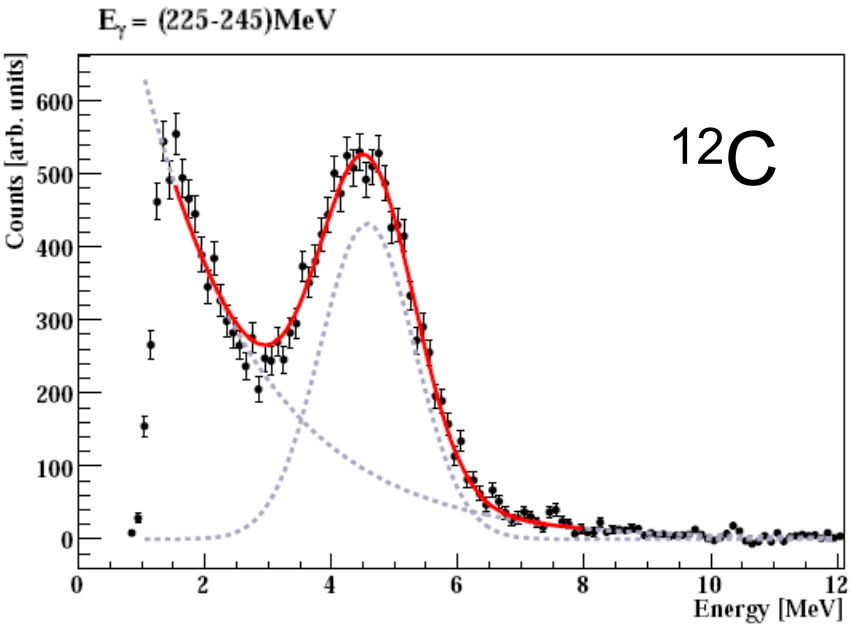


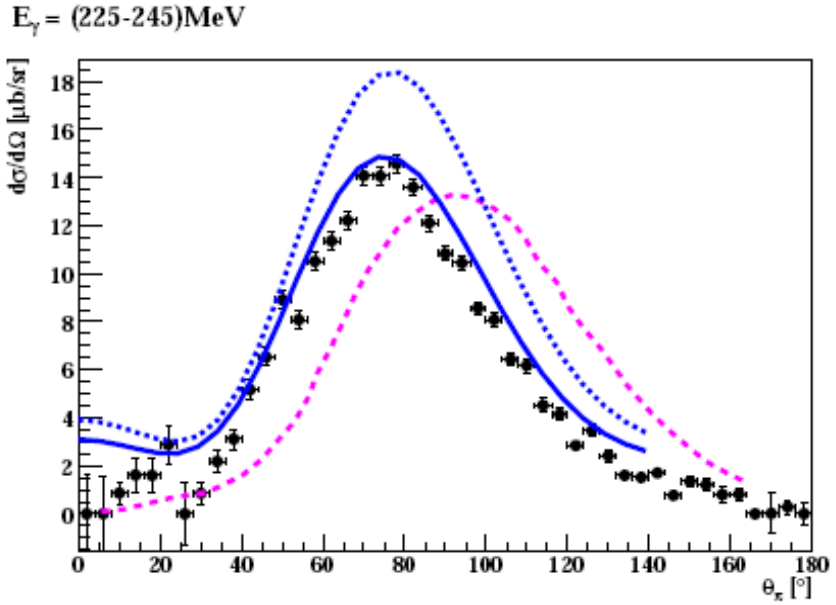
- estimate: $\Delta R \sim 0.15$ fm matter radius > charge radius
- Comparison to calculations (DWIA, e.g. Drechsel et al. 1999)
- → matter distribution

Incoherent π^0 production on nuclei

$$A\,(\gamma\,,\,\pi^0\,)\,A^* \rightarrow A\quad\gamma$$

$$^{12}C\,(\gamma\,,\,\pi^0\,)\,^{12}C^{*(4.4MeV)} \rightarrow {}^{12}C\,\gamma$$





-------- no Δ–N interaction

transition form factor to the 2^+ state at 4.4 MeV

Δ-hole models

Takaki et al., NPA 443, 570 (85)

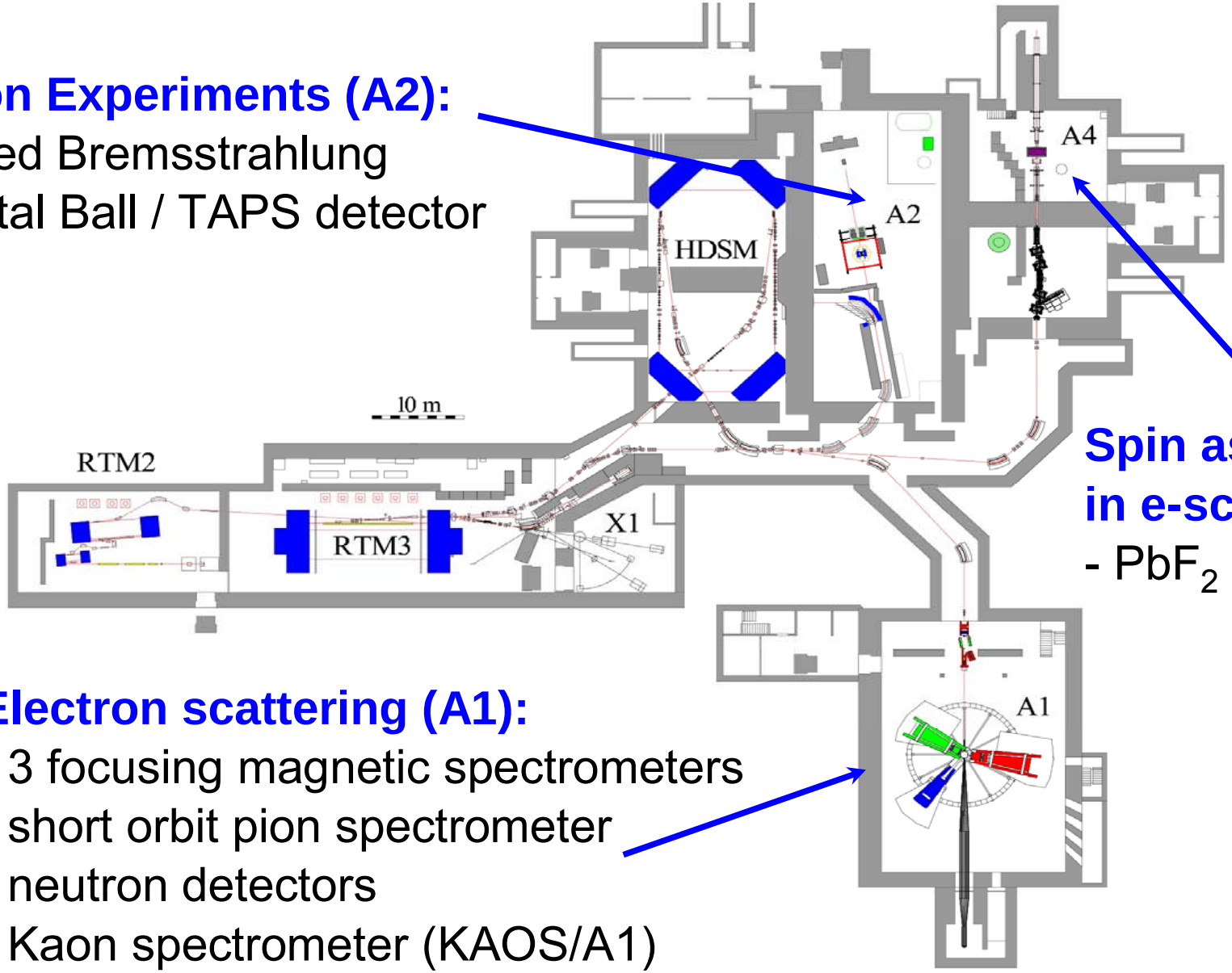
Tryasuchev et al., Yad. Phys. 70, 861 (07)

data:

C. Tarbert et al., PRL 100, 132301 (2008)

Experiments at MAMI

Photon Experiments (A2):
- tagged Bremsstrahlung
- Crystal Ball / TAPS detector

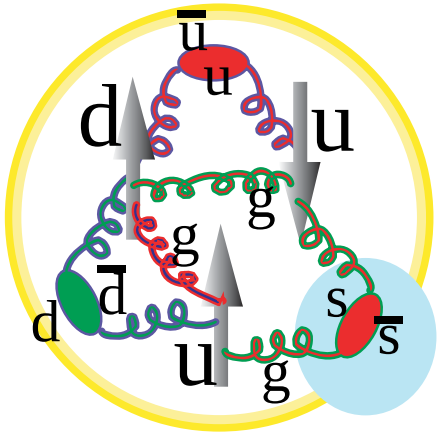


Spin asymmetries in e-scattering (A4):
- PbF_2 Calorimeter

Electron scattering (A1):
- 3 focusing magnetic spectrometers
- short orbit pion spectrometer
- neutron detectors
- Kaon spectrometer (KAOS/A1)

A4: Strangeness in the nucleon

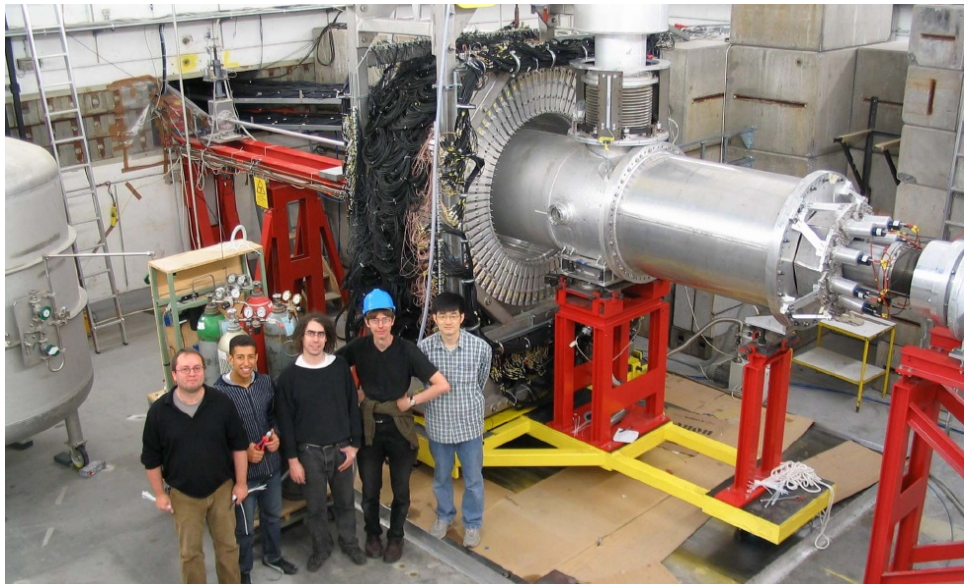
elastic $\vec{e}$-N scattering with **longitudinally** polarized e- ,
=> Parity violation

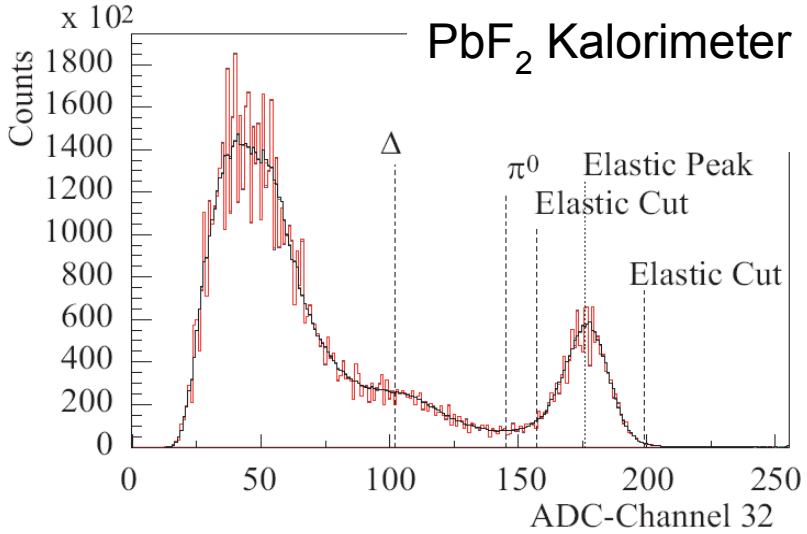


$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim \frac{\left|M_{PV}^{NC}\right|}{\left|M^{EM}\right|} \sim \frac{Q^2}{(M_Z)^2} \approx 10^{-6}$$

challenge für experiment and accelerator !

Spin-Asymmetries in electron scattering





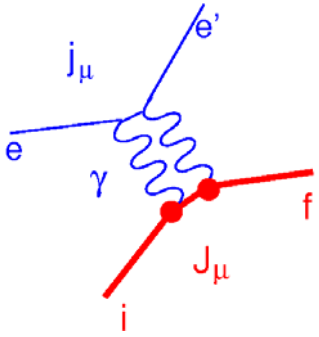
PbF$_2$ Kalorimeter

Single spin asymmetries in elastic $\vec{e}$ N-scattering $\approx 10^{-6}$

event rates ~ 100 MHz

- longitudinally pol. electrons:
  parity violating helicity asymmetry, contribution of s-quarks

- transversely pol. electrons:
  two-photon exchange, absorptive part of the two-photon amplitude



Future plans - Overview

A1- Collaboration (3-spectrometer setup, KAOS)

- Elm. formfactors (G_{en}, G_{ep} and G_{mp} – high precision)
- Generalized polarizabilities (VCS) - cont.
- Elementary kaon electro production, hyper nuclei

A2- Collaboration (Crystal Ball &TAPS, frozen-spin target, recoil pol.)

- Helicity structure at higher energies
- Complete experiment in meson photoproduction (beam-target-recoil polarization)
- Magnetic moment μ of $S_{11}(1535)$ from $\gamma p \rightarrow \eta \gamma' p$
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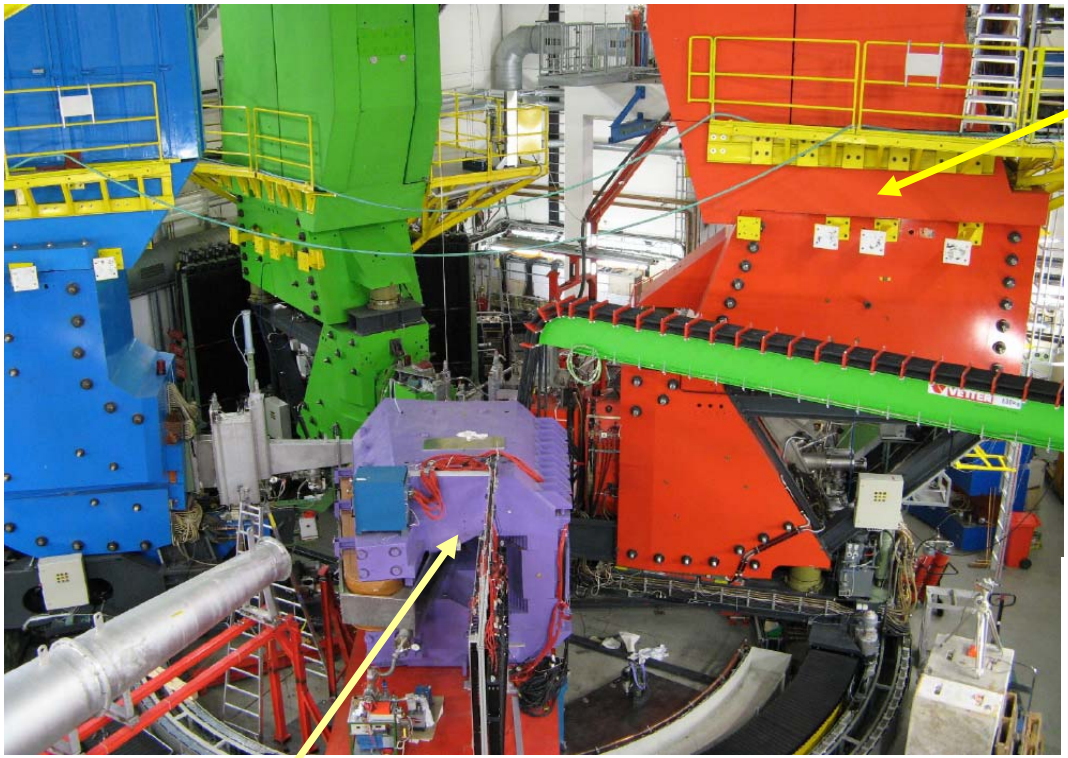
- Kaon threshold photoproduction
- In medium modification in $\gamma A \rightarrow \omega X$

A4- Collaboration ($\vec{e}$-scattering, PbF_2 calorimeter)

- Parity violating ep- scattering and transverse polarization at backward angles from proton and deuterium

Kaon spectrometer (KAOS)

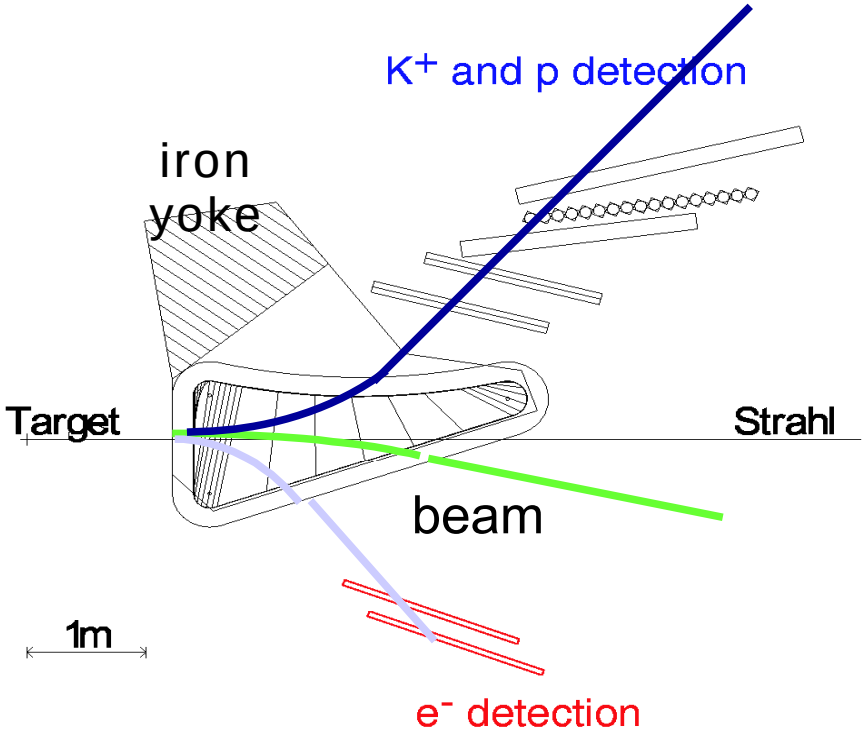


KAOS/A1 spectrometer (GSI)

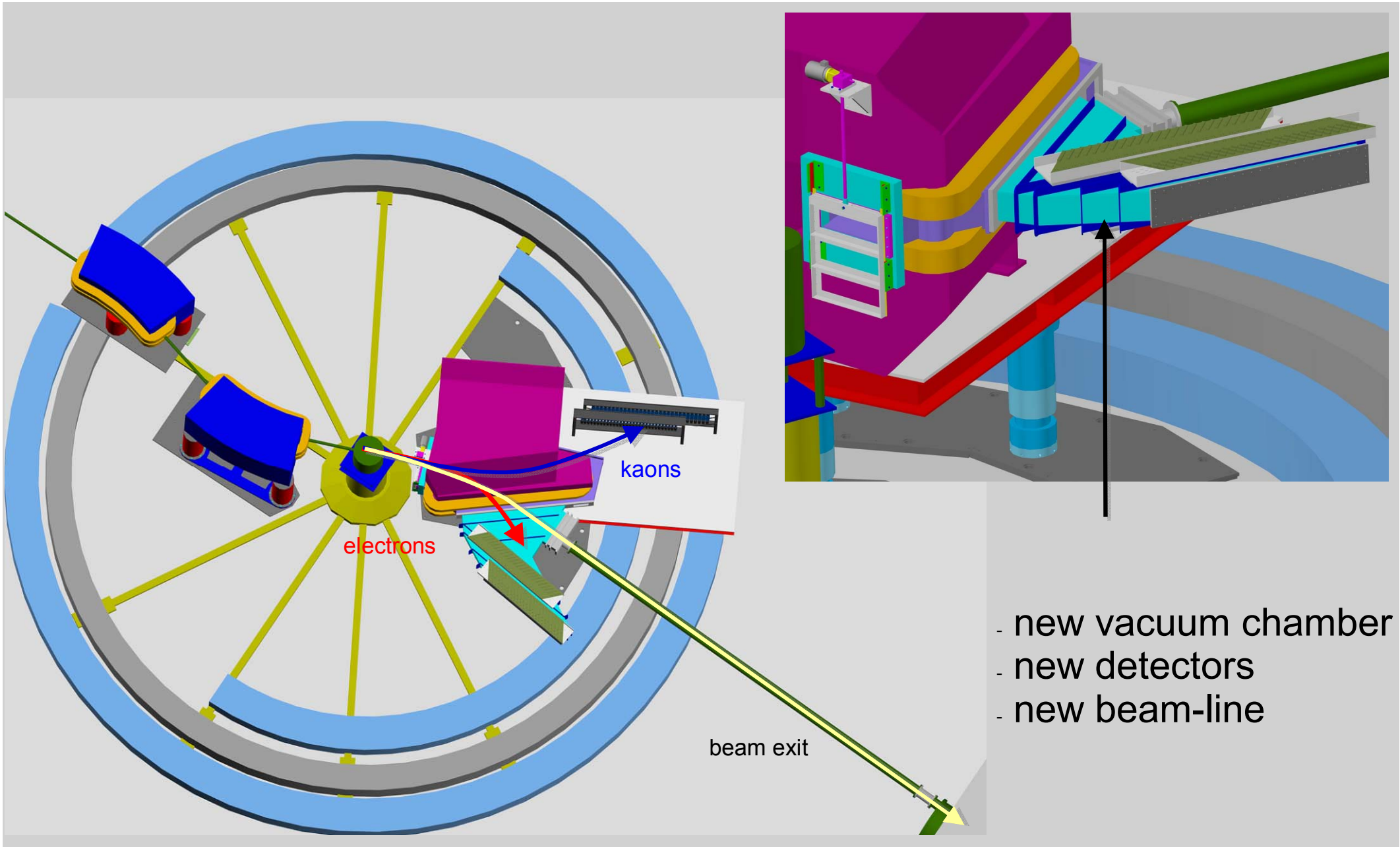
- dedicated kaon detection
- 2 focal planes
- acceptance at forward angles
- p(e,e' K^+)Λ/Σ in 2008

3-spectrometer setup

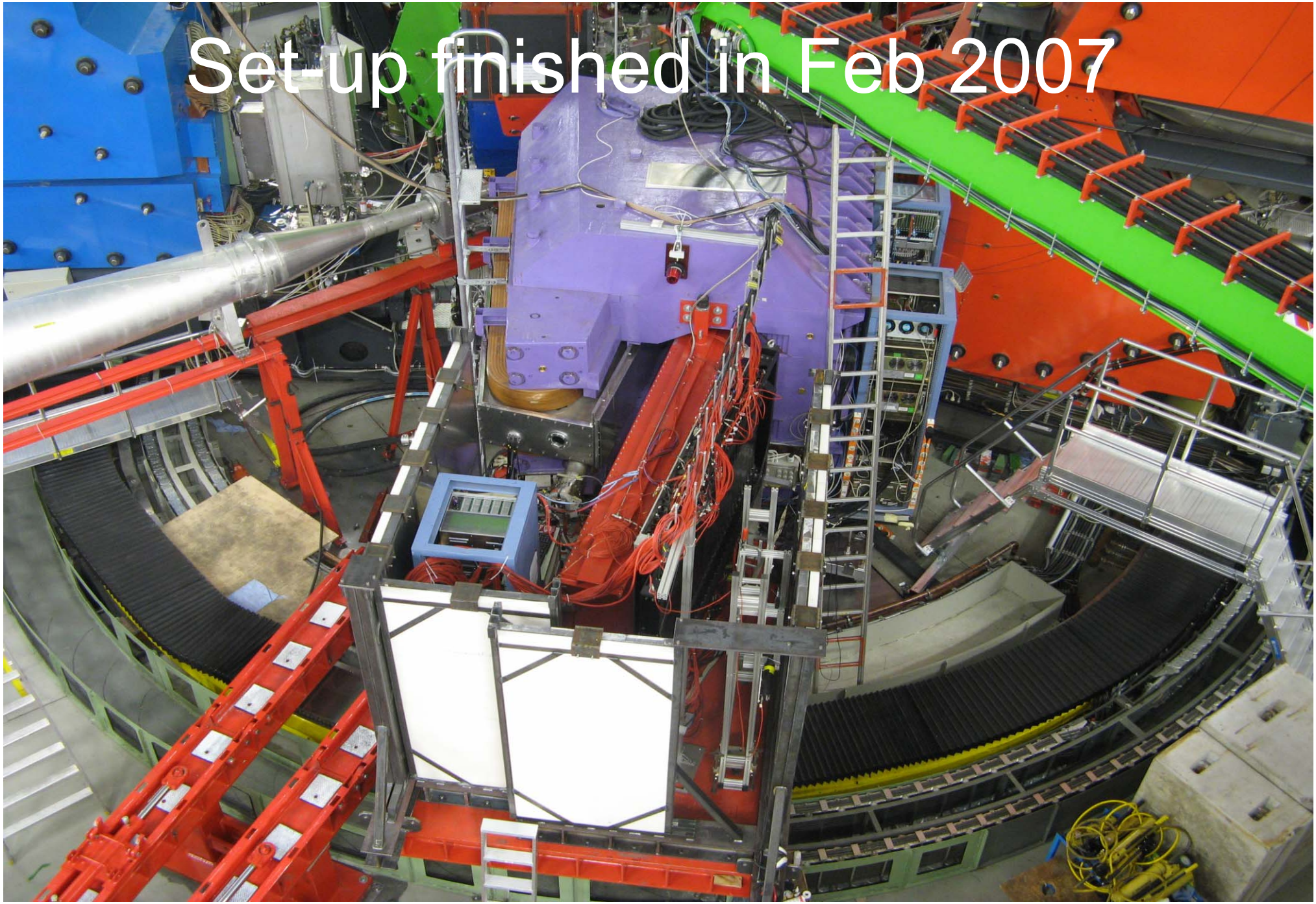
- resolution $\delta p/p < 10^{-4}$
- acceptance $\Delta p/p = 20\%$
- $\Delta\Omega = 28$msr
- proton polarimeter



Two-arm spectrometer operation scheduled for 2009



- new vacuum chamber
- new detectors
- new beam-line


Set-up finished in Feb 2007

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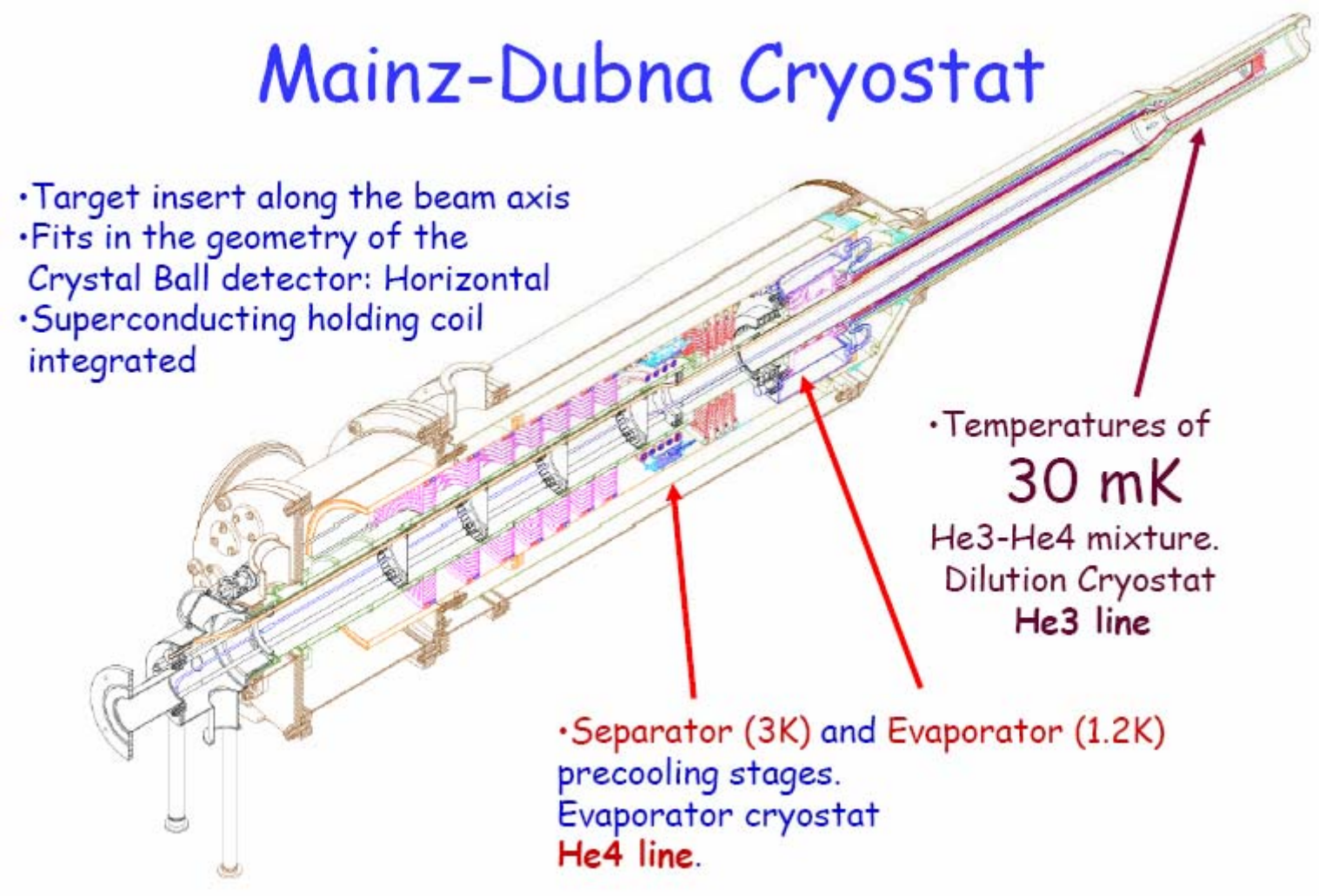
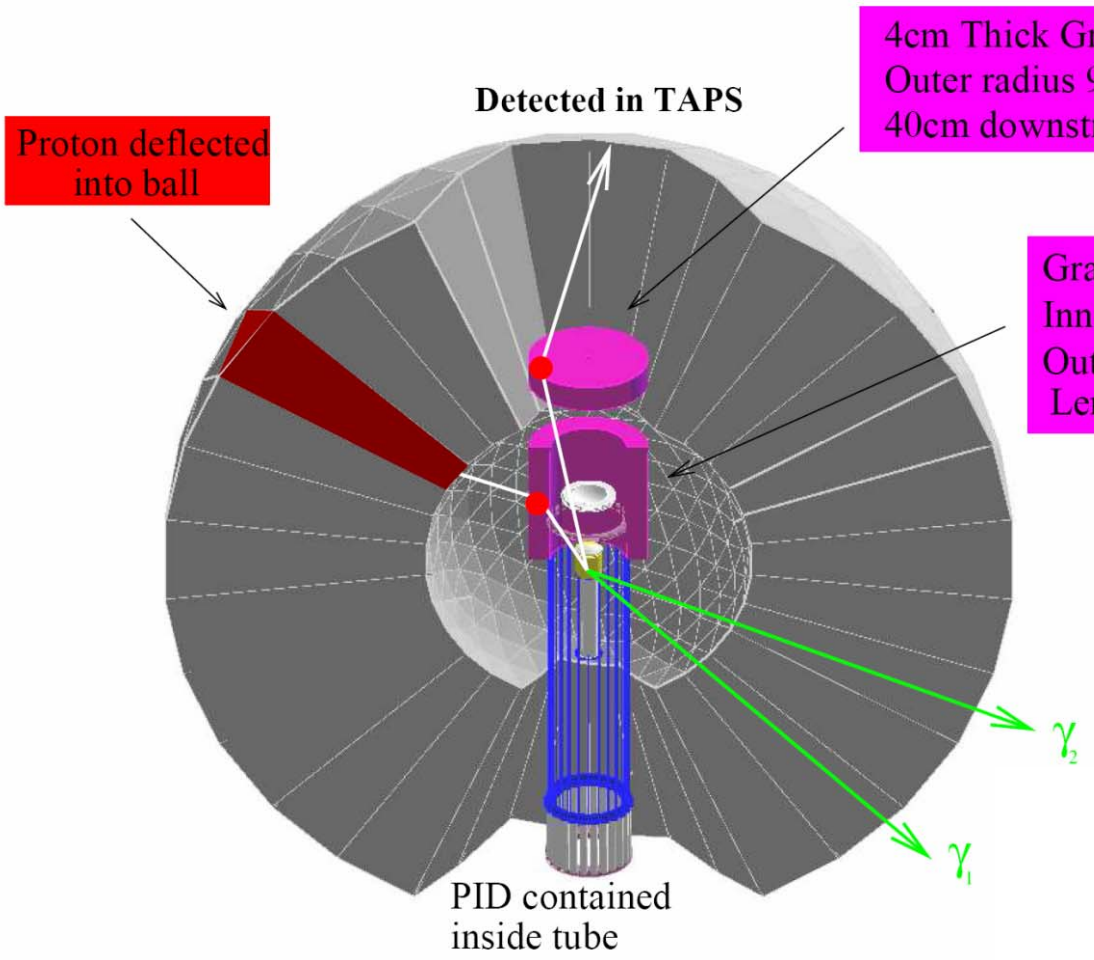
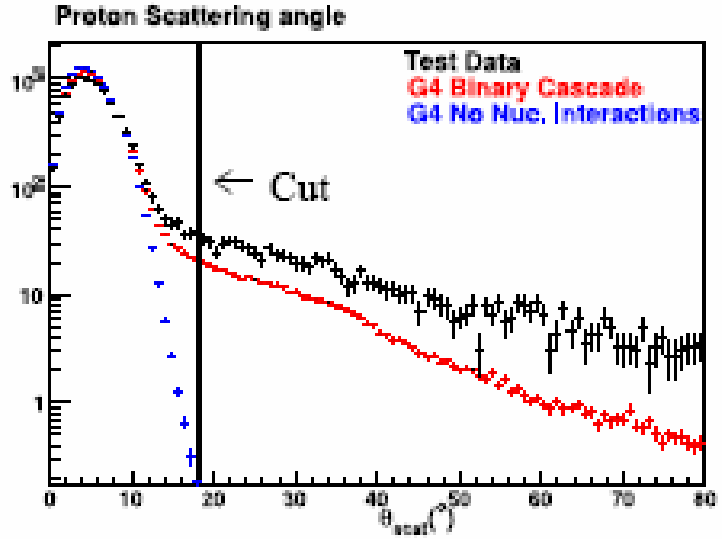
New Frozen-spin target

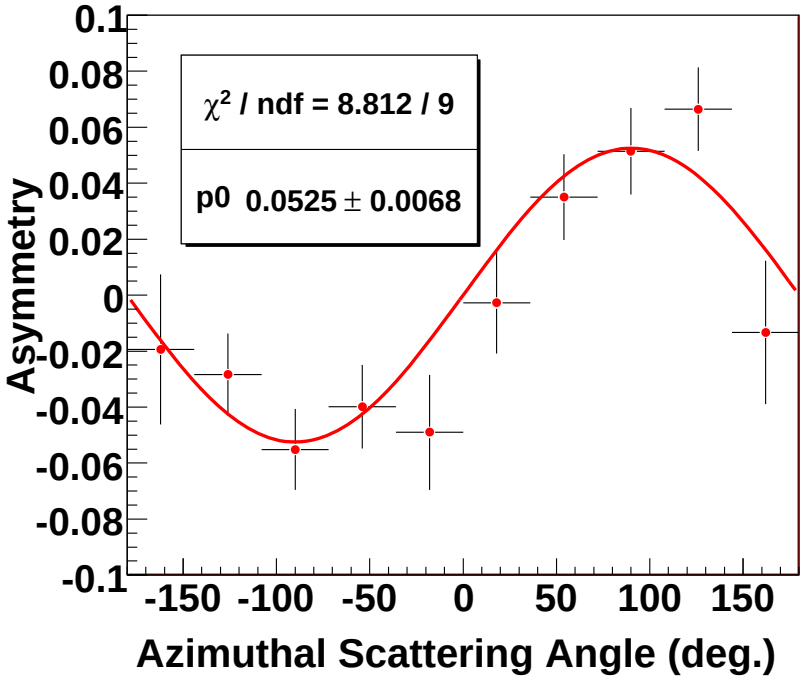


The polarimeter setup





Almost full angular acceptance !



$$\frac{N^+\left(\phi'_p\right) - N^-\left(\phi'_p\right)}{N^+\left(\phi'_p\right) + N^-\left(\phi'_p\right)} = C_{x'} P_\gamma^{circ} A \sin\phi'_p$$

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Conclusions

- MAMI C:
- 1.5 GeV high-intensity polarised electron and photon beams with excellent quality und stability
- different complementary detector systems, polarised targets, recoil polarimeters
- sensitive tools to investigate the structure of hadrons

- key questions in the near future:
- nature of nucleon resonances (complete experiment using
- polarisation observables!!)
- form factors (high precision, flavor decomposition, 2γ–exchange)
- polarisabilities of nucleon and pion
- threshold production (predictive power of chiral dynamics)
- meson decays (η, η')
- (coherent) meson production on nuclei
- hyper nuclei