Compton Scattering with Tagged Photons at MAX-lab

- Polarizabilities of the neutron
- d(γ,γ)d studies at MAX-lab
- Long-term future at MAX-IV

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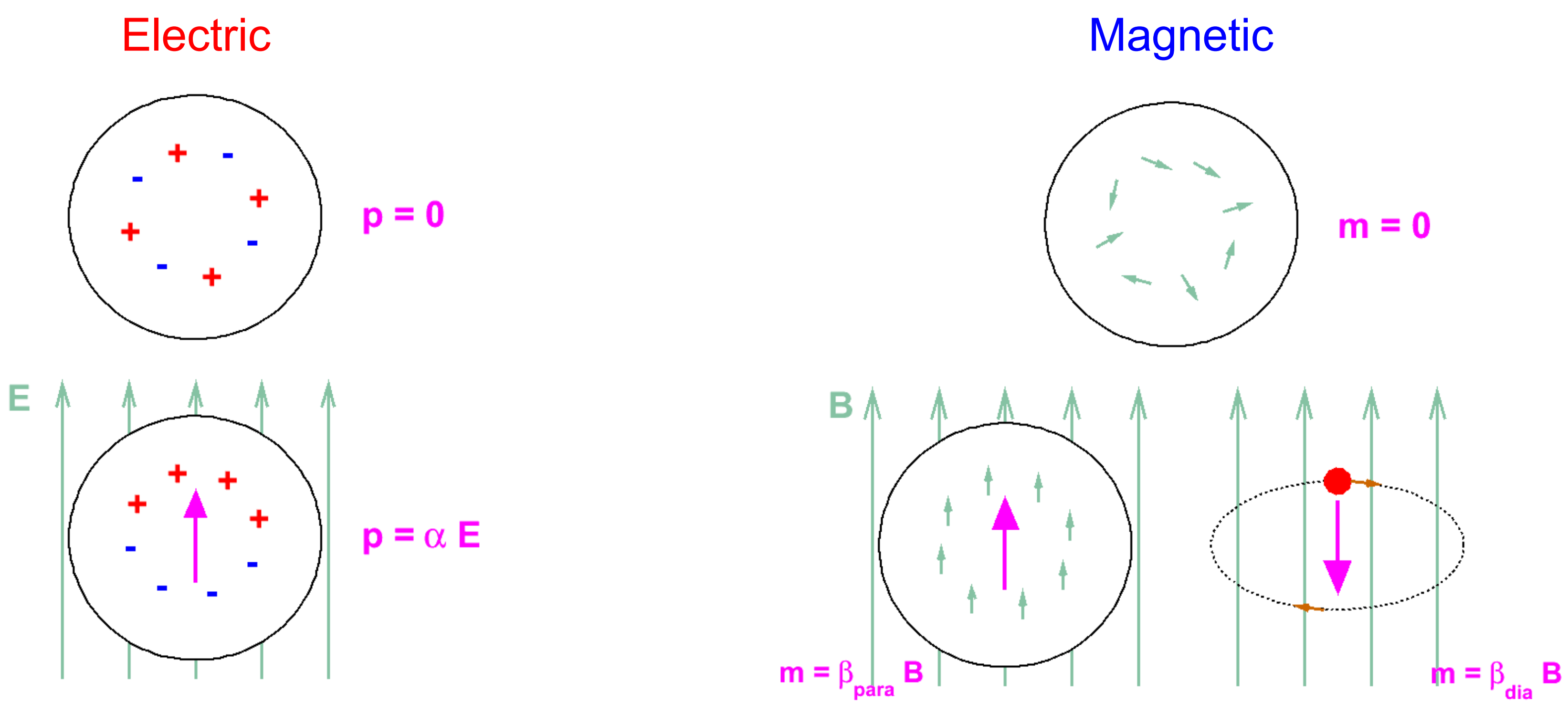
COMPTON@MAX-lab Collaboration

Chiral Dynamics Workshop
August 7, 2012

Compton Scattering and Nucleon Polarizabilities

- Polarizability: relates induced dipole moment to external field



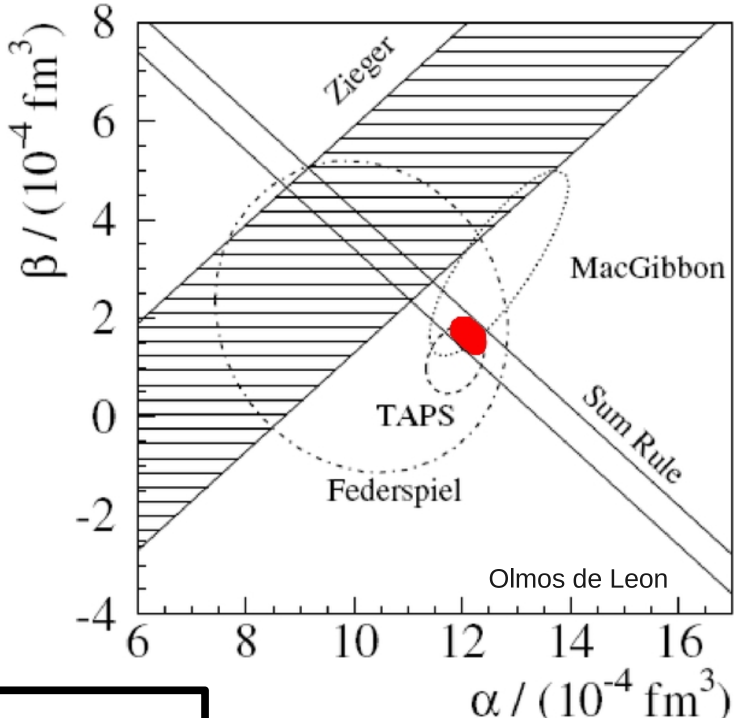
- α, β are
  - fundamental structure constants
  - leading order response of *internal* structure of nucleon
  - well-known for proton, but neutron needs more data

Compton Scattering and Nucleon Polarizabilities

- Most common method of studying α, β
- Experimentally, usually measured below π threshold (LEX)

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Powell} - \frac{e^2}{4\pi M_N}\left(\frac{\omega'}{\omega}\right)^2 \omega\omega'\left\{\frac{\alpha+\beta}{2}(1+\cos\theta)^2 + \frac{\alpha-\beta}{2}(1-\cos\theta)^2\right\} + O(\omega^4)$$

Proton



α_p = 10.7 ± 0.3
β_p = 3.1 ± 0.3

Griesshammer, et al., http://arxiv.org/pdf/1203.6834

Neutron

- No free target!

What about bound neutrons?

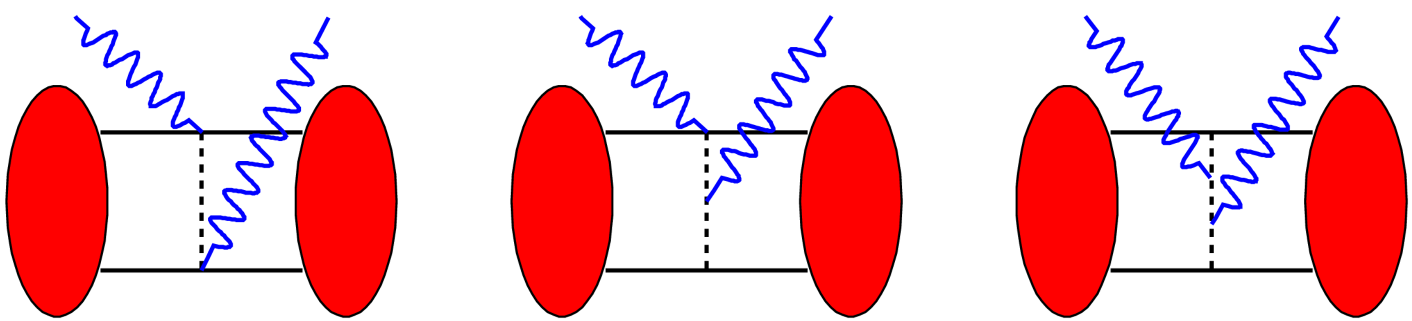
- Uncharged ⇨ $\frac{d\sigma}{d\Omega} \approx O(\omega^4)$

Solution: Compton Scattering on the Deuteron

Compton Scattering and Nucleon Polarizabilities

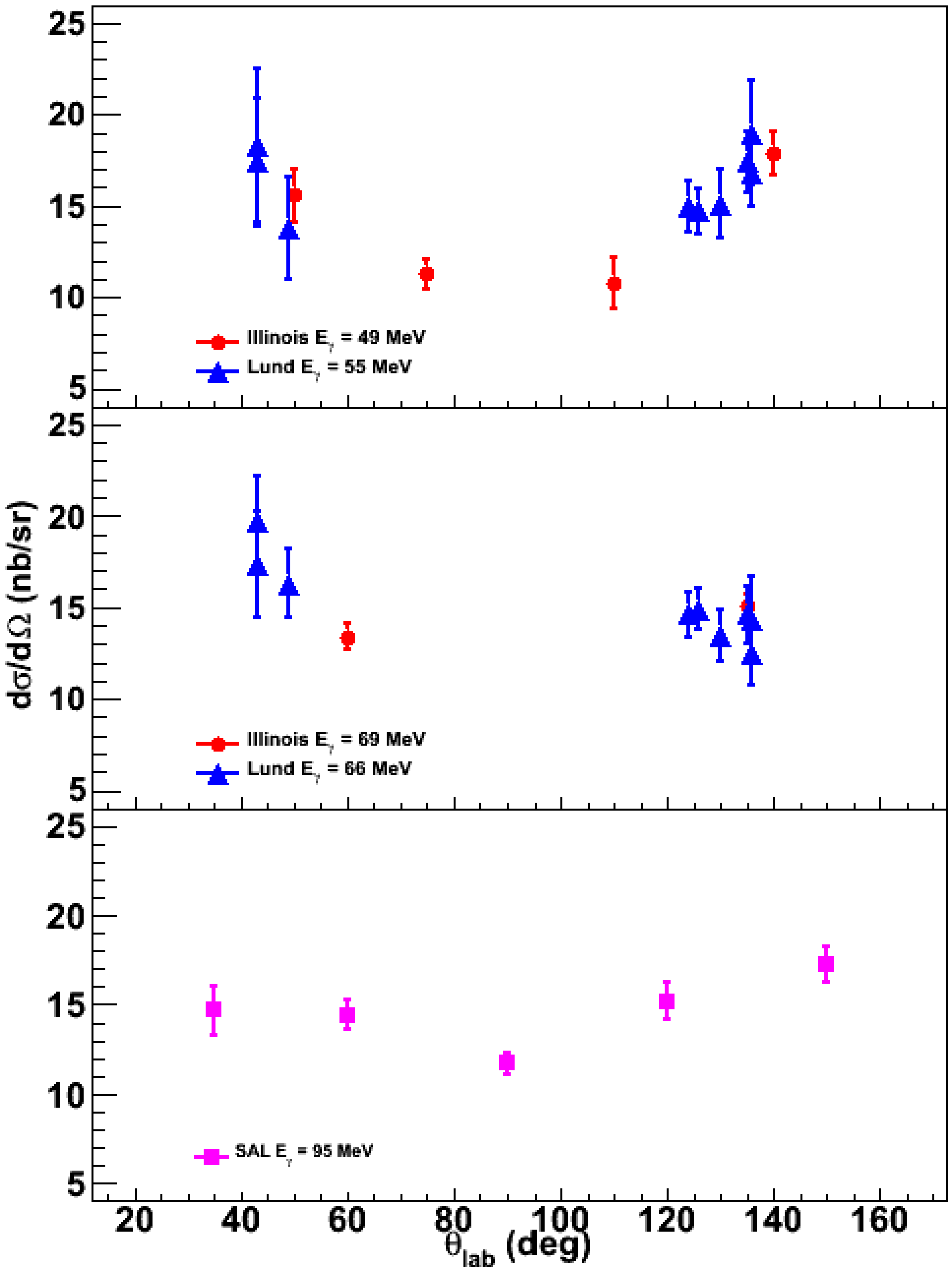
Compton Scattering on the Deuteron

Advantage	Disadvantage
Deuteron has net charge	Must know proton polarizabilities
Sensitive to isoscaler polarizabilities at $O(\omega^2)$	Must understand meson-exchange current scattering
	Must separate elastic scattering from break-up



Subset of possible scattering diagrams involving meson exchange currents

Compton Scattering and Nucleon Polarizabilities



d(γ,γ)d data sets

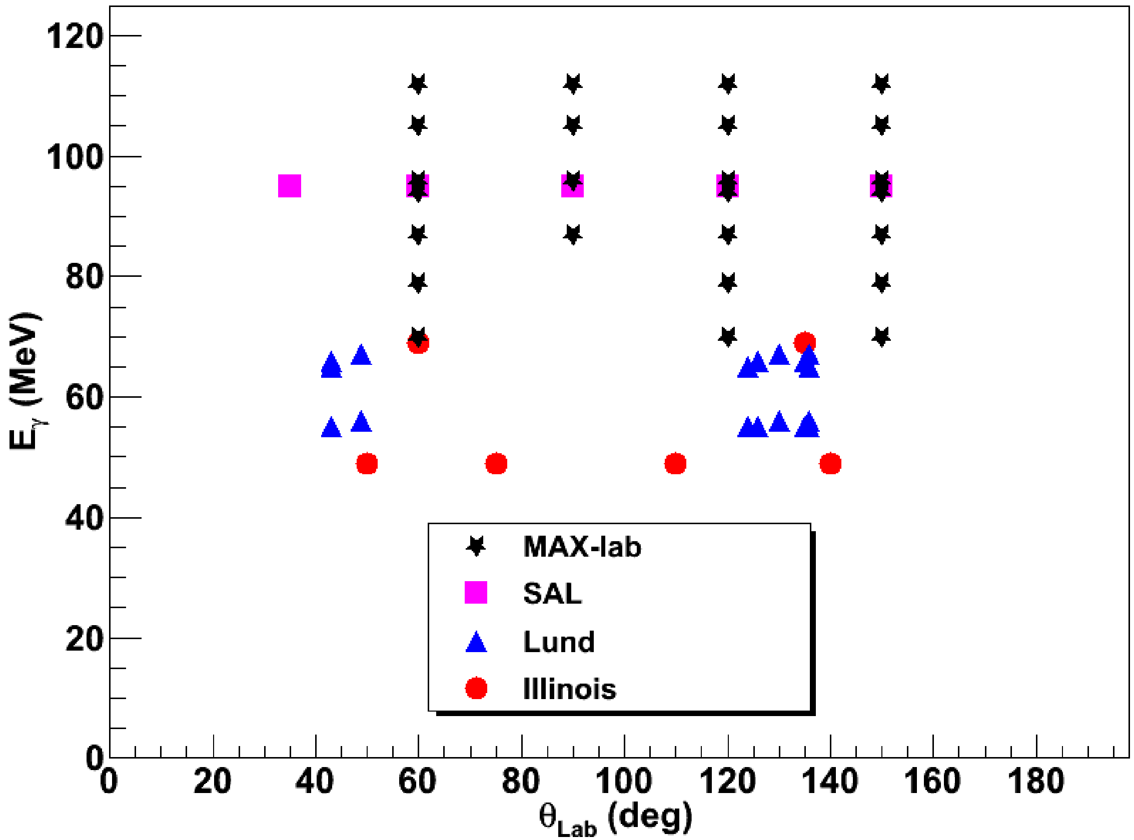
	E [MeV]	ΔE [MeV]	Statistical	Systematic
Illinois	49, 69	6.5, 7.7	4.2–12.6%	3.6–4.0%
Lund	55, 66	10, 10	7.5–24.4%	6.5–14.3%
SAL	95	20	5.2–9.8%	4.8–6.4%

$$\alpha_n = 11.1 \pm 1.8$$
$$\beta_n = 4.1 \pm 1.8$$

Griesshammer, et al., http://arxiv.org/pdf/1203.6834

- Improvements Needed
  - Better statistics at lower energies
  - Narrower energy bins at high energies
  - Greater coverage of kinematic space
  - Push to even higher photon energies

Compton Scattering and Nucleon Polarizabilities



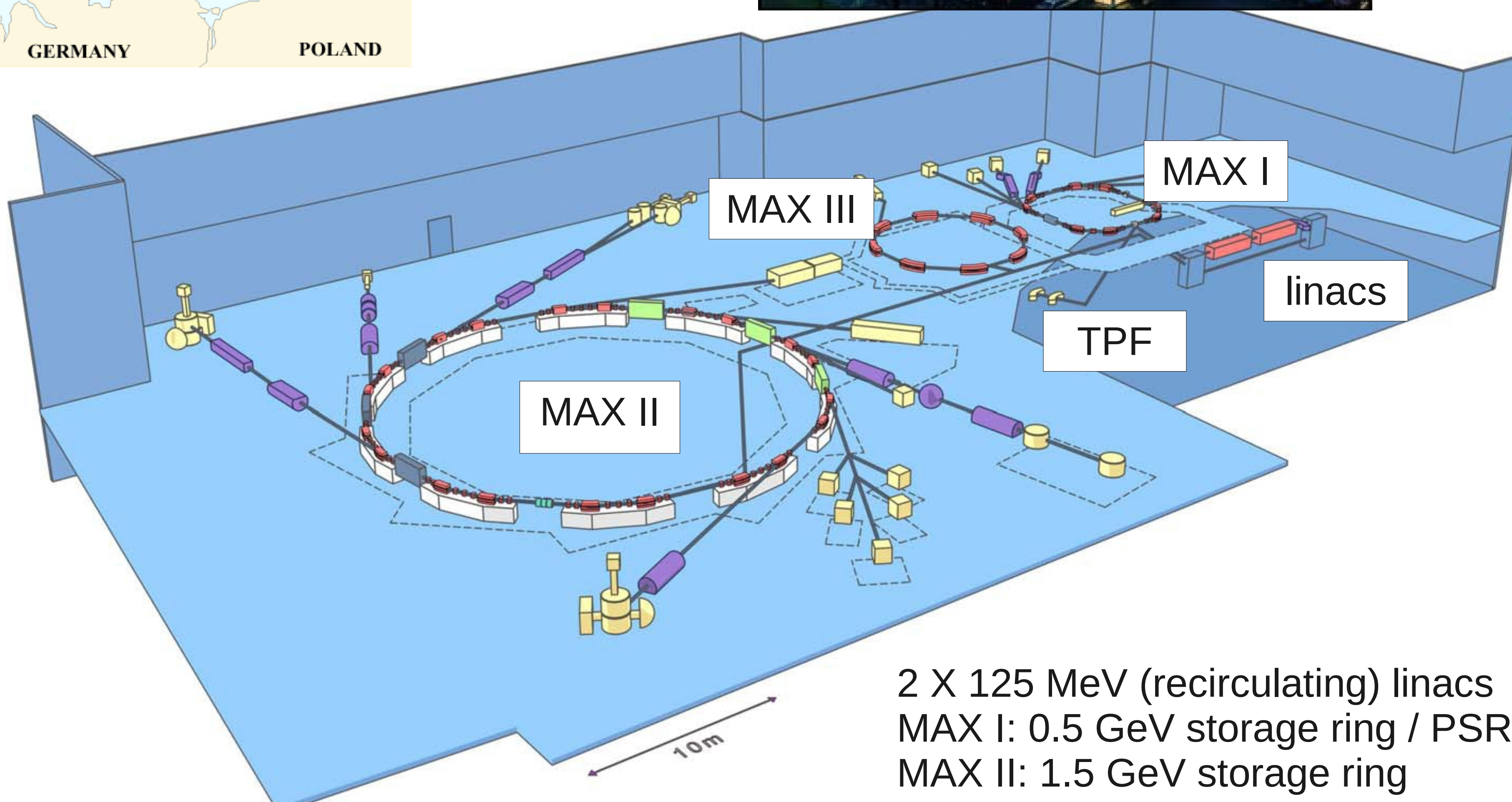
MAX-lab program goals

- Double the number of d(γ,γ)d data points
- Keep statistical and systematics < 5 – 10%
- Push to higher energies

Implications of these data

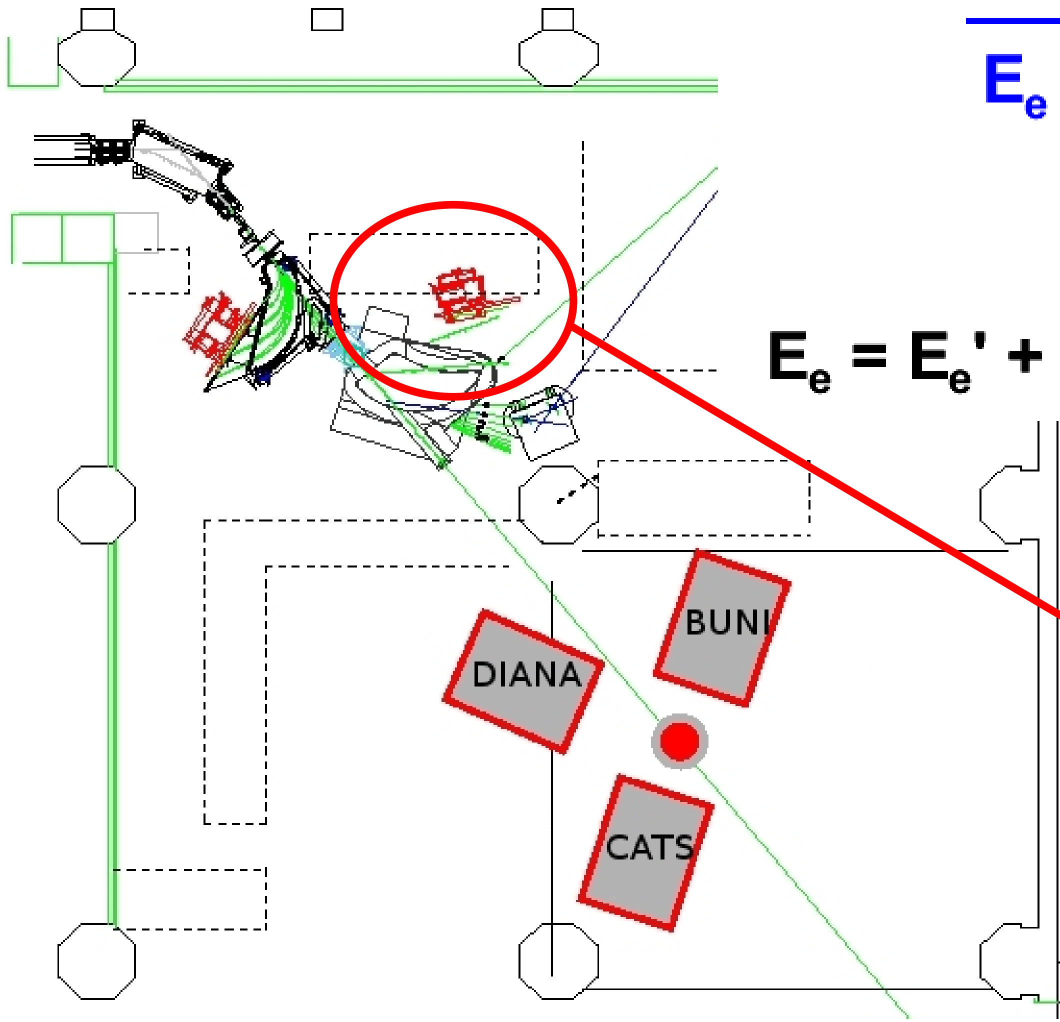
- Test theory of two-photon response of the nucleon
- Understanding meson-exchange currents
- Reduce uncertainty in the evaluation of $M_n – M_p$

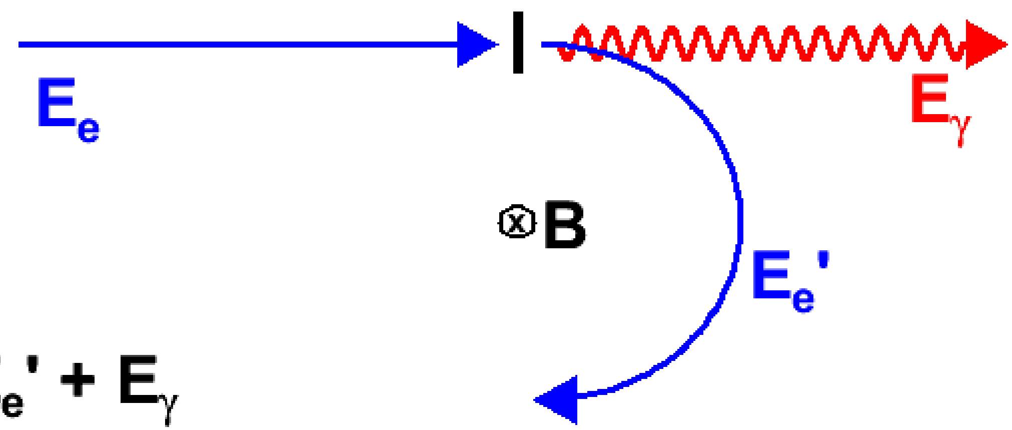
The MAX-lab Facility



2 X 125 MeV (recirculating) linacs
MAX I: 0.5 GeV storage ring / PSR
MAX II: 1.5 GeV storage ring
MAX III: 0.7 GeV storage ring

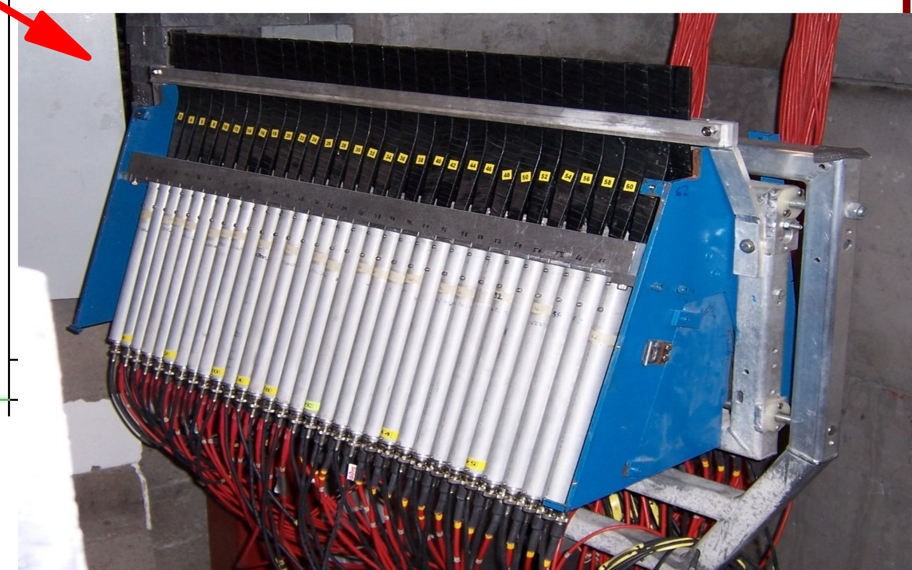
The MAX-lab Facility



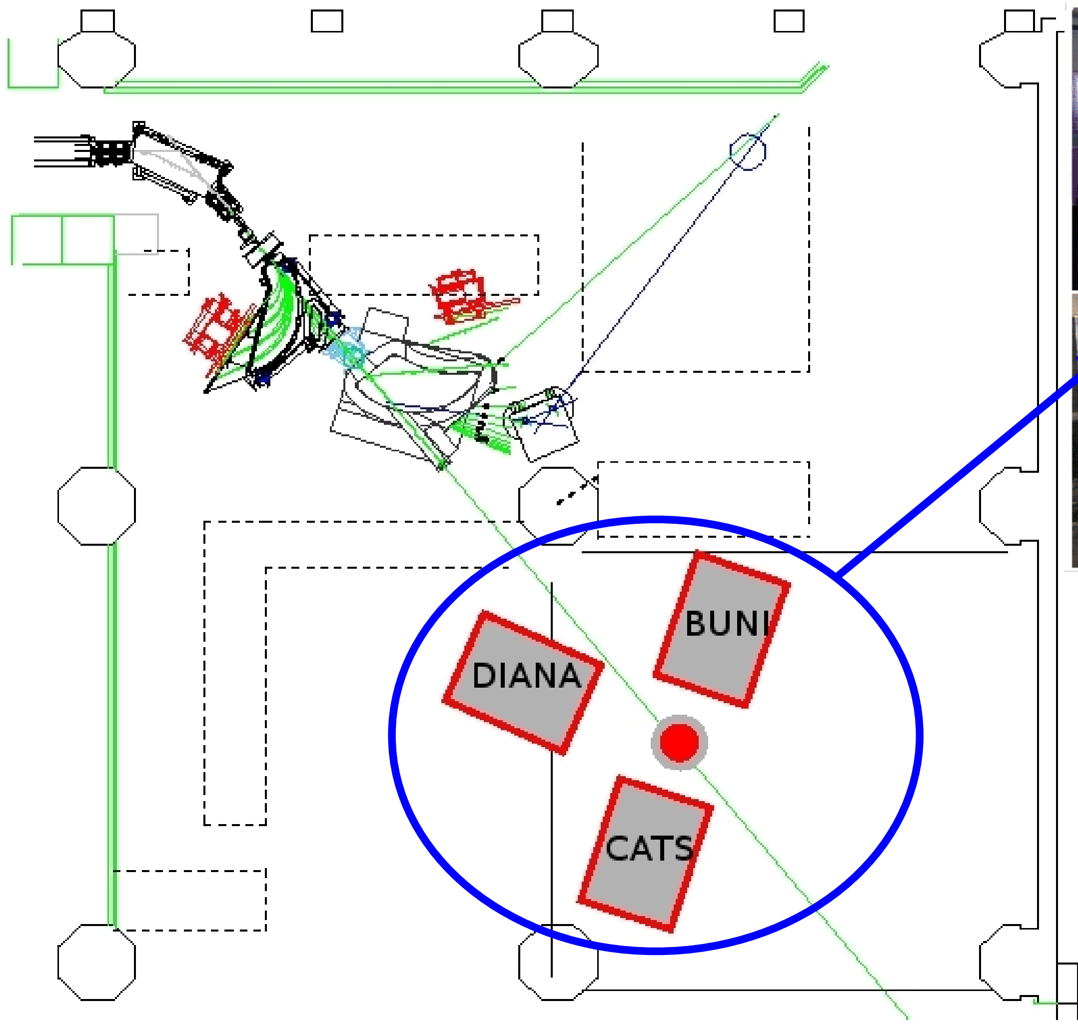


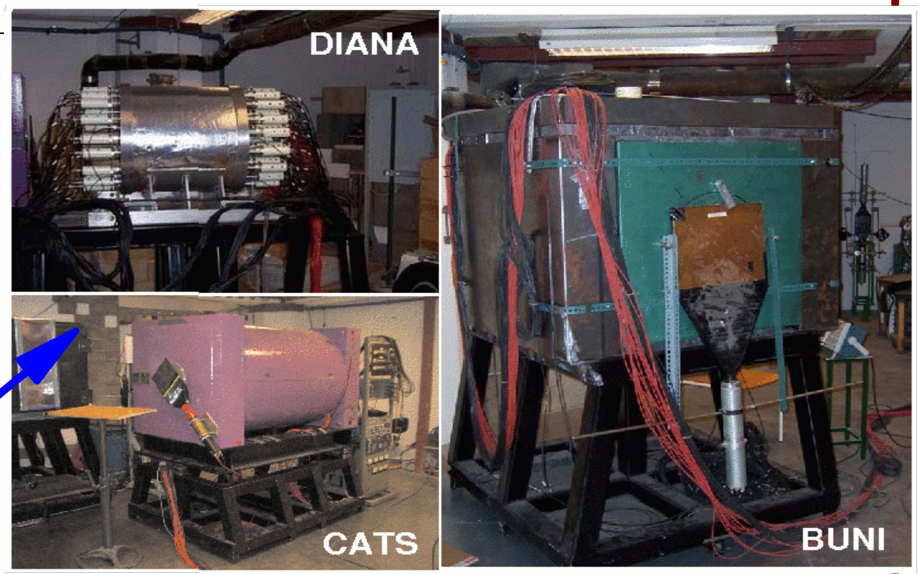
$$E_e = E_e' + E_\gamma$$

$\Delta E_\gamma \sim 0.5$ MeV



The MAX-lab Facility





- 3 20” x 20” segmented NaI detectors
- ΔE/E ~ 2% @ 100 MeV
- Separate elastics from break-up

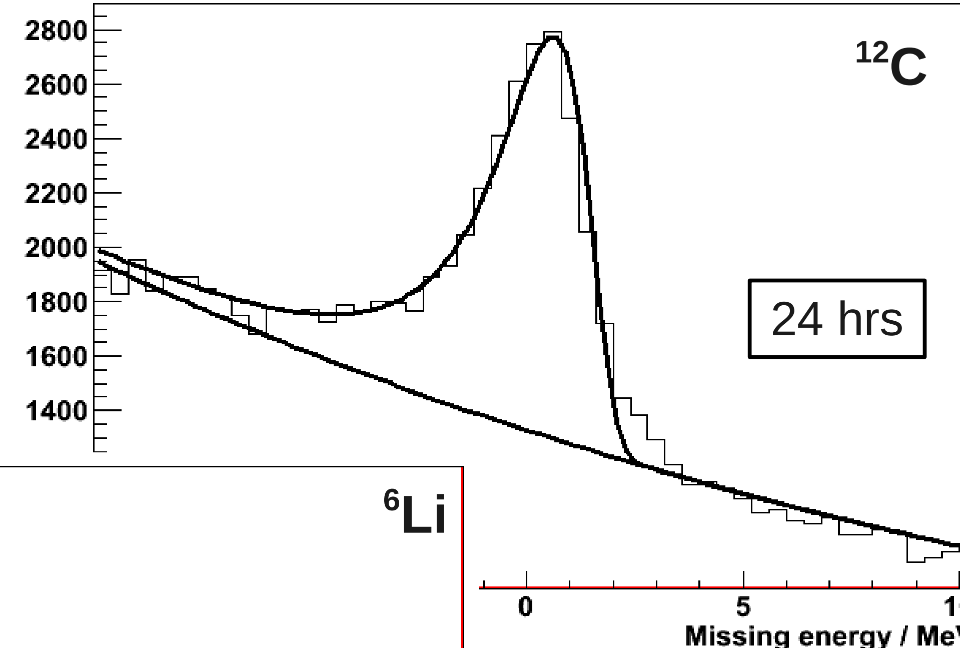
The COMPTON@MAX-lab Program

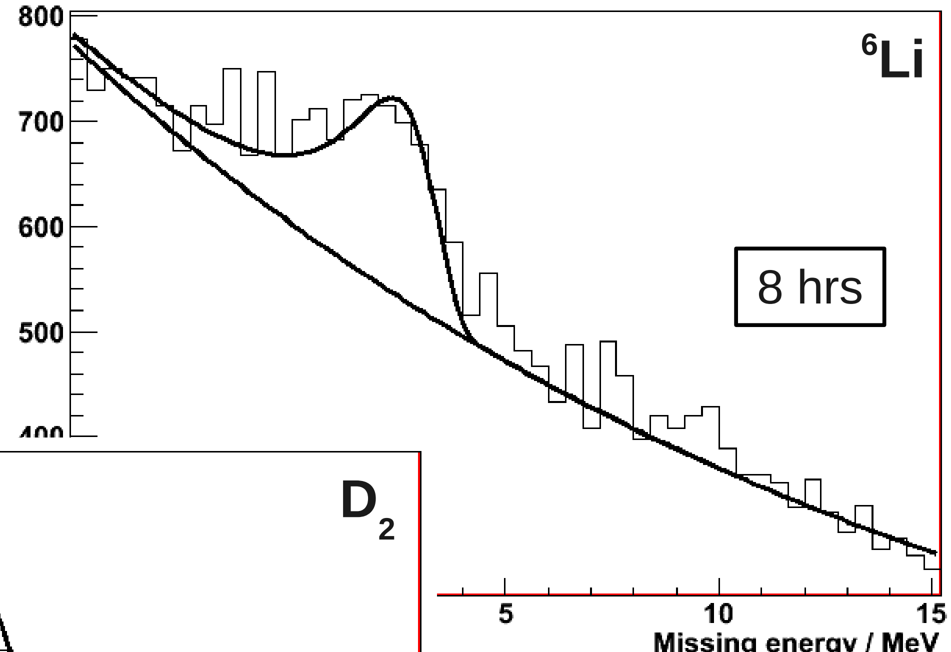
Run Period	Target	Angles	E_γ [MeV]	R_{ave} [MHz]
Nov 2007	D_2, ^{12}C	60, 120, 150	66 – 98	~1.0
Nov 2008	D_2, ^{12}C	60, 120, 150	81 – 116	~1.0
Nov 2009	D_2, ^{12}C	60, 90, 150	81 – 116	~0.6
Sept 2010	D_2, ^{12}C	60, 120, 150	81 – 116	~0.7
June 2011	D_2, ^{12}C	60, 120, 150	145 – 166	~0.2
Apr 2012	^6Li, ^{12}C	60, 120, 150	61 – 100	~0.4

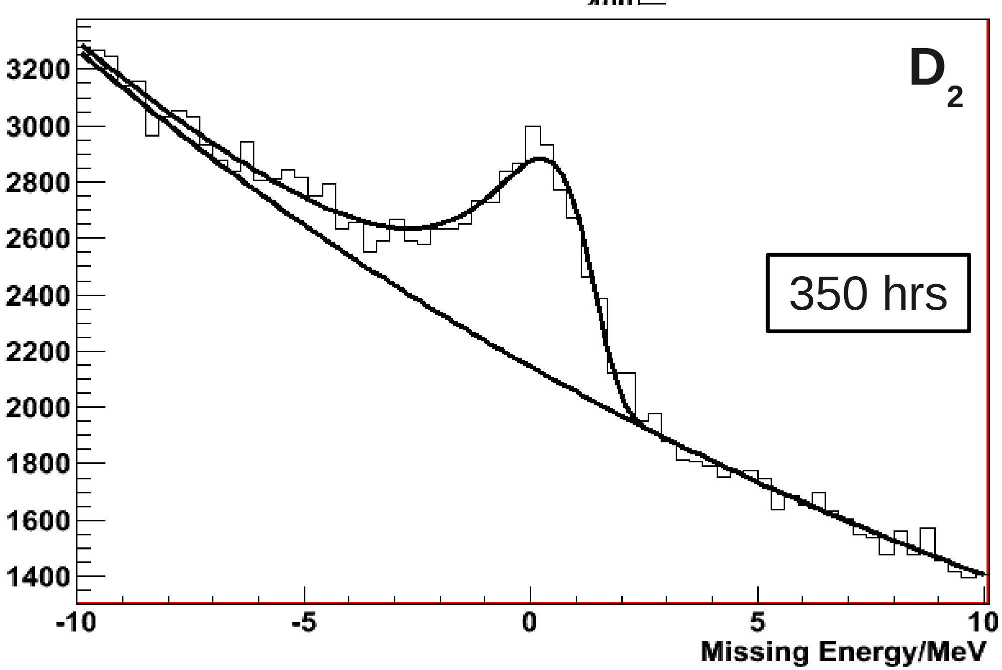
(Upgrade 2002–2004, commissioned 2005, experimental commissioning 2006)

- Earlier data sets have larger rate corrections
  - Higher beam rate
- ^{12}C data used for normalization checks

Elastic Scattering Peaks



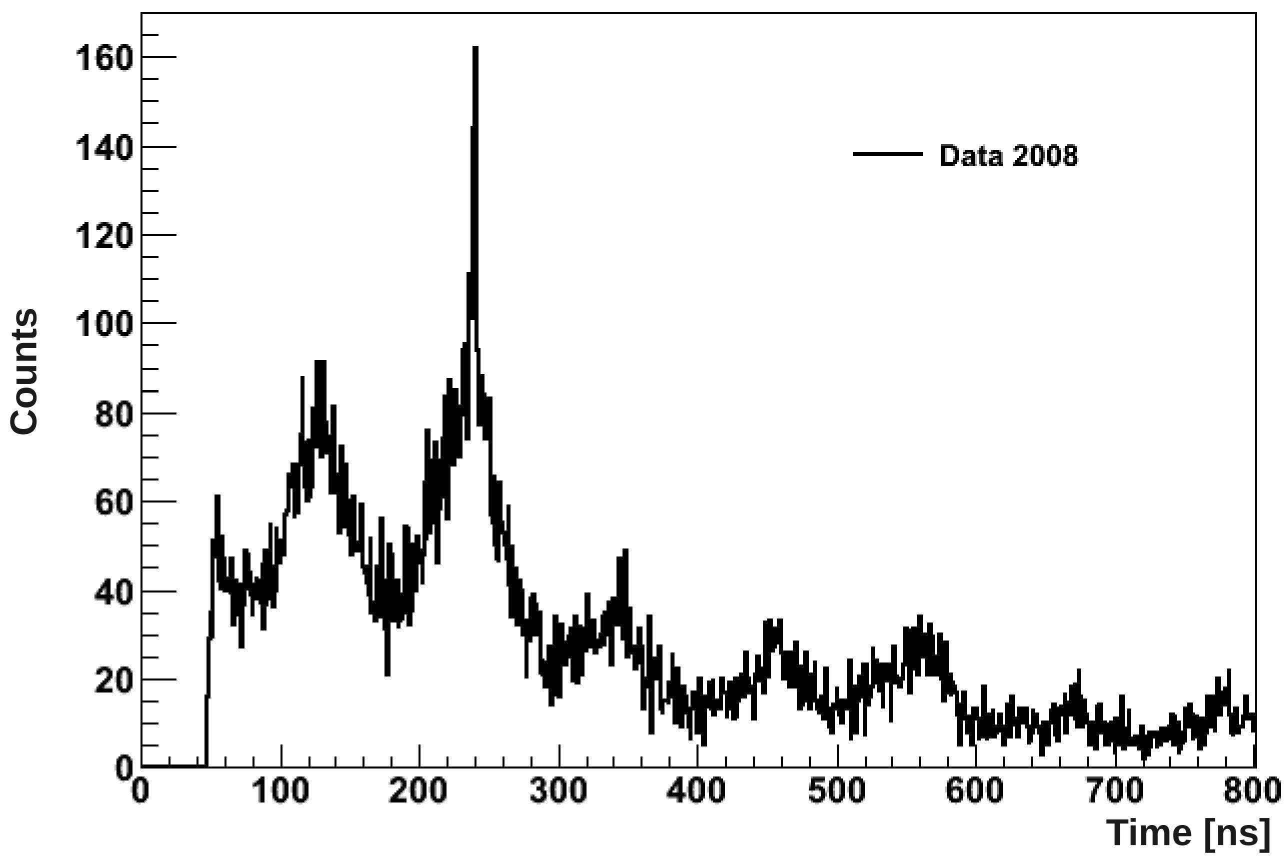




Target	S:N Ratio	E [MeV]
Carbon	~1:1	81 – 116
Lithium	~1:2	61 – 100
Deuterium	~1:3	81 – 116

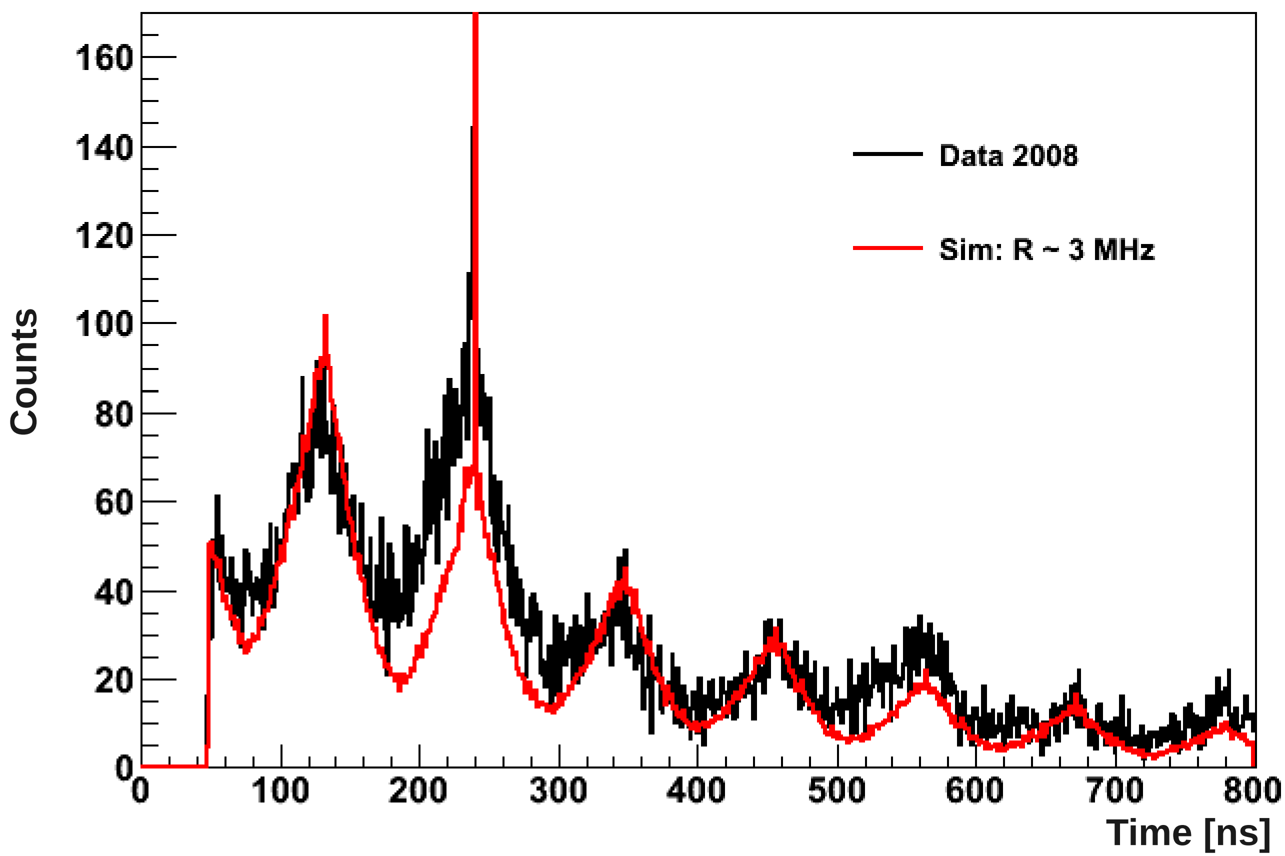
Preliminary Analysis

- Rate–dependent corrections large due to
  1. High average rates, low duty factor
  2. Complicated time profile in the beam
  3. Can not determine all the correction analytically

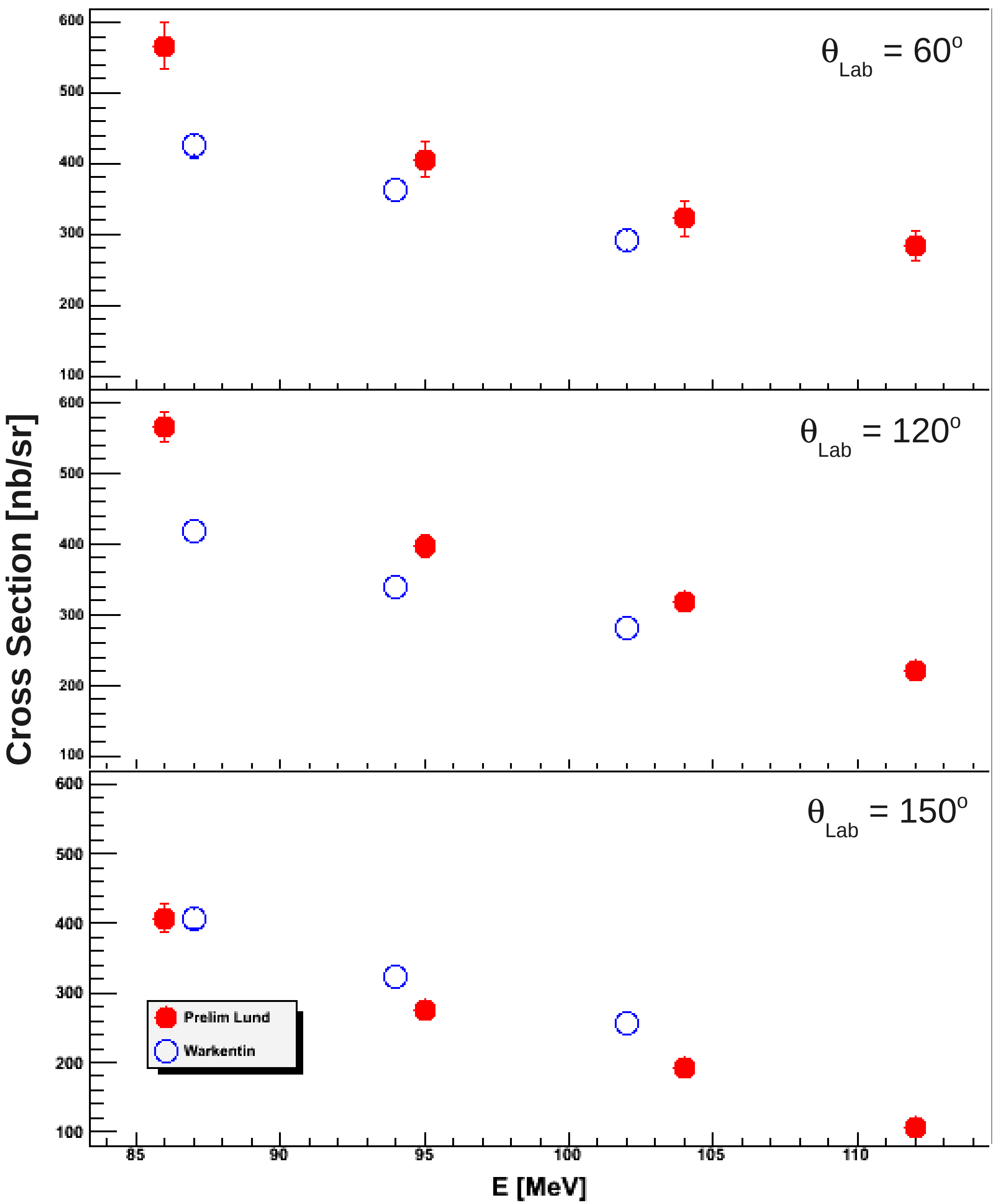


Preliminary Analysis

- Develop a simulation to model the electronics behavior
- Include beam profile and rates
- Determine rate–dependence via simulation

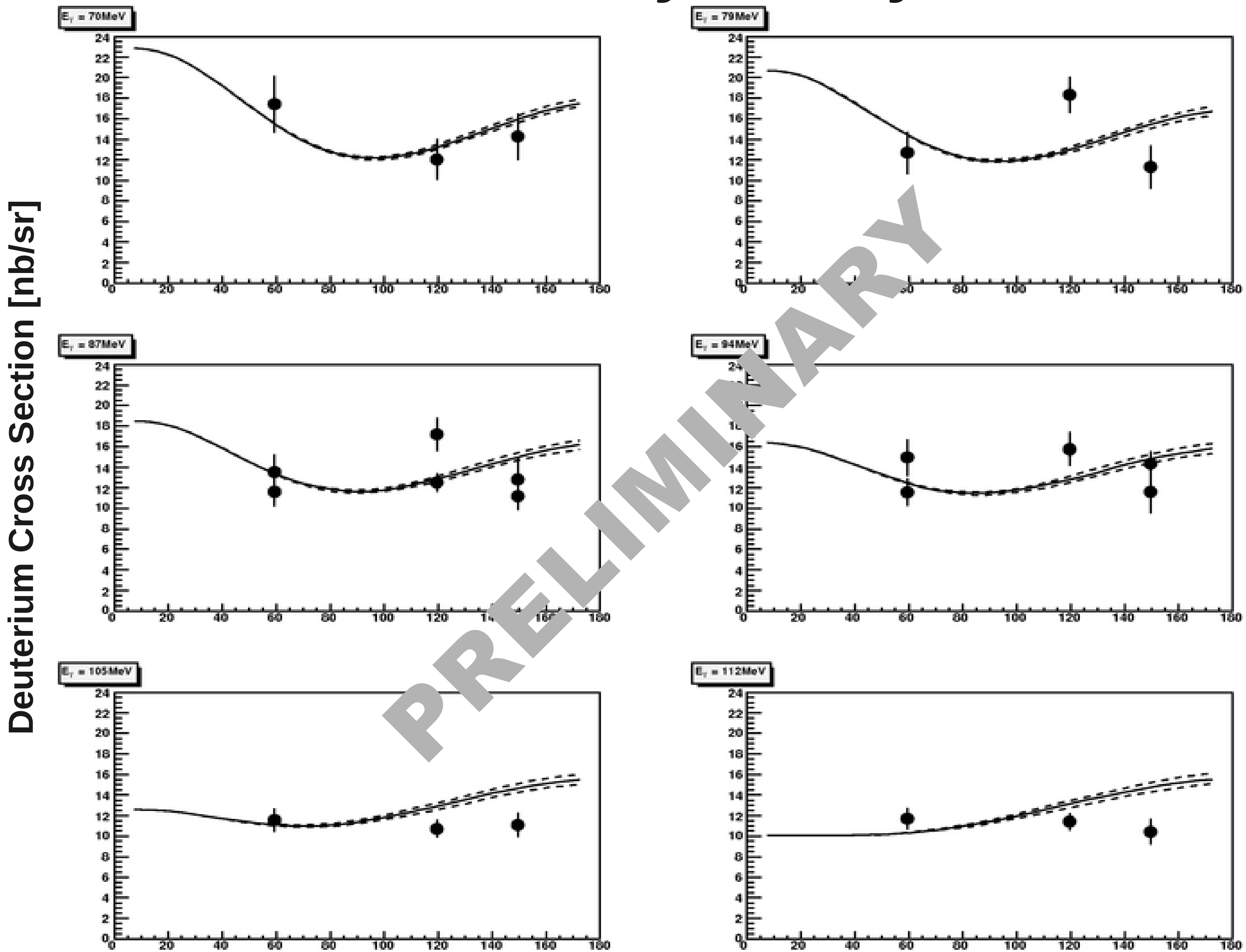


Preliminary Analysis



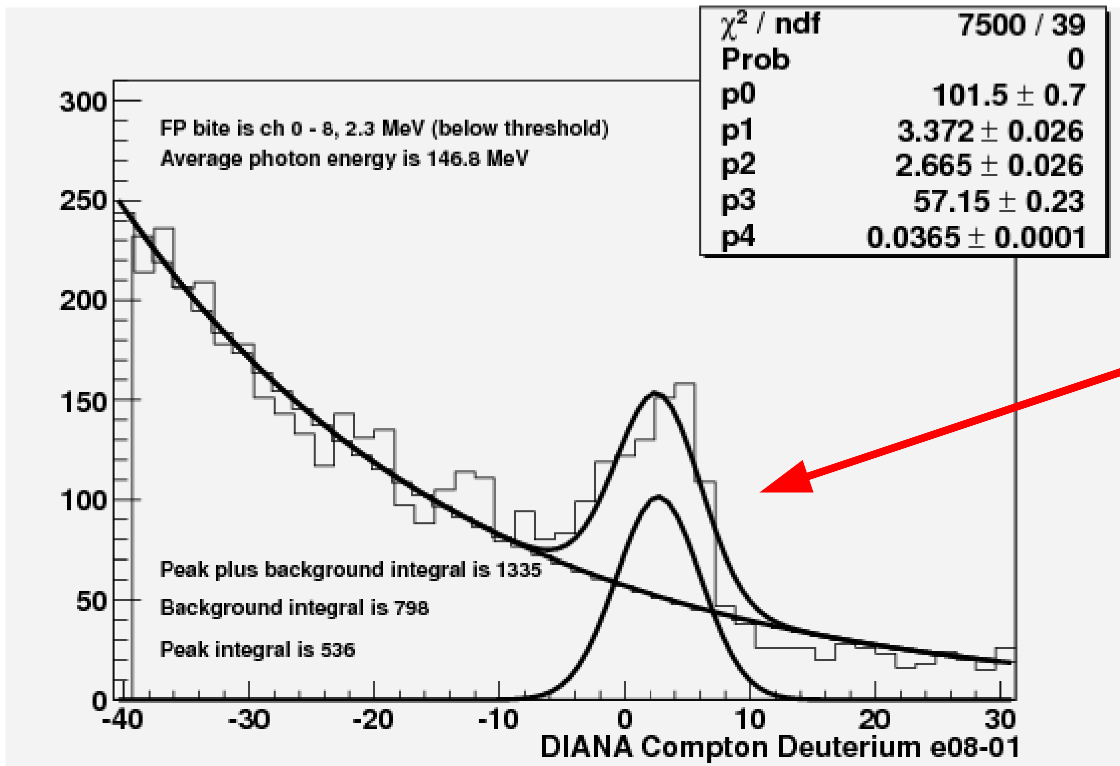
- ***Preliminary*** ^{12}C cross sections
  - Agree with previous publication within ±15%
  - Must refine rate-dependent corrections

Preliminary Analysis



Preliminary Analysis

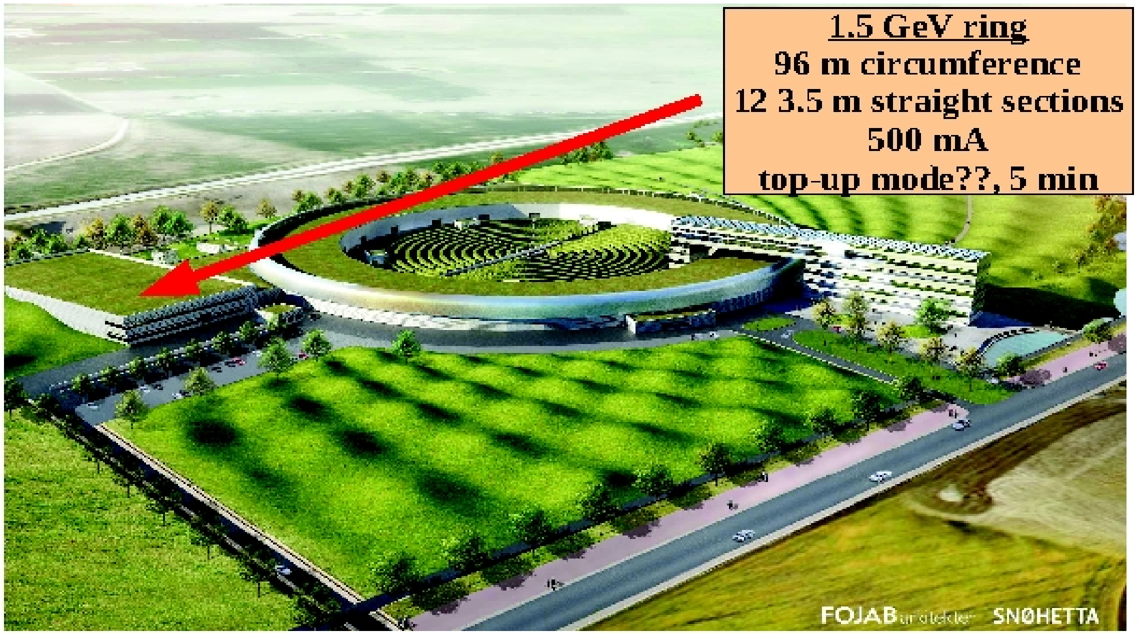
- d(γ,γ)d above 140 MeV



- ~300 hrs of beam time
- ⅛ of the FP
- ~500 counts

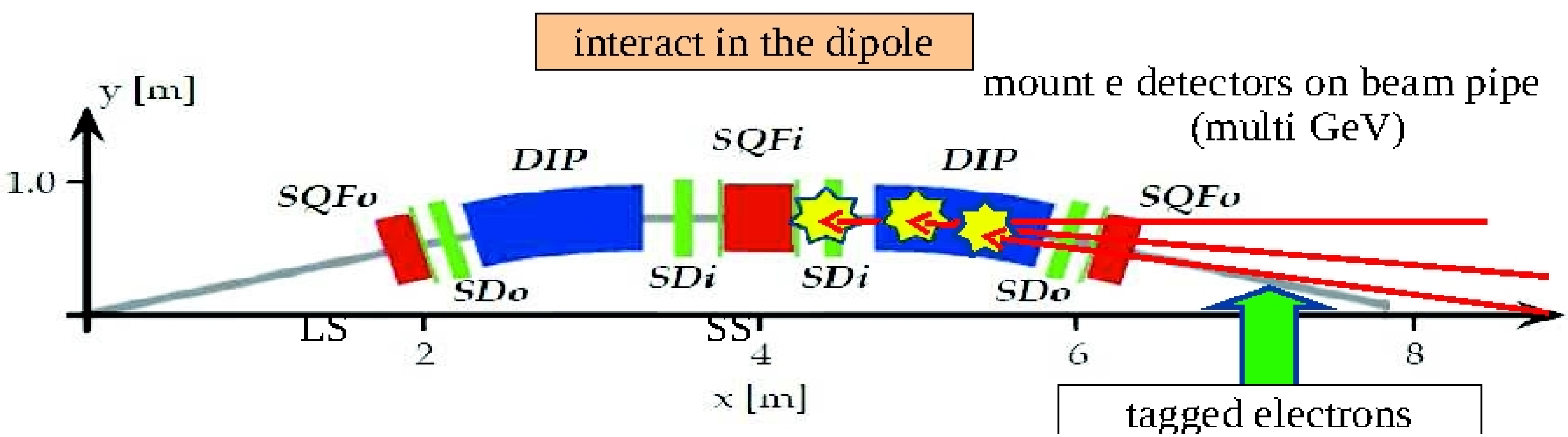
Needs more data!

The Future at MAX–IV



Facility/Project: LBSF@M4
Institution: MAX-IV Lab
Country: Sweden
Energy (MeV): 100 – 170
Accelerator: Storage Ring, 1.5 GeV
Laser: 229 nm (5.42 ev); 244 nm (5.80 eV)
Total flux: 4×10^{6} g/s (10% of ebeam lifetime)
Status: White paper/CDR in preparation

Use synchrotron light port for laser



Future

- Analysis goals
  - Determine rate-dependent corrections
  - Keep errors low (stat: 9-13%, syst: 5-10%)
  - Analyze 2009 & 2010, too ▶ Publish!
- Experimental
  - More data from near threshold pion measurements
  - Explore the MAX–IV possibilities

Thank You

To the organizers from the

COMPTON@MAX-lab collaborators