

Status and plans for 2013, CERN NA63

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Status:

1. Quantum suppression
2. Structured target resonance
3. Low-Z LPM
4. Positron production (test, 4 MIMOSAs)

Plans (for 2014):

1. Heavy ion bremsstrahlung
2. Positron production (8 MIMOSAs)

STATUS

Quantum suppression
2009 measurement

Strong fields

- Strong – compared to what?
relativistic (c) quantum (\hbar) field for electrons (m, e)
- The critical field:

$$\begin{aligned}\mathcal{E}_0 &= m^2 c^3 / e \hbar \\ &= 1.32 \times 10^{16} \text{ V/cm}\end{aligned}$$

$$B_0 = 4.41 \times 10^9 \text{ T}$$

Exists at the surface of some
neutron stars (magnetars)

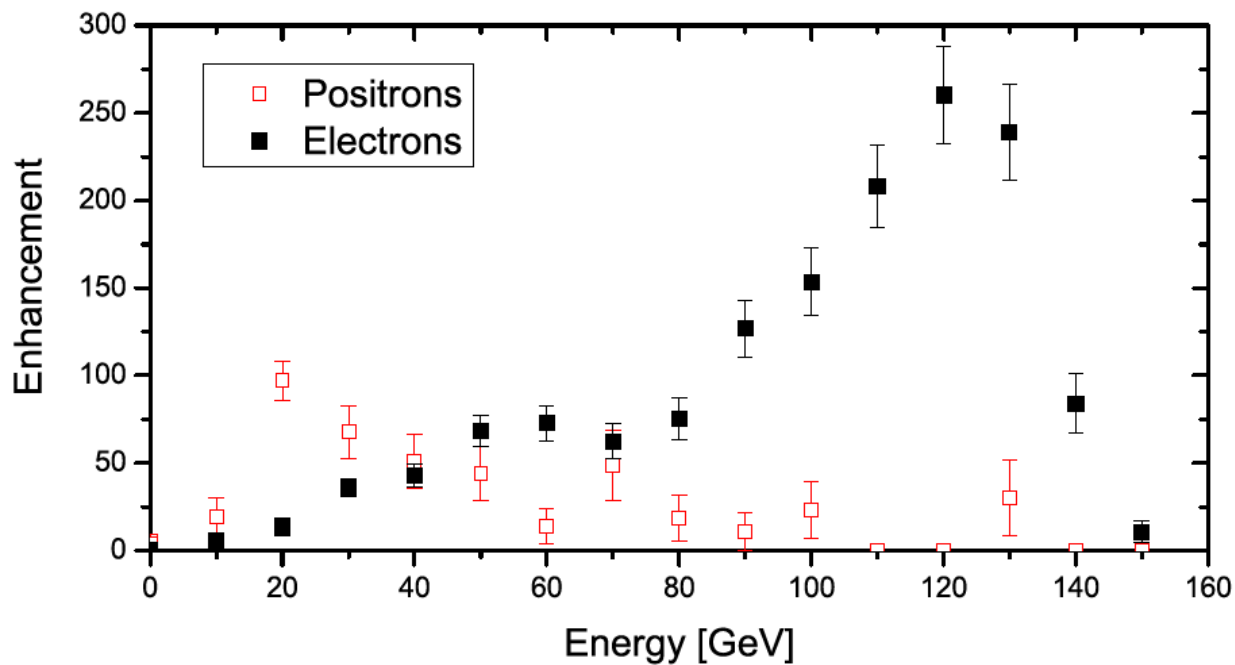
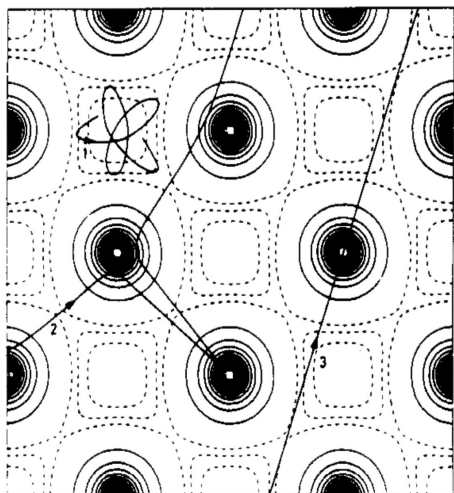
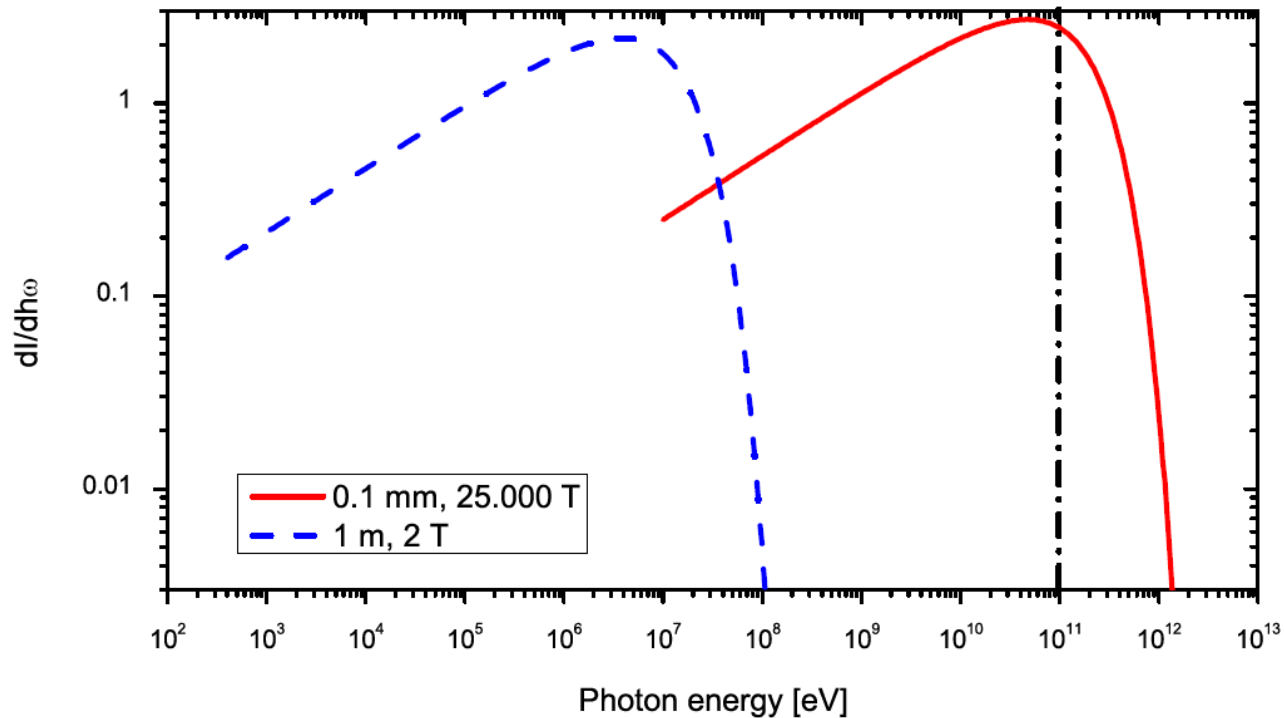
Relativistic invariant:

$$\chi = \gamma \mathcal{E} / \mathcal{E}_0$$



Radiation emission

$$\chi = \gamma \mathcal{E} / \mathcal{E}_0$$



Beamstrahlung – synchr.rad.

PHYSICAL REVIEW D

VOLUME 36, NUMBER 1

1 JULY 1987

Quantum treatment of beamstrahlung

Richard Blankenbecler and Sidney D. Drell

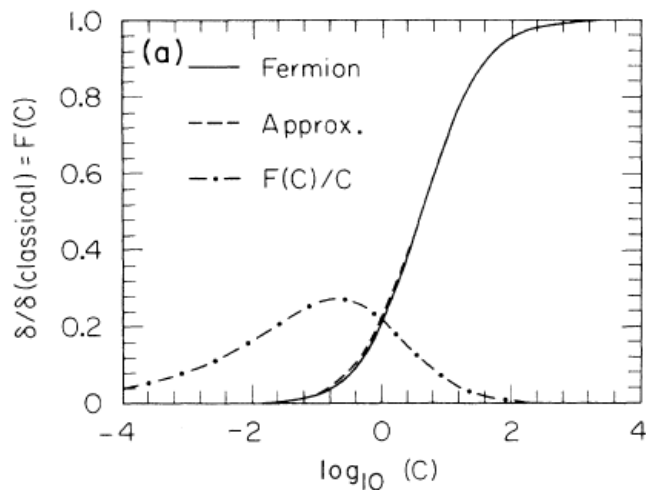
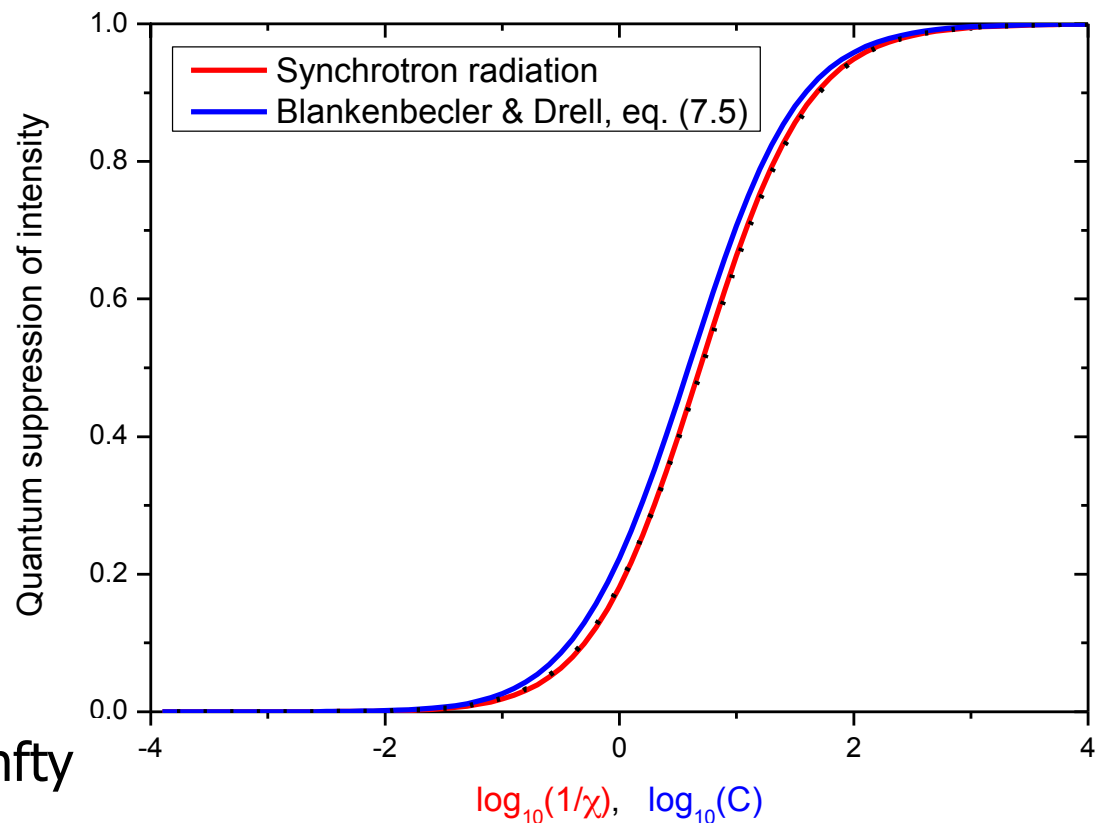


FIG. 1. (a) The form factor

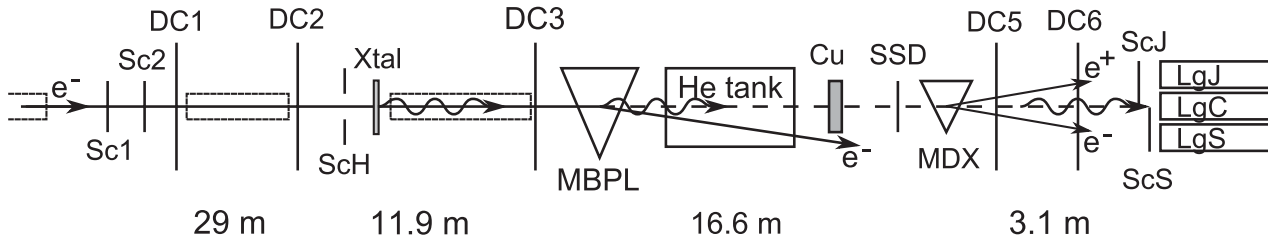
$$C_b = \frac{m^2 c^3 R L}{4 N e^2 \gamma^2 \hbar}$$

Classical: $\rightarrow 0 \Rightarrow C_b \rightarrow \text{infy}$

$$\frac{I_e}{I_{cl}} = (1 + 4.8(1 + \chi) \ln(1 + 1.7\chi) + 2.44\chi^2)^{-2/3}.$$



Quantum suppression



PHYSICAL REVIEW D **86**, 072001 (2012)

Experimental investigations of synchrotron radiation at the onset of the quantum regime

K. K. Andersen,¹ J. Esberg,¹ H. Knudsen,¹ H. D. Thomsen,¹ U. I. Uggerhøj,¹ P. Sona,² A. Mangiarotti,³
T. J. Ketel,⁴ A. Dizdar,⁵ and S. Ballestrero⁶

$$\Delta E_\mu = \gamma^2 \beta \frac{\mathcal{E}}{\mathcal{E}_0} mc^2 = \chi \beta \gamma mc^2$$

$$\tau_{\text{sf}} = \frac{8\hbar}{5\sqrt{3}\alpha mc^2} \frac{\gamma}{\chi^3}$$

$$c\tau_{\text{sf}} = \varepsilon_{\text{sf}} \gamma a_0 / \chi^3$$

$$\varepsilon_{\text{sf}} = 8/5\sqrt{3} \approx 92.4\%$$

100 GeV

$\chi=1$

$c\tau_{\text{sf}} = 10 \mu\text{m}$

$\tau_{\text{sf}} = 32 \text{ fs}$

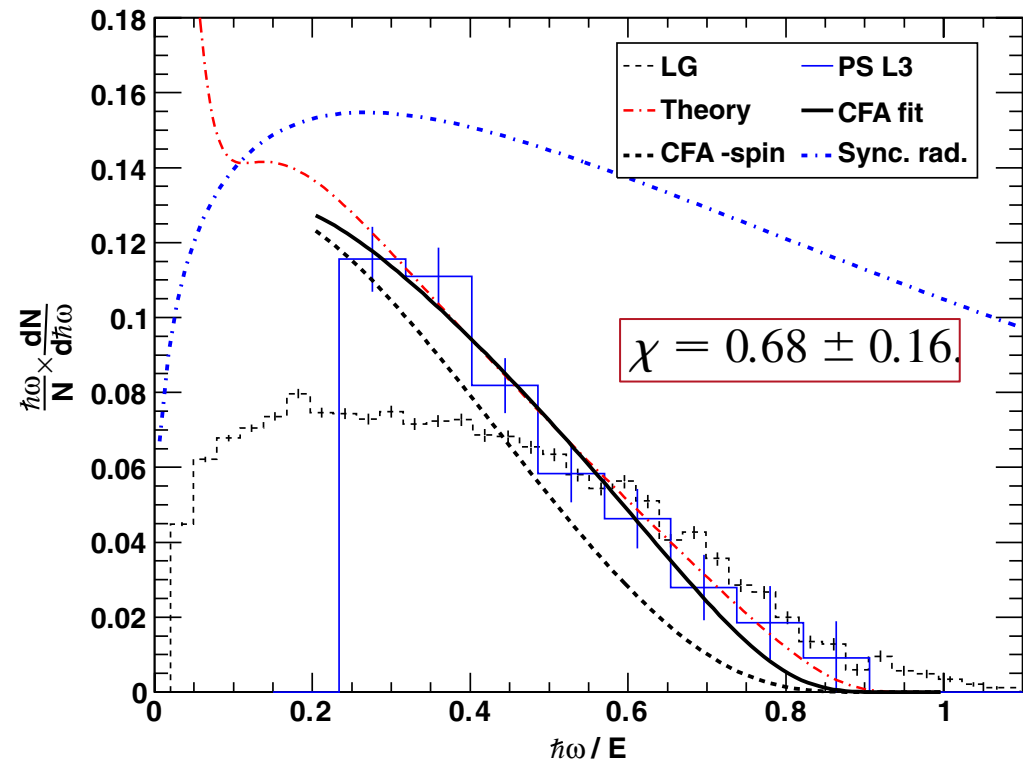
1 GeV

B=1 T

$c\tau_{\text{sf}} = 7.3 \text{ A.U.}$

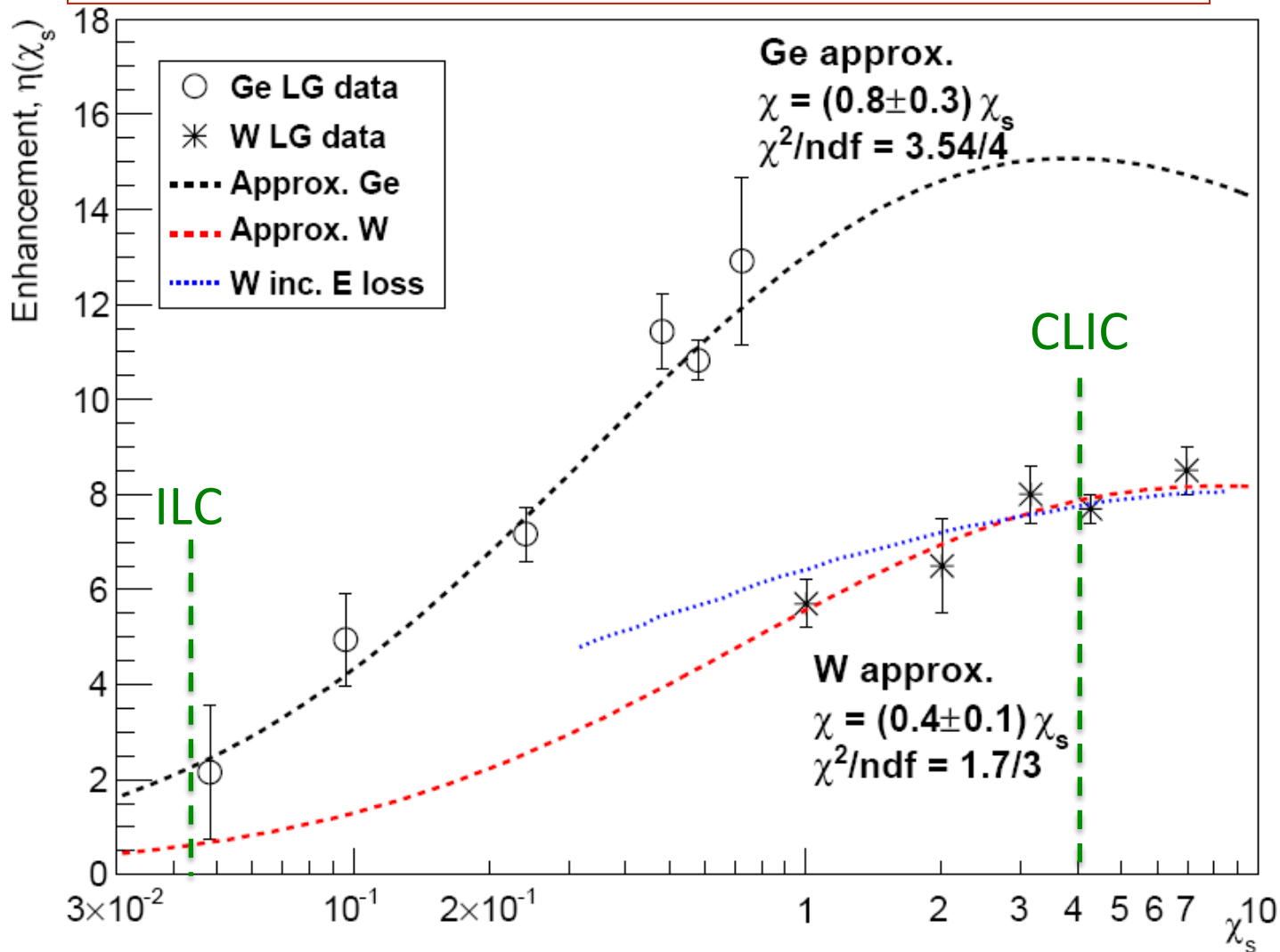
$\tau_{\text{sf}} = 61 \text{ min.}$

(CERN NA63)



Classical -> Quantum synchrotron

$$\frac{I_e}{I_{cl}} = (1 + 4.8(1 + \chi) \ln(1 + 1.7\chi) + 2.44\chi^2)^{-2/3}. \quad \text{Plotted as: } \cdots \cdots$$



K.K. Andersen *et al.*

Phys.Rev. D **86**,
072001, 2012

GUINEA-PIG (D. Schulte, CERN) simulations of beamstrahlung are now 'experimentally verified'

STATUS

Low-Z LPM

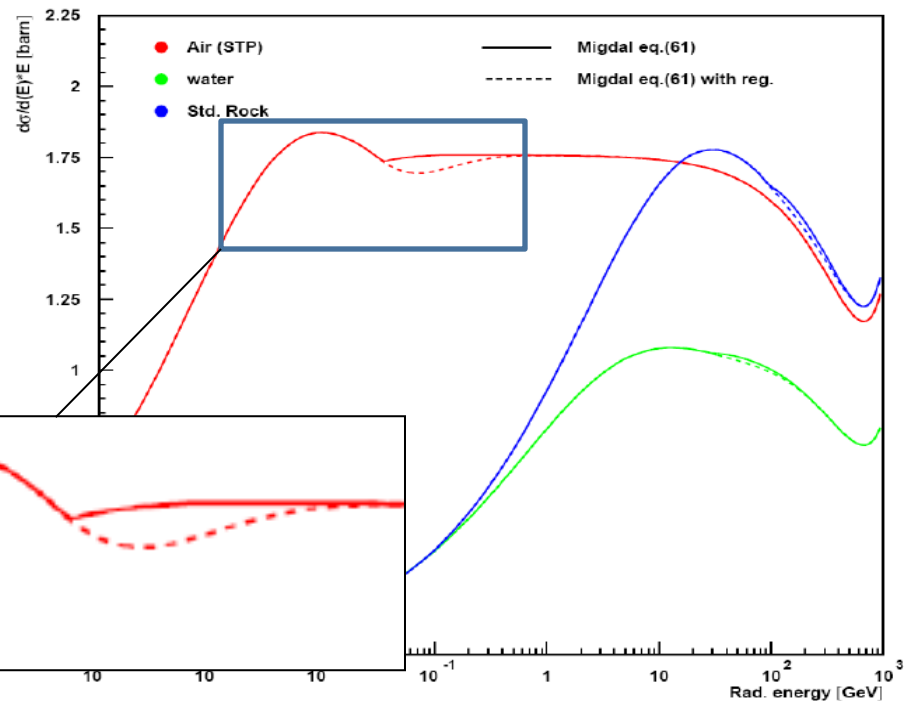
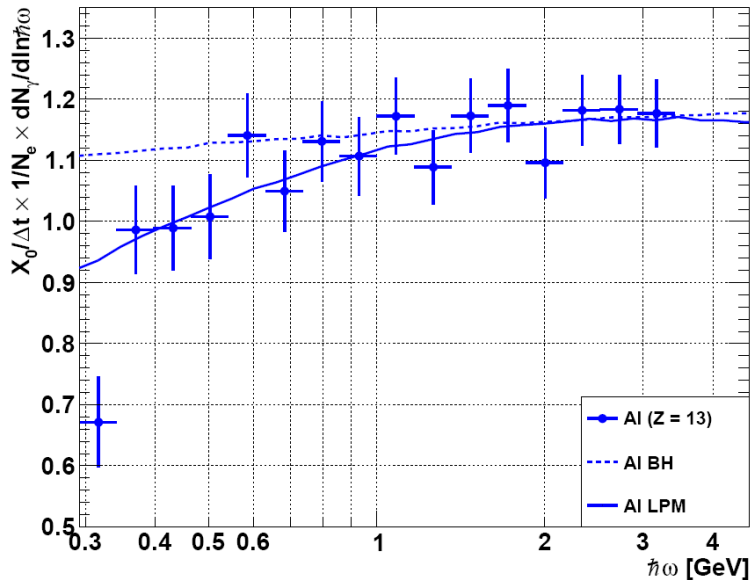
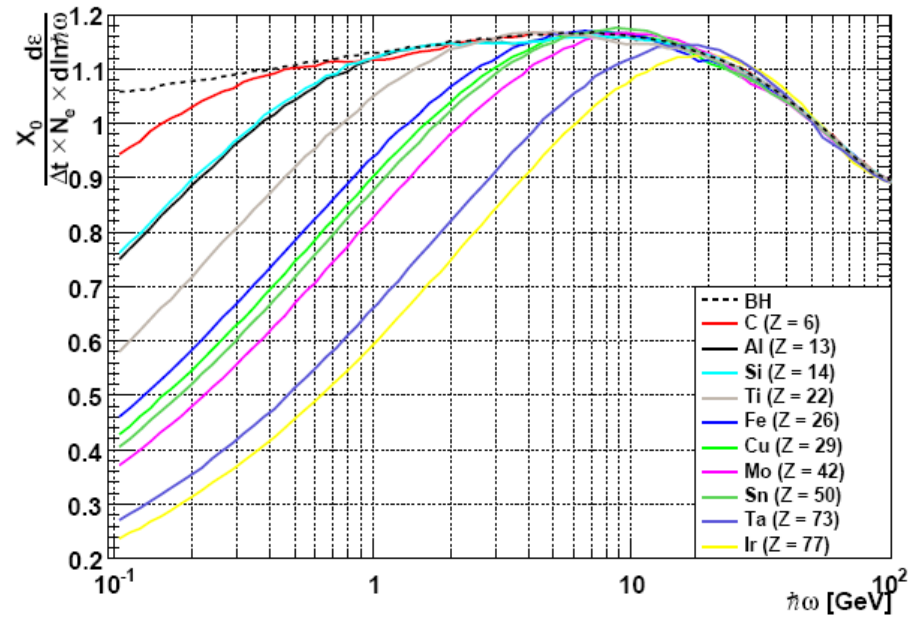
2010 measurement

2012 measurement

Low-Z LPM

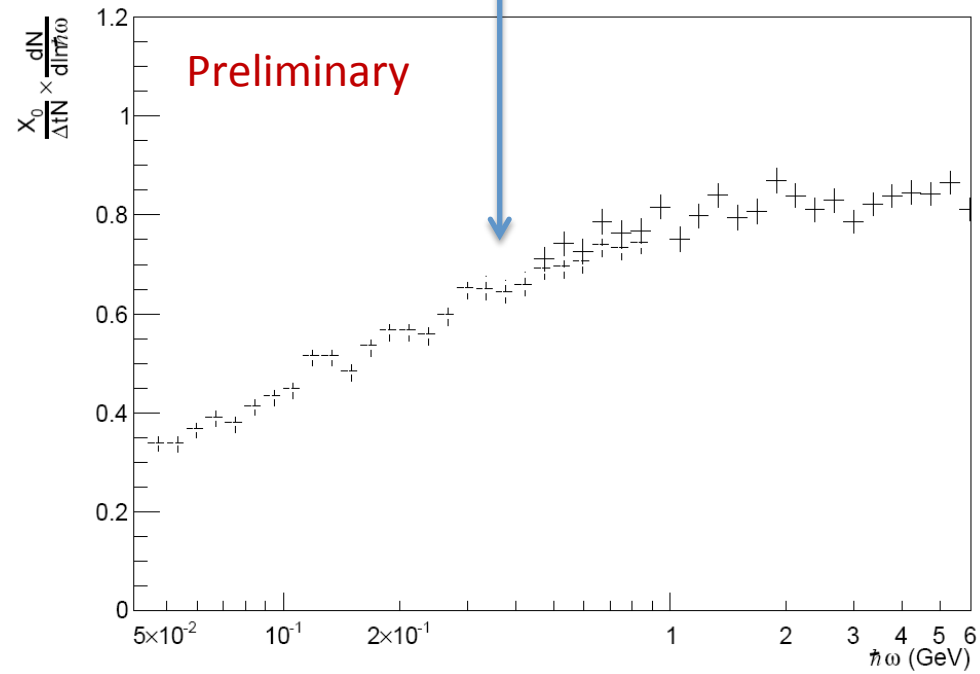
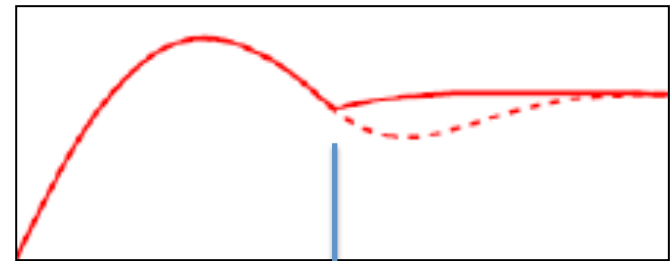
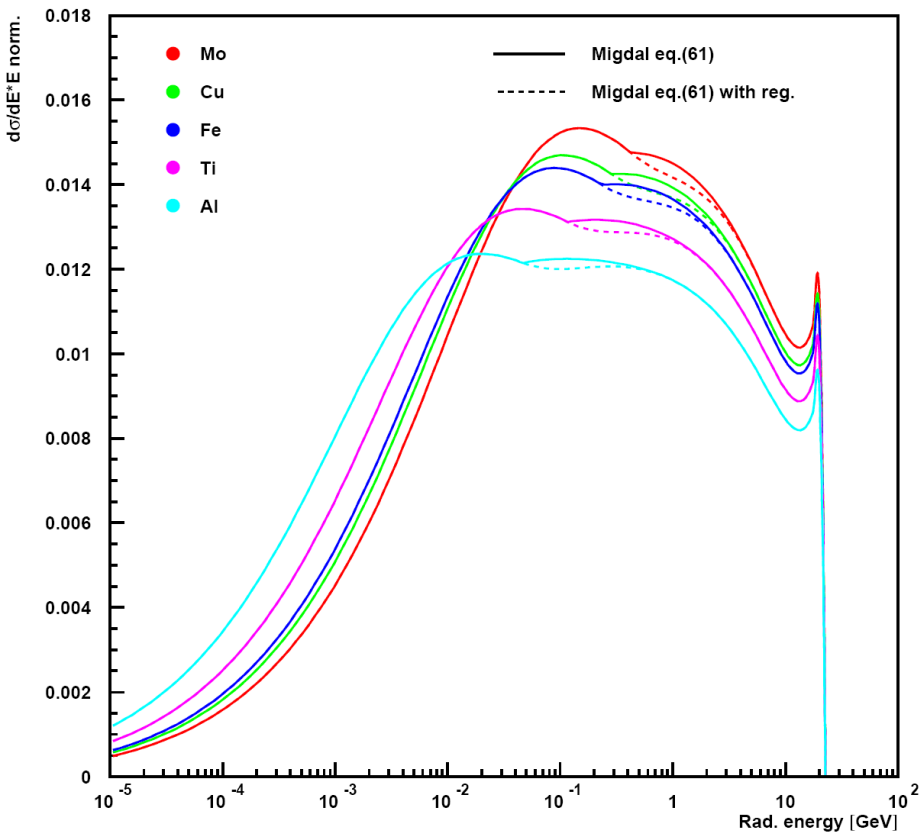
- Test LPM theory in low-Z targets
- 2010 measurement: deconvolution of synchr. rad. given up
- Experiment redone in 2012 with a much improved setup

2.5% X0



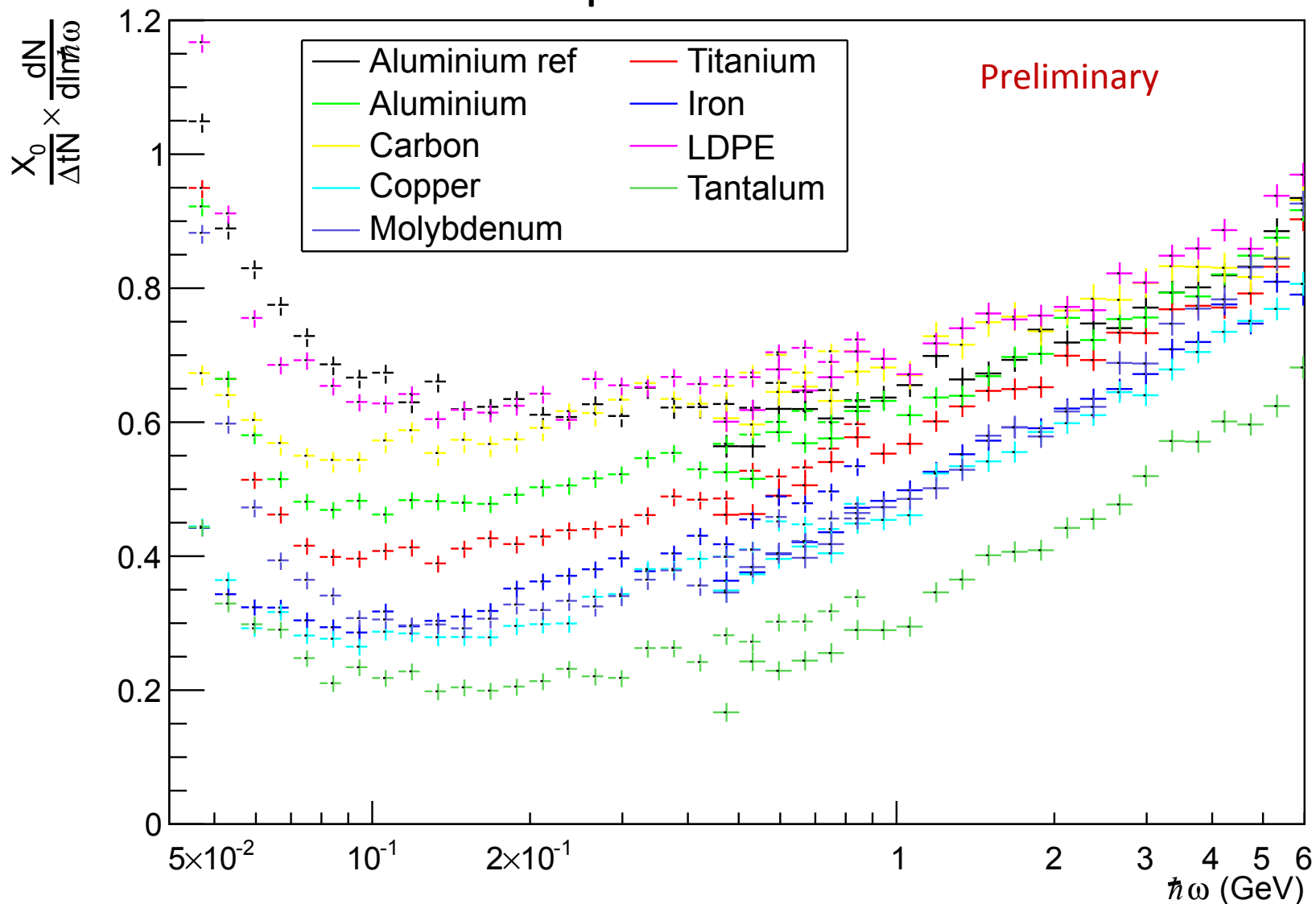
Low-Z LPM

20 GeV electrons in Copper:
No signs of kink-like structure



Low-Z LPM

178 GeV electrons in various targets:
Analysis in progress – looking good.
Expected finished end-2012.



STATUS

Structured targets

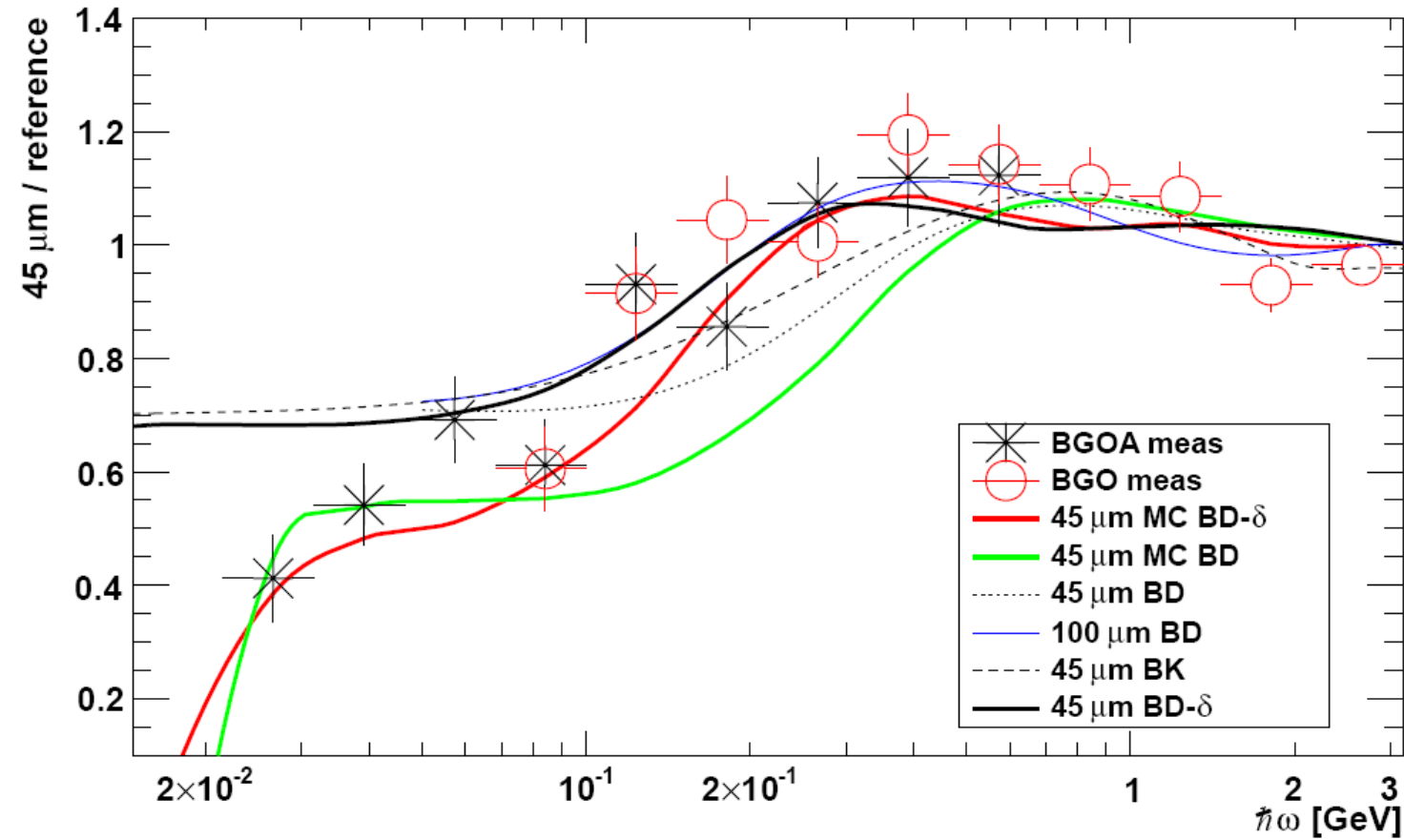
2011 measurement

2012 measurement

Direct Measurement of the Formation Length of Photons

Kristoffer K. Andersen,^{1,*} Søren L. Andersen,¹ Jakob Esberg,¹ Helge Knudsen,¹ Rune Mikkelsen,¹ Ulrik I. Uggerhøj,¹
Pietro Sona,² Alessio Mangiarotti,³ Tjeerd J. Ketel,⁴ and Sergio Ballestrero⁵

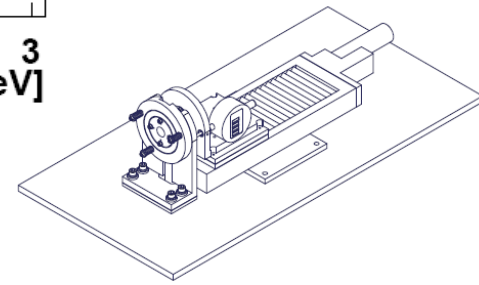
(CERN NA63)



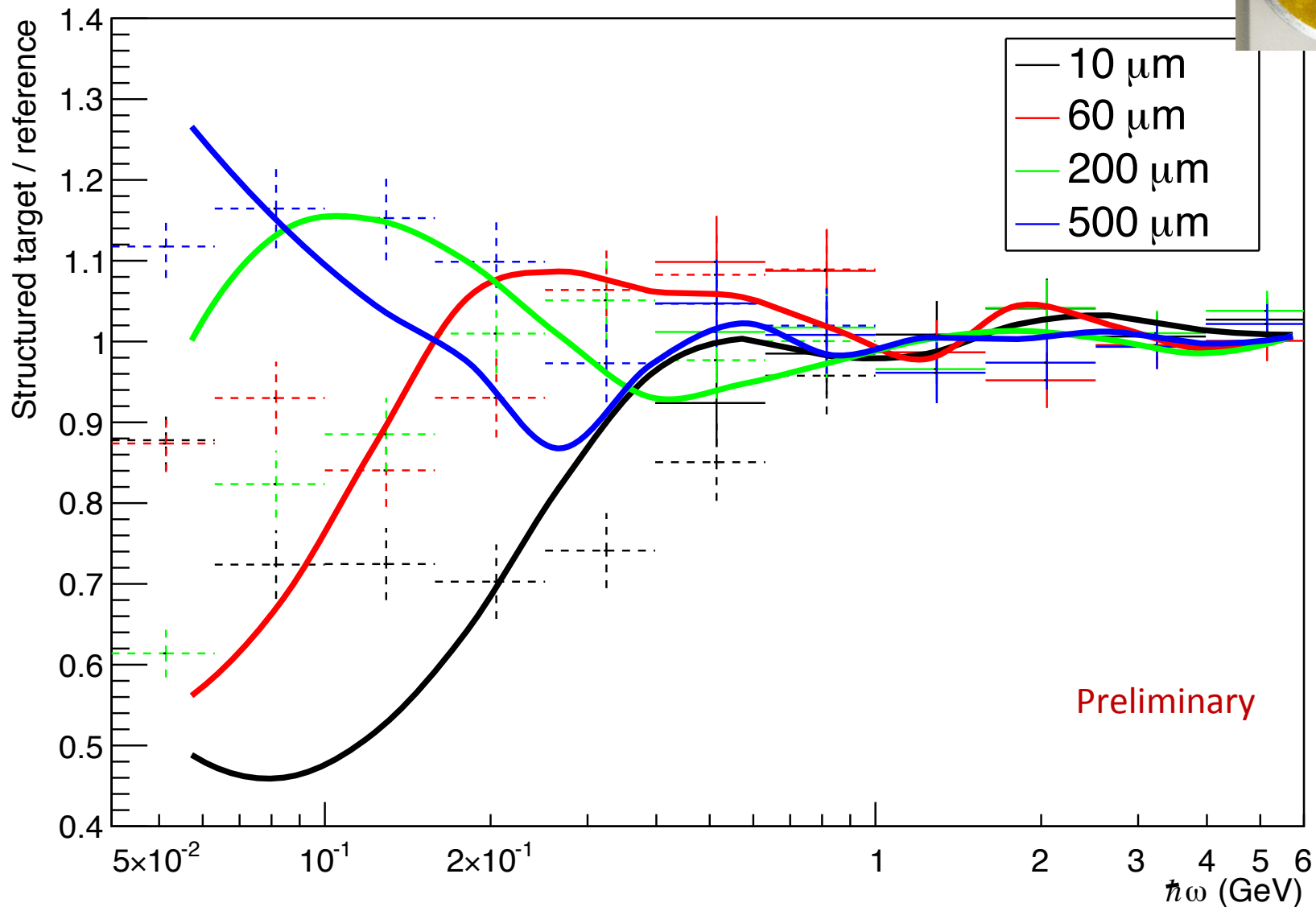
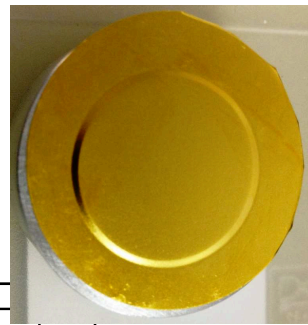
SPS H4 exp.,
Sept. 2011

Discrepancy
reported at
SPSC Oct
2011 was a
theory
problem.

Measuring the formation length with a micrometer screw....



Structured targets – systematic investigation



STATUS

Positron production
2012 measurement

Positron production

MIMOSA detectors (M. Winter, Strasbourg)

- Vertex detectors for CLIC (?)

CMOS-based position sensitive detectors

1152 columns of

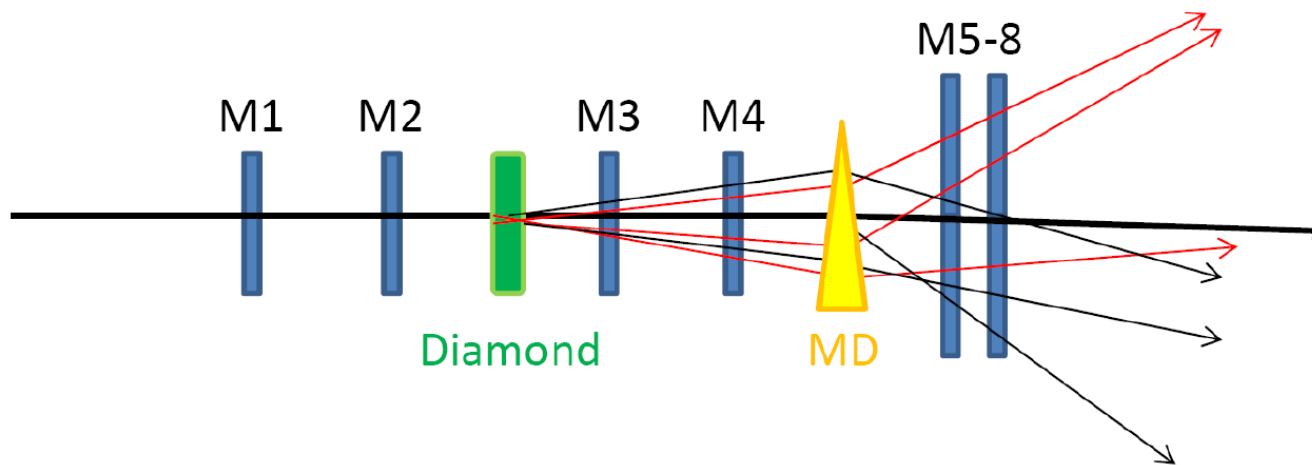
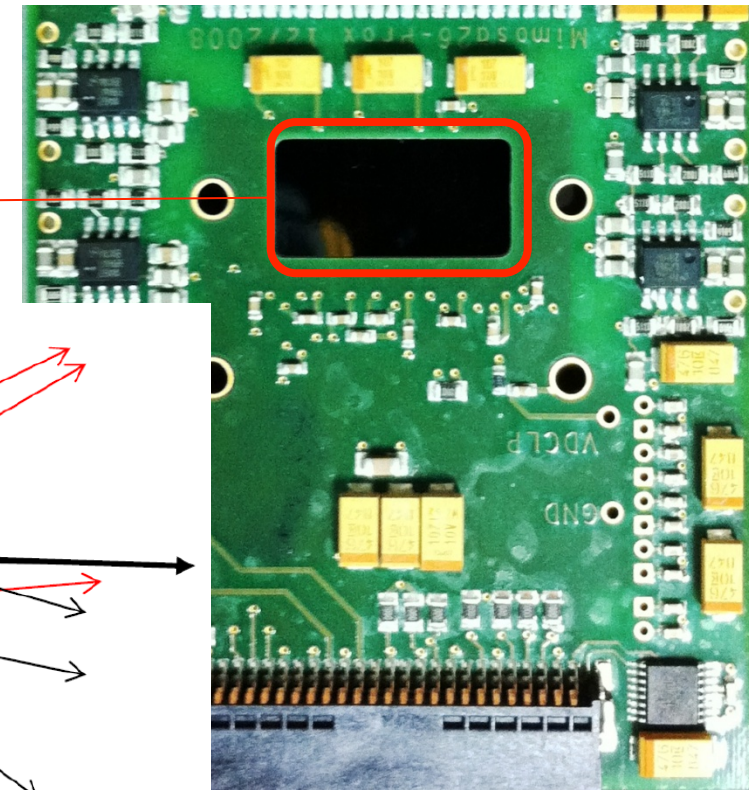
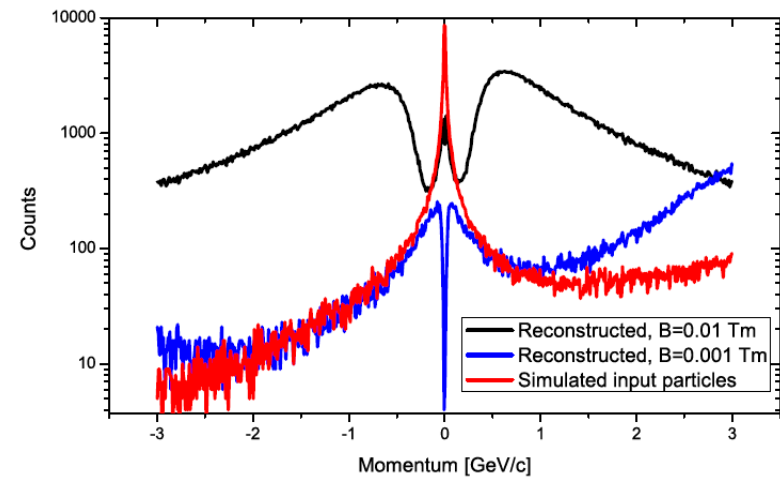
576 pixels, $\approx 18.4 \mu\text{m}$ pitch

readout in 110 ms, $\approx 3.5 \mu\text{m}$ resolution

true multi-hit capability

$1 \times 2 \text{ cm}^2$

$\Delta t/X_0 \approx 0.05\%$

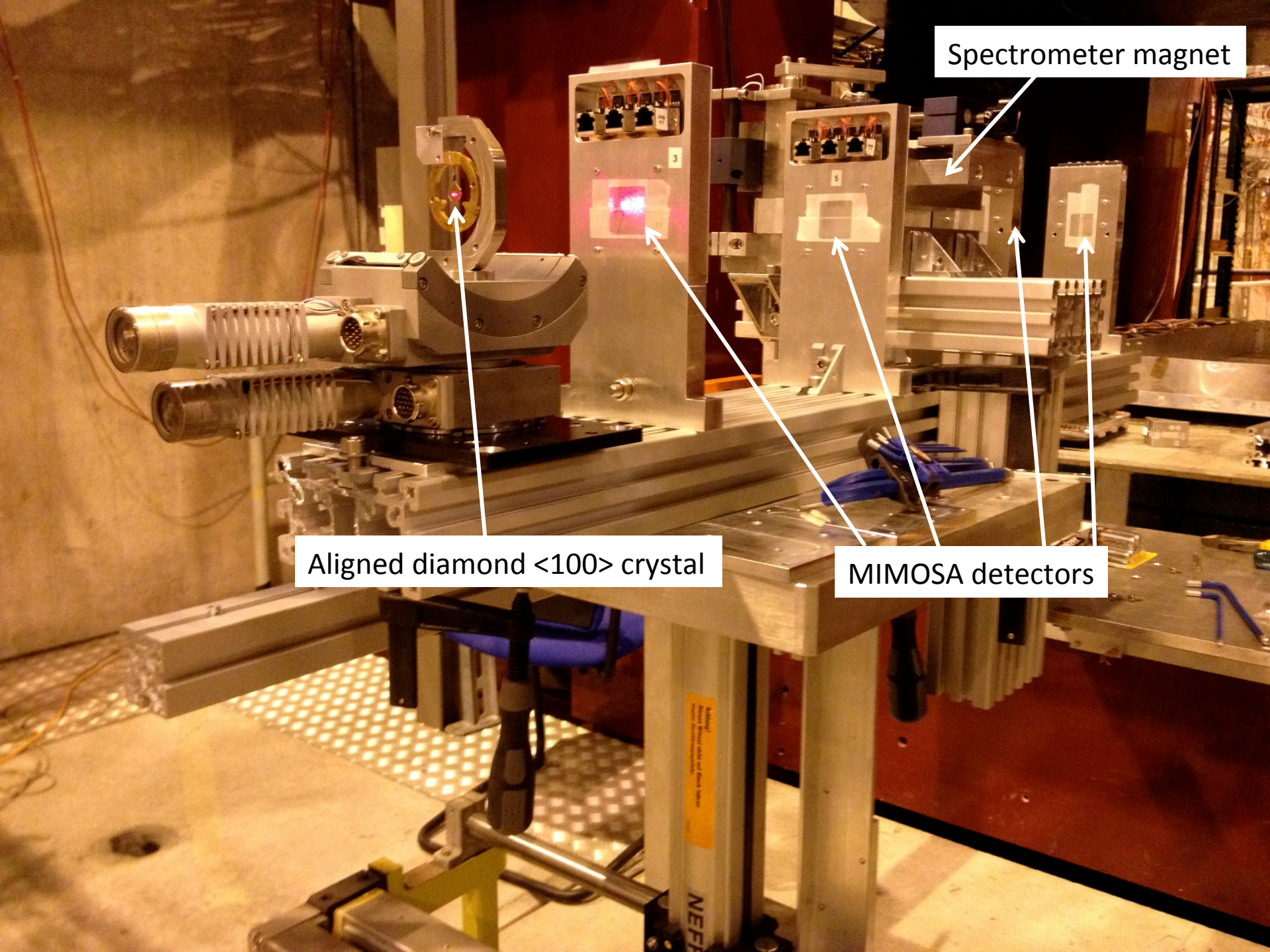


Read-out electronics operational – triggered readout. Wrongly patched MIMOSAs prevent large coverage in momentum.

Spectrometer magnet

Aligned diamond $\langle 100 \rangle$ crystal

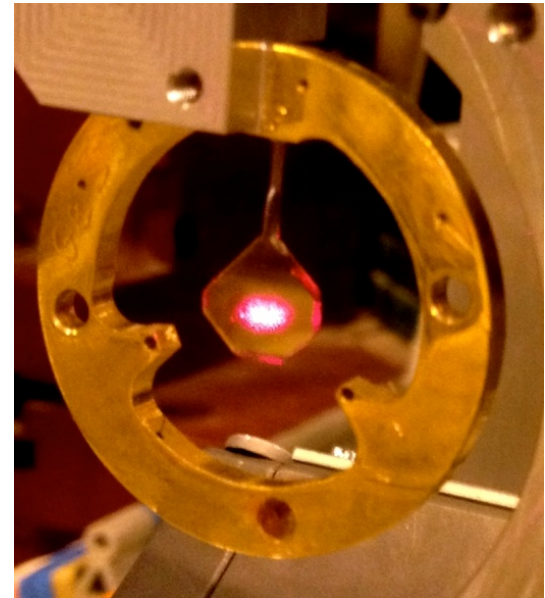
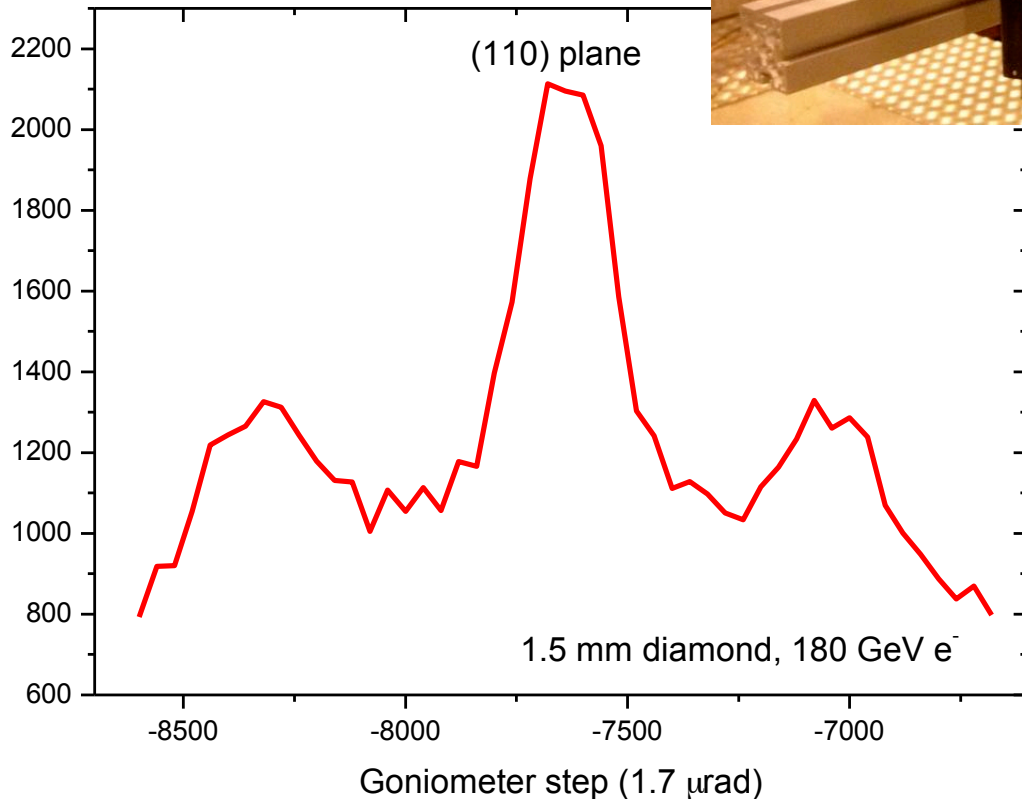
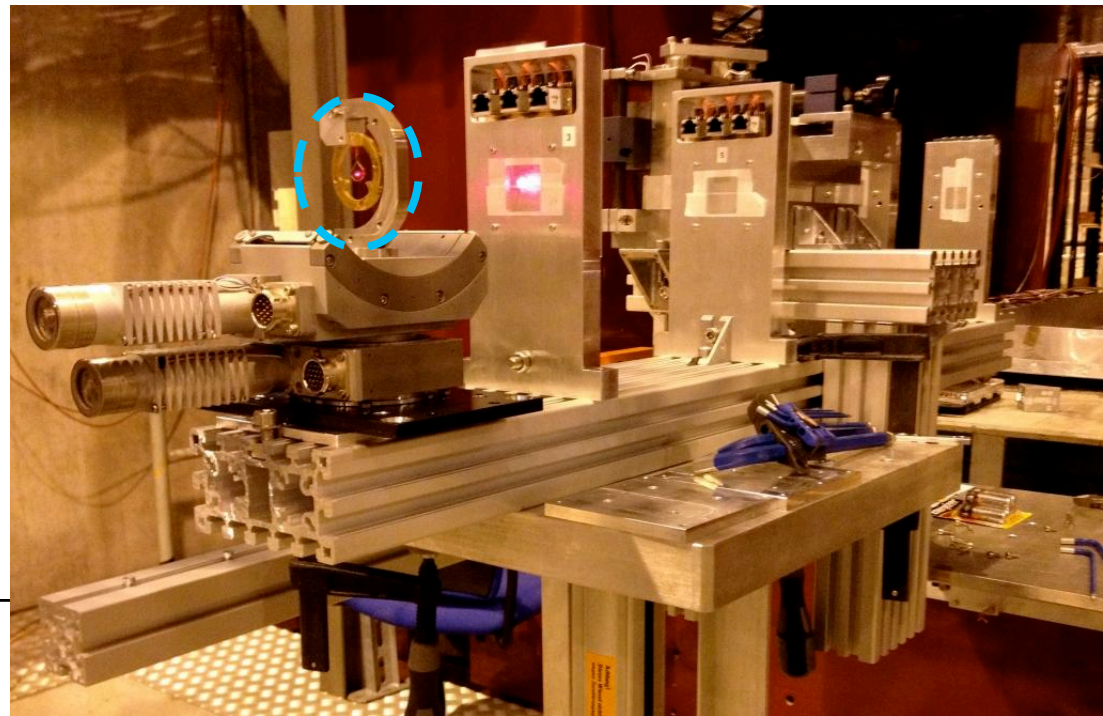
MIMOSA detectors



Angular scans

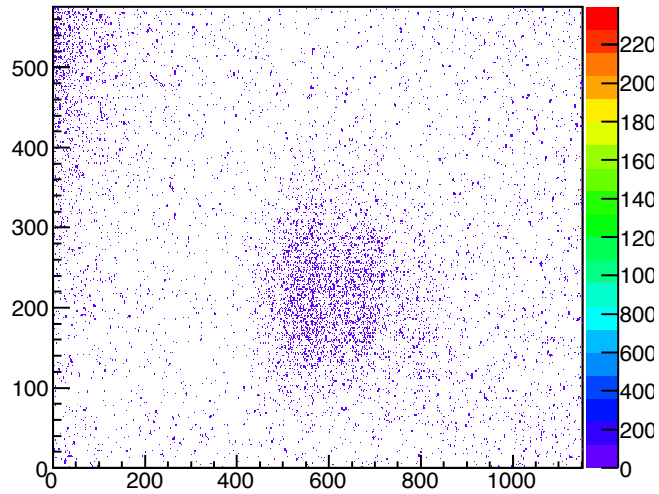
- Radiation enhancement observed w/ 180 GeV electrons (signal = radiation above 50 GeV, 'strong field radiation')

September 2012, CERN
with 1.5 mm diamond:

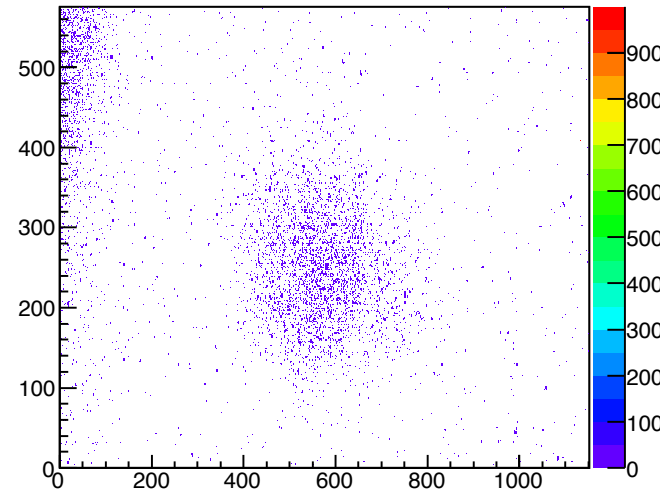


MIMOSA read-out

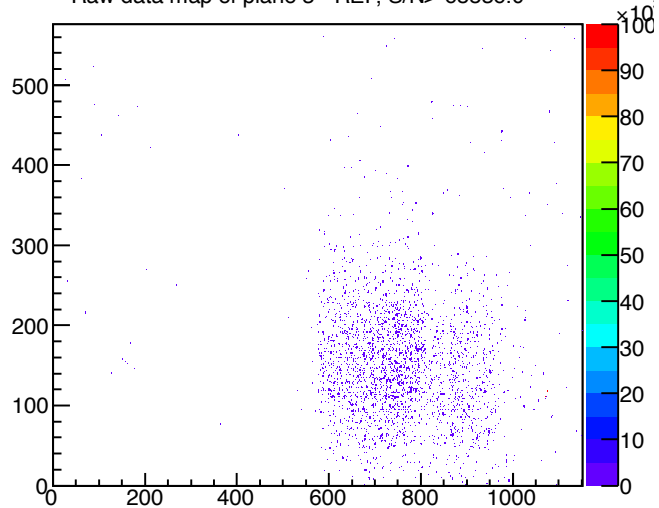
Raw data map of plane 1 - REF, S/N>65536.0



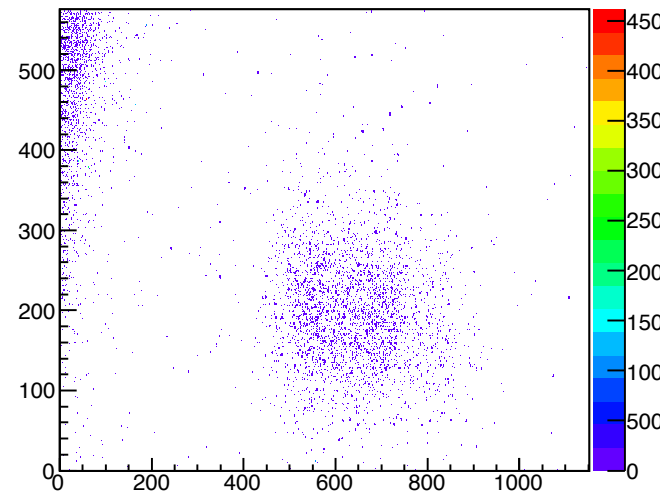
Raw data map of plane 2 - REF, S/N>65536.0



Raw data map of plane 3 - REF, S/N>65536.0



Raw data map of plane 4 - DUT, S/N>65536.0



PLANS FOR 2014
(to be reported in 2013)

Heavy ion bremsstrahlung

PHYSICAL REVIEW A **81**, 022901 (2010)

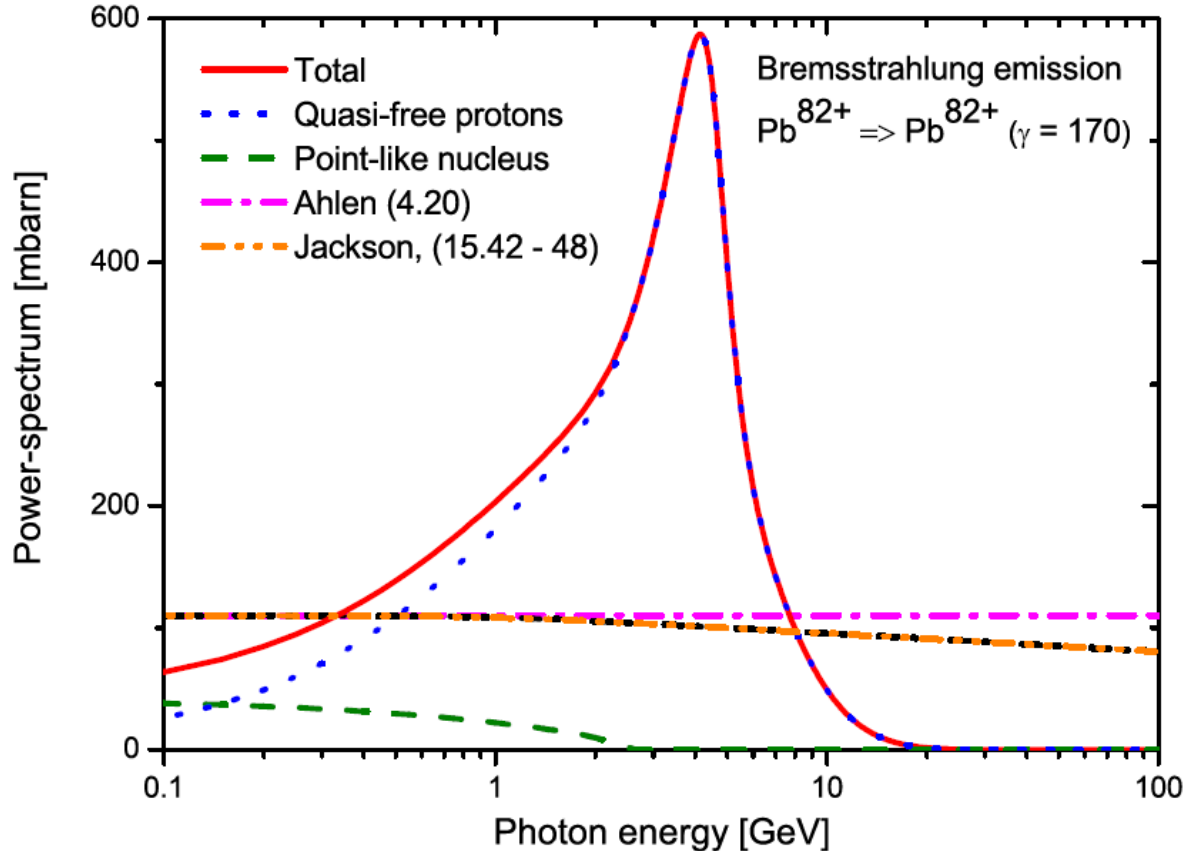
Bremsstrahlung from relativistic heavy ions in matter

Allan H. Sørensen

Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark

(Received 24 September 2009; published 8 February 2010)

Radiation
emission

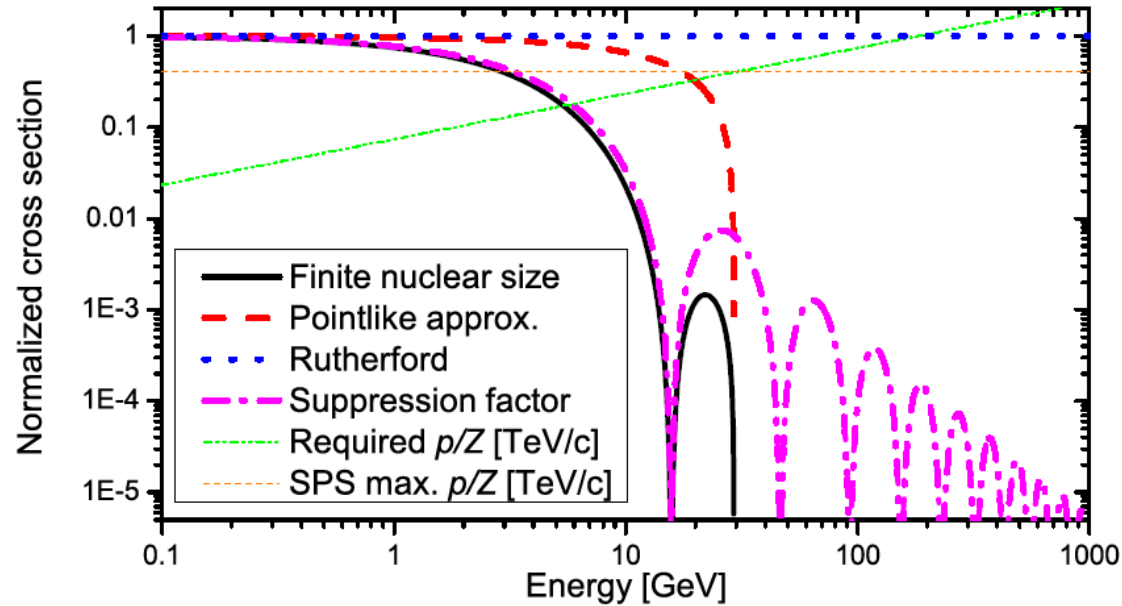


Peak structure
due to finite
nuclear size

Heavy ion bremsstrahlung

Delta-electrons

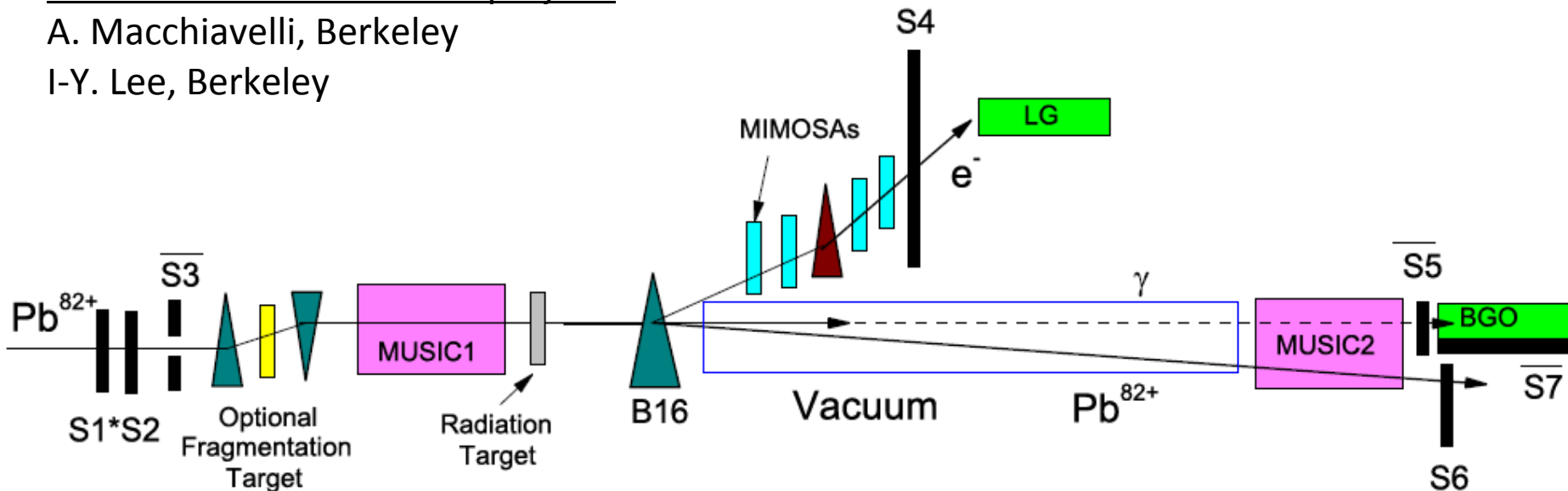
'Oscillations' due to finite nuclear size



New collaborators for this project:

A. Macchiavelli, Berkeley

I-Y. Lee, Berkeley



Publications, NA63

- Up to 2011:
 - 4 NuclInstrMethB, 1 JPhysB, 1 JPhysConfSer, 2 PRD, 1 PRL
- In 2012:
 1. Mangiarotti, P. Sona, S. Ballestrero, K.K. Andersen and U. I. Uggerhøj:
Comparison of analytical and Monte Carlo calculations of multi-photon effects in bremsstrahlung emission by high-energy electrons, Nucl. Instr. Meth. B **289** 5-17 (2012)
 2. K.K. Andersen, S.L. Andersen, J. Esberg, H. Knudsen, R. Mikkelsen, U.I. Uggerhøj, P. Sona, A. Mangiarotti, T.J. Ketel and S. Ballestrero (CERN NA63): *Direct measurement of the formation length of photons*, Phys. Rev. Lett. **108** 071802 (2012); see also accompanying Physics Synopsis and Science Daily.
 3. K.K. Andersen, J. Esberg, H. Knudsen, H.D. Thomsen, U.I. Uggerhøj, P. Sona, A. Mangiarotti, T.J. Ketel, A. Dizdar and S. Ballestrero (CERN NA63): *Experimental investigations of synchrotron radiation at the onset of the quantum regime*, Phys. Rev. D **86**, 072001 (2012)
- ‘In the pipeline’ (to be finished in 2013):
 - Low-Z LPM
 - *Structured targets*