

Physics program with a low energy e-e, e- γ , γ - γ collider, and e-beam on target at IRIDE

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International Conference on the Structure and the Interactions of the Photon
including the 20th International Workshop on Photon-Photon Collisions
and the International Workshop on High Energy Photon Linear Colliders

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PHOTON 2013 Paris 23 May 2013

IRIDE

Interdisciplinary Research Infrastructure with Dual Electron linacs&lasers

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on behalf of

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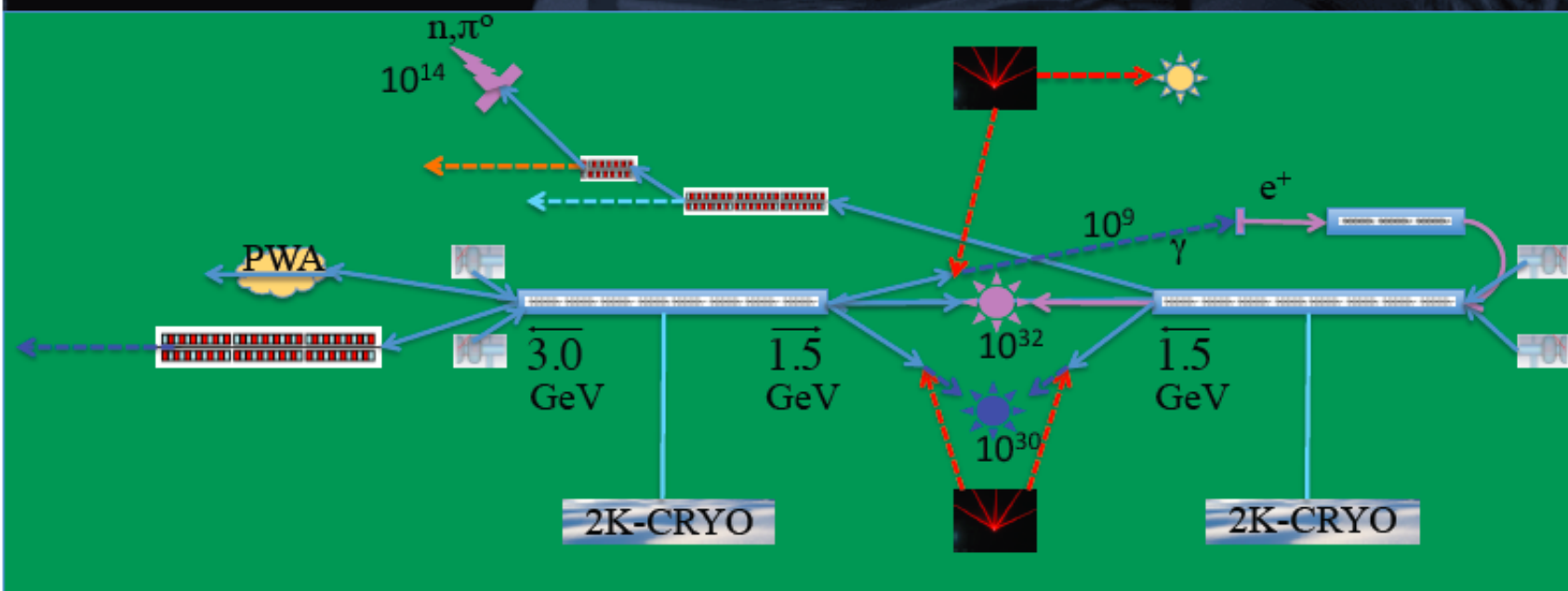
IRIDE

Interdisciplinary Research Infrastructure with Dual Electron
linac&laser

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on behalf of

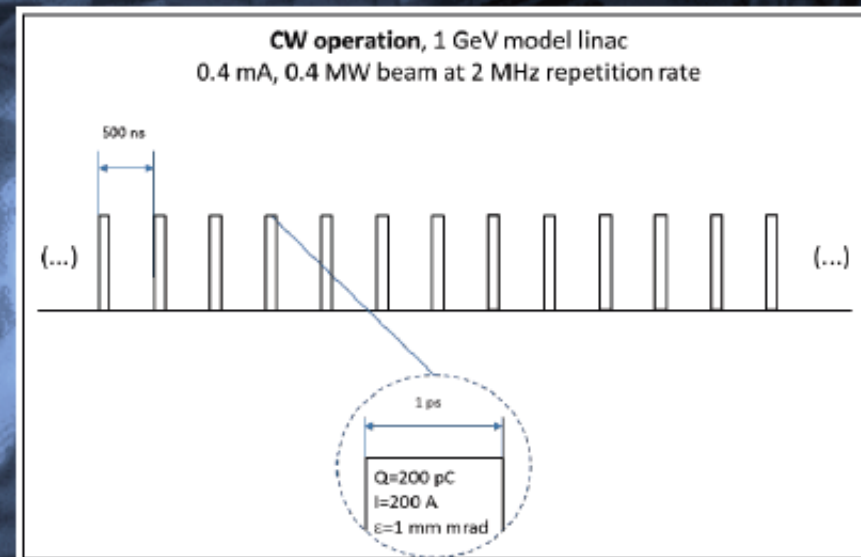
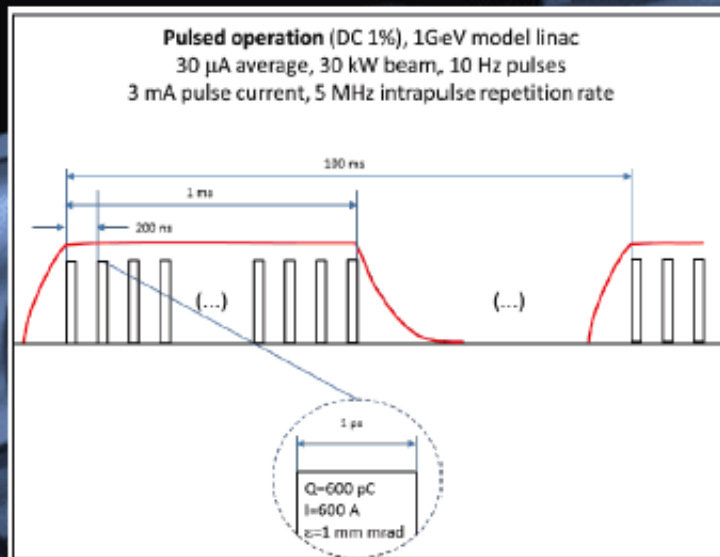
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- (16) CNISM and Università' di Roma"La Sapienza"

technological and industrial applications, it will be a high priority”.



Based on a combination of a **high duty cycle radio-frequency superconducting electron linac** (SC RF LINAC) and of **high energy lasers** it will be able to produce a high flux of **electrons, photons (from infrared to γ -rays), neutrons, protons and eventually positrons**, that will be available for a wide national and international scientific community interested to take profit of the most advanced particle and radiation sources.

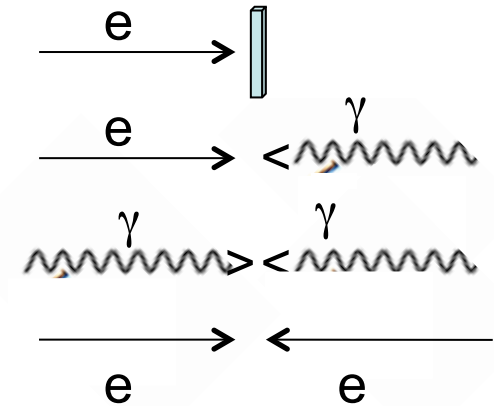
The main feature of a **SC linac relevant for IRIDE** is the possibility to operate the machine in **continuous (CW)** or **quasi-continuous wave (qCW)** mode with high average beam power (**>1 MW**) and high average current (**>300 μA**).



The **CW or qCW** choice, combined with a proper bunch distribution scheme, offers the **most versatile solution to provide bunches to a number of different experiments**, as could be envisaged in a multi-purpose facility.

At IRIDE we will consider 4 different scenarios:

- Electron beam on target, $E_e \sim 0.1\text{-}3\text{ GeV}$
- $e\text{-}\gamma$ interaction, $E_e \sim 0.1\text{-}1.5\text{ GeV}$; $E_\gamma: 1\text{-}50\text{ MeV}$
- $\gamma\text{-}\gamma$ interaction $\sqrt{s} \sim 1\text{ MeV}$
- $e\text{-}e^-$ and e^+e^- interactions ($\sqrt{s} \sim 3\text{ GeV}$)



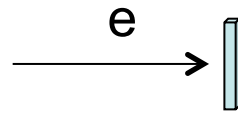
Physics case:

- Precision tests of QED, QCD, EW sectors of the SM at low energy
- Search for Physics beyond SM
- Test of QM
- Other motivations

Theory is the Standard Model:
 $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ local gauge theory
broken to $SU(3)_{\text{QCD}} \otimes U(1)_{\text{QED}}$
by the Higgs mechanism

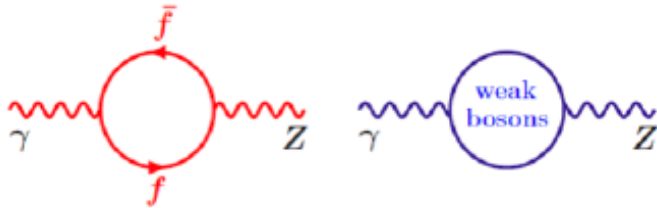
Testing EW sector at IRIDE

(with electron beam on target)

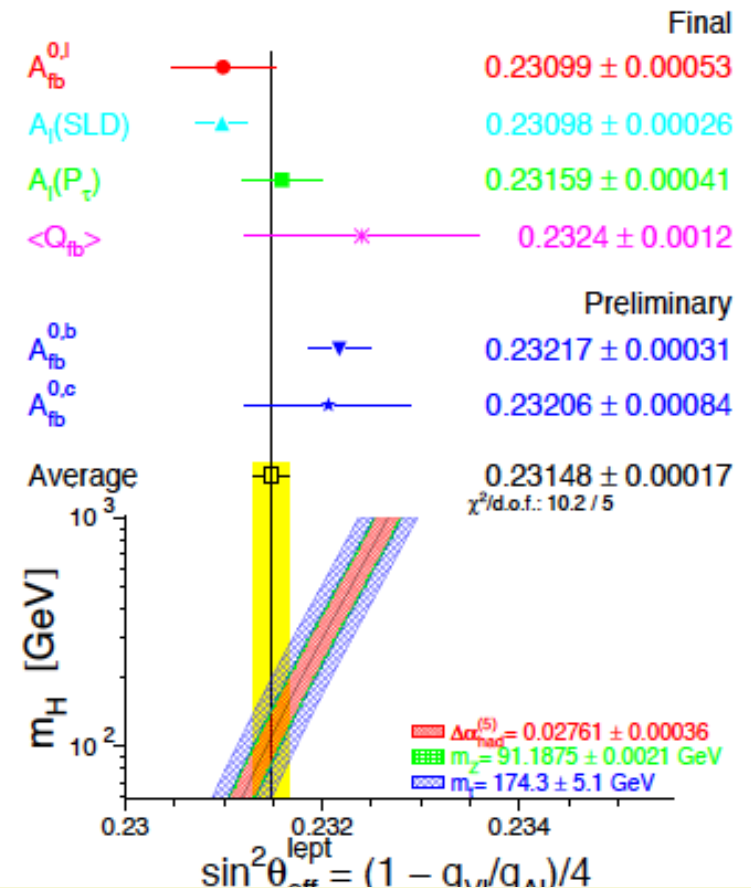
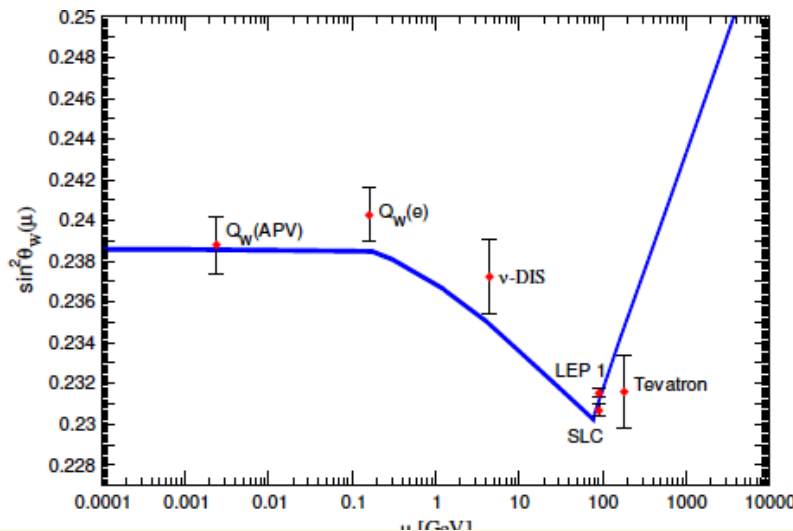


Precision Test of the EW sector of the SM

- $\sin^2 \theta_W = (e/g)^2 = 1 - (M_W/M_Z)^2$ a key parameter of the SM
- Incorporates: $SU(2)_L \times U(1)_Y$ + Higgs Mechanism + Renormalizability
- Rad. Corrections strongly correlated with masses of top quark, Higgs, New Physics!



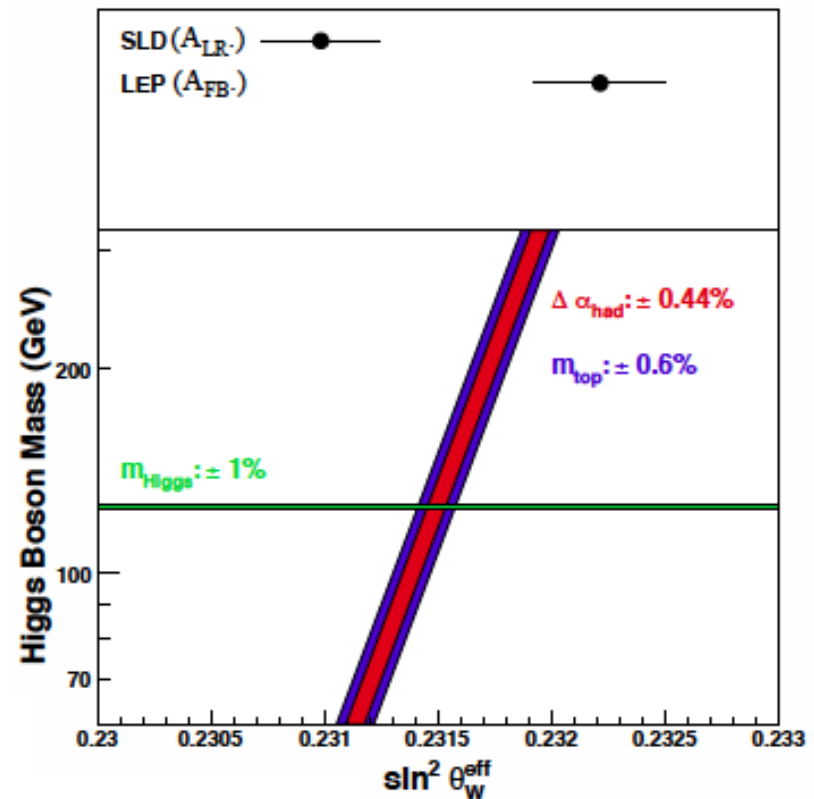
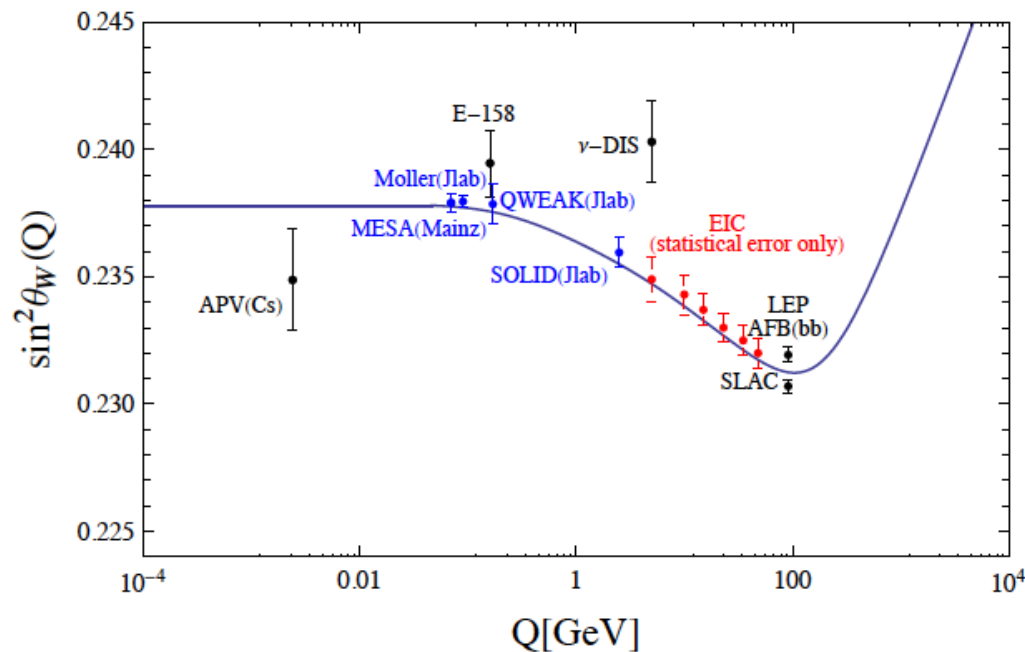
- Low $Q^2 \Rightarrow$ High sensitivity to New Physics



See e.g. 2011/12 Review of Particle Properties: Sec. 10. ELECTROWEAK MODEL AND CONSTRAINTS ON NEW PHYSICS (Erler & Langacker)

EW Precision Physics after Higgs Discovery

K.S.Kumar, S.Mantry, W.J.Marciano and P.A.Souder,
 “Low Energy Measurements of the Weak Mixing Angle”
 arXiv:1302.6263 [hep-ex].



Experimental status:

- 2 precision measurement at LEP and SLC/SLD on Z pole
- Low Energy experiments (e-e-, Neutrino scattering, APV)
- New measurements at JLAB and Mainz (e- on p target)

A Low-Q² Measurement of $\sin^2\theta_w$ at IRIDE

- Scattering of longitudinally polarized electrons on unpolarized protons
- Z boson exchange in e-p scattering introduces parity-violating effect
- Measure parity-violating Left-Right cross section Asymmetry A_{LR}

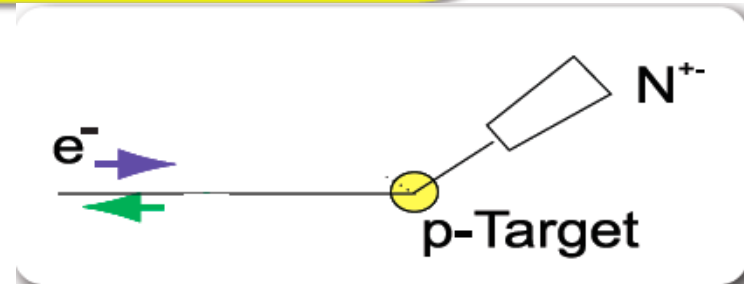
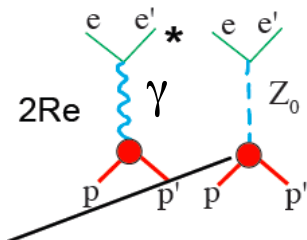
$$A_{LR} = \frac{\sigma(e \uparrow) - \sigma(e \downarrow)}{\sigma(e \uparrow) + \sigma(e \downarrow)} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} (Q_W - F(Q^2))$$

$$Q_W = 1 - 4\sin^2\theta_w(\mu)$$

↑
hadron structure

IRIDE Goal:
Measure A_{LR} of with ~1-2% precision

V-A: parity
violating
asymmetry

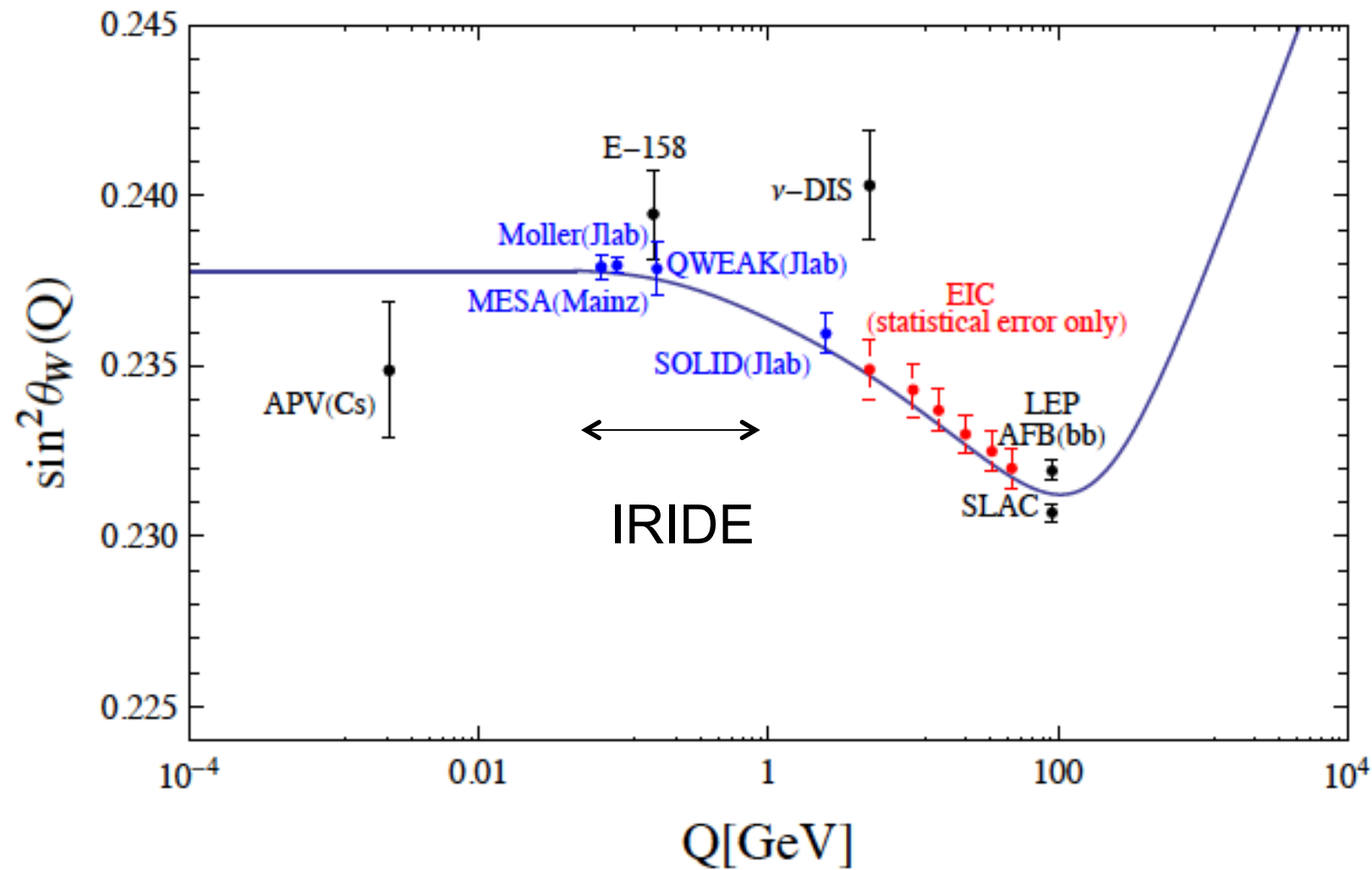


Comparison with present and future experiments:

PARAM.	QWEAK @JLAB (2006-2012)	P2@MAINZ (>2017)	IRIDE
E_e (GeV)	~1.1	0.2	0.1-3
P_e	89%	85%	?
Curr (μ A)	180	150	>300
θ_e (deg)	8	20	
Q^2 (GeV ²)	0.03	0.0048	0.001-1
Apv (ppm)	0.28	0.02	
δ Apv (%)	2.1 _{sys} +1.3 _{sta}	1.7	Goal:1-2%
δs_w (%)	0.3	0.15	Goal: ~0.1%
Rate (TH)	6.4 x10 ⁻³	0.5	
Time (h)	2x10 ³	10 ⁴	
H ₂ Target (cm)	35	60	

Very challenging measurement:

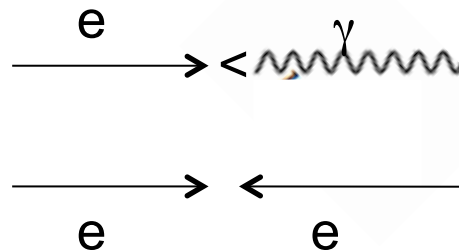
- Control of the electron beam and target density fluctuations.
- Control of e- beam polarization
- False Asymmetries
- Systematics of the detector at <1% level



IRIDE: $Q^2 = 0.001 \text{ GeV}^2$ ($E_e = 100 \text{ MeV}$) \div 1 GeV^2 ($E_e = 3 \text{ GeV}$)
 (Assuming $\theta = 20^\circ$) $Q \sim 40 \text{ MeV} \div 1 \text{ GeV}$

Testing QCD sector at IRIDE

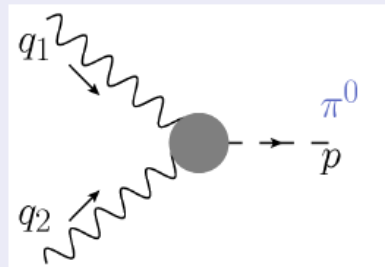
(with electron-photon and e-e interactions)



Precision Test of fundamental prediction of QCD: Measurement of π^0 decay width

- This is a very important measurement which tests the QCD behaviour at low energy. The transition is mainly due to the axial current anomaly (Adler, Bell, Jackiw):

Massless QCD exact prediction



$$\Rightarrow \frac{\alpha}{\pi f_0} \epsilon_{\mu\nu\alpha\beta} q_1^\alpha q_2^\beta$$

f_0 — pion decay constant in the **chiral limit**
(we don't know the value of f_0)

- There are theoretical corrections which bring $f_0 \rightarrow f_\pi = 92.42 \pm 0.25$ MeV, leading to non perturbative QCD prediction (leading order)

$$\Gamma(\pi^0 \rightarrow \gamma\gamma) = \frac{\alpha^2 m_\pi^3}{64 \pi^3 f_\pi^2} = (7.725 \pm 0.044) \text{eV}$$

Corrections to pion decay width

- NNLO ChPT

[Kampf, Moussallam, PoS (CD09) 039 (2009)]

- NLO ChPT $\oplus 1/N_c$

[Goity, Bernstein, Holstein, Phys.Rev. D66 076014 (2002)]

- QCD sum rules

[Moussallam, Phys. Rev. D51, 4939(1995)]

✓ agree very well, **theory uncertainty $\sim 1\%$**

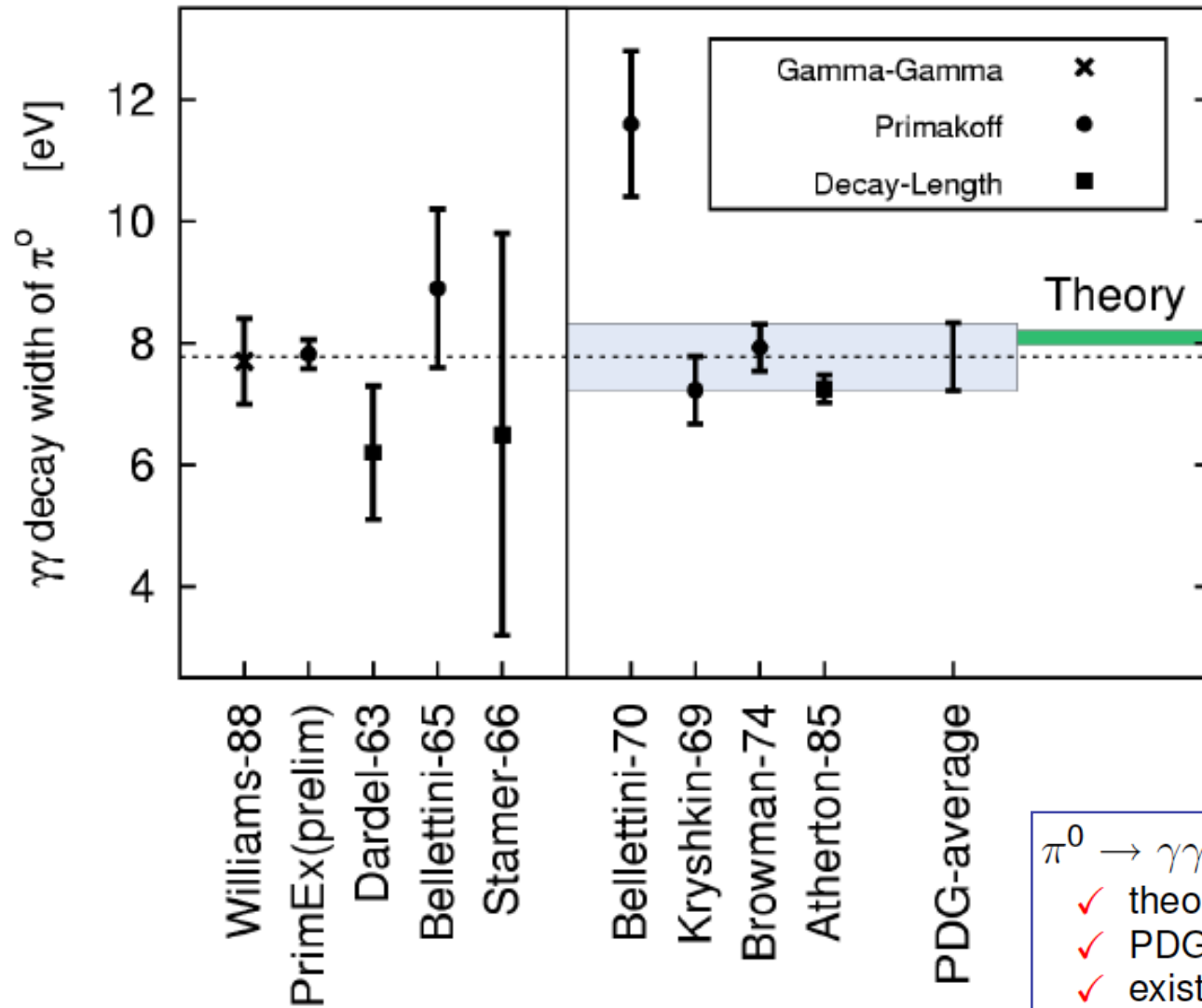
NNLO theory prediction

$$\Gamma(\pi^0 \rightarrow \gamma\gamma) = (8.09 \pm 0.11)\text{eV}$$

[K.Kampf, B.Moussallam, PoS (CD09) 039 (2009)]

(including isospin breaking and mixing)

Experimental status of $\pi^0 \rightarrow \gamma\gamma$ width

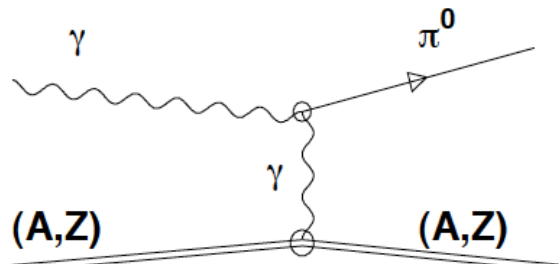


$\pi^0 \rightarrow \gamma\gamma$ decay width (π^0 lifetime)

- ✓ theory prediction uncertainty $\sim 1\%$
- ✓ PDG error $> 7\%$
- ✓ existing data are over 25 years old

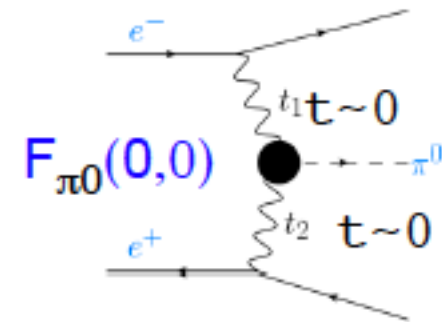
Current experimental activities to measure $\Gamma(\pi^0 \rightarrow \gamma\gamma)$ at 1%

Primex (JLAB): $\gamma N \rightarrow \pi^0 N$

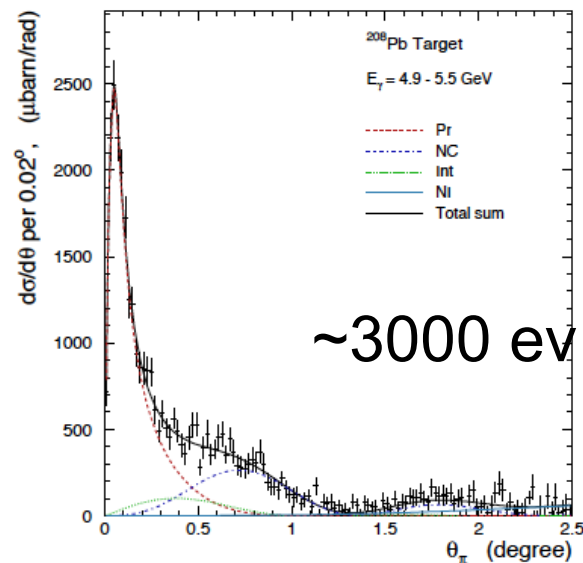


$$\frac{d\sigma_{Pr}}{d\Omega} = \Gamma(\pi^0 \rightarrow \gamma\gamma) \frac{8\alpha Z^2}{m^3} \frac{\beta^3 E^4}{Q^4} |F_{EM}(Q)|^2 \sin^2 \theta_\pi$$

KLOE-2 (LNF): $ee \rightarrow \pi^0 ee$



$$\Gamma(\pi^0 \rightarrow \gamma\gamma) \propto |F_{\pi^0}(0,0)|^2$$



~ 3000 ev

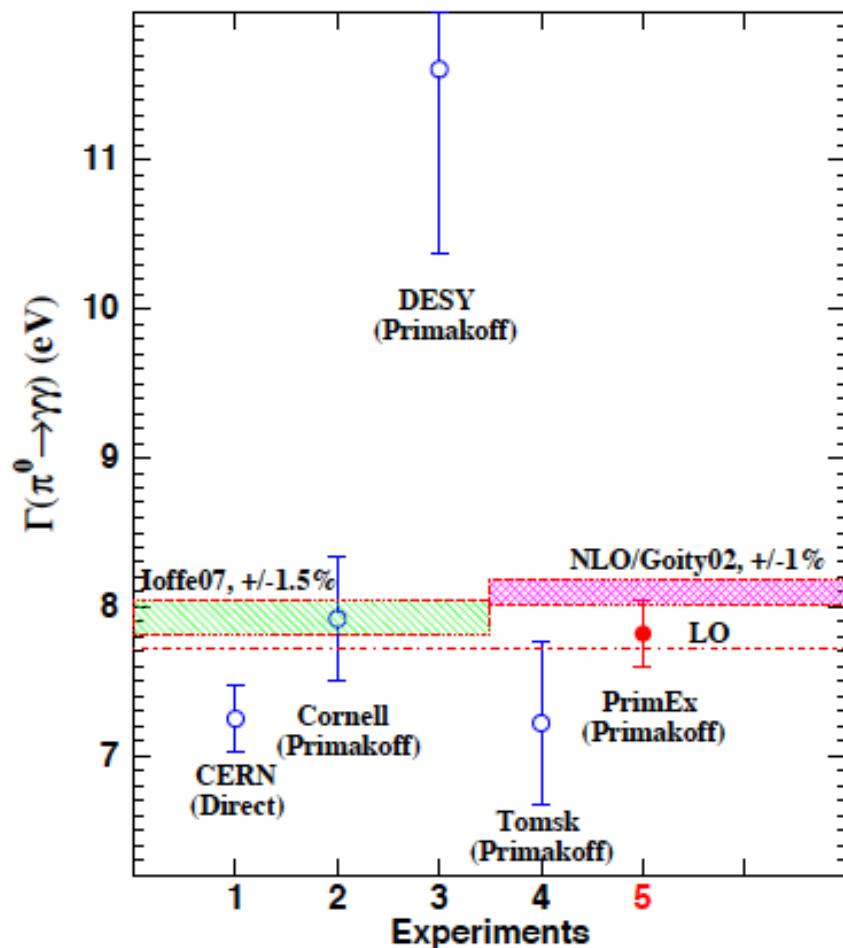
$$\sigma_{\text{obs}} \sim 3 \text{ pb}$$

10^4 events with $L \sim 3 \text{ fb}^{-1}$

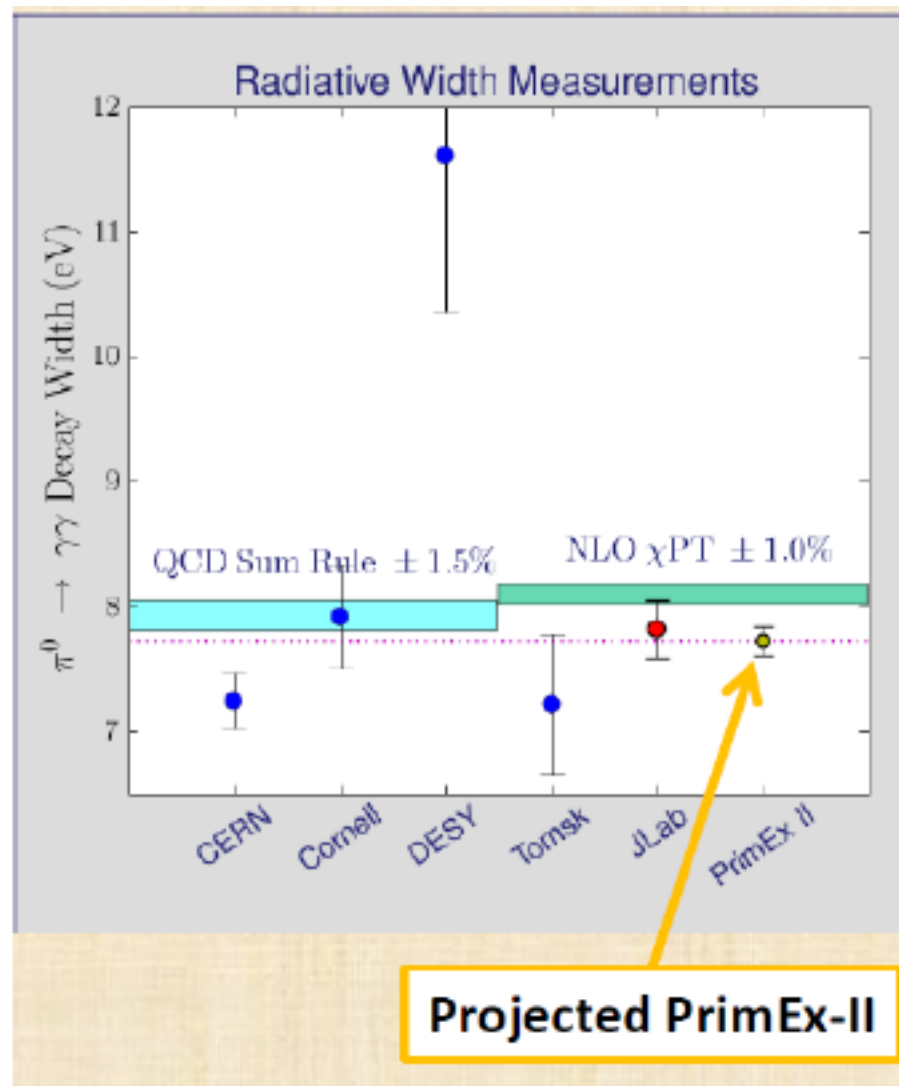
1% is a challenging measurement!!!

Primex result: PRL 106 (2011) 162303

$$\Gamma(\pi^0 \rightarrow \gamma\gamma) = 7.82 \pm 0.14 \text{ (stat.)} \pm 0.17 \text{ (syst.) eV}.$$



2.8% total error (before was 7%!)

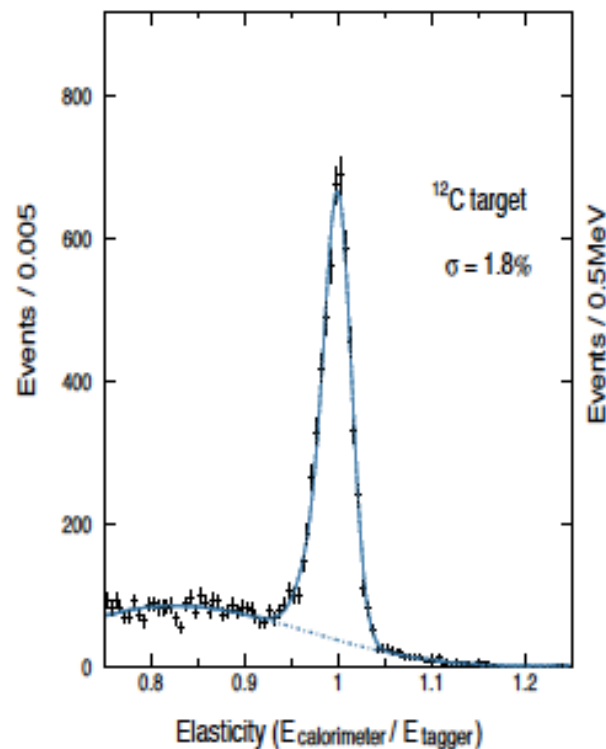


Goal of 1.4% (0.4% stat)

Primex result: PRL 106 (2011) 162303

angular bin. The typical background in the event selection process was only a few percent of the real signal events (see Fig. 2). However, the uncertainty of 1.6% in the background extraction in this much upgraded experiment still remained one of the largest contributions to the total systematic uncertainty.

Nuclear background is an issue!



ward angles. The cross section of this process can be expressed by four terms: Primakoff (Pr), nuclear coherent (NC), interference between strong and Primakoff amplitudes (Int), and nuclear incoherent (NI):

$$\begin{aligned}\frac{d\sigma}{d\Omega} &= |T_{Pr} + e^{i\varphi}T_S|^2 + \frac{d\sigma_{NI}}{d\Omega} \\ &= \frac{d\sigma_{Pr}}{d\Omega} + \frac{d\sigma_{NC}}{d\Omega} + \frac{d\sigma_{Int}}{d\Omega} + \frac{d\sigma_{NI}}{d\Omega},\end{aligned}$$

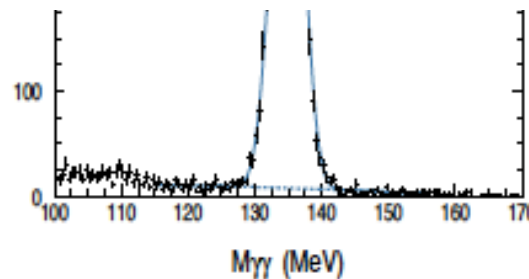


FIG. 2: Typical distribution of reconstructed “elasticity” (left panel) and $M_{\gamma\gamma}$ (right panel) for one angular bin.

1.6% syst error comes from uncertainty on background (nuclear) subtraction

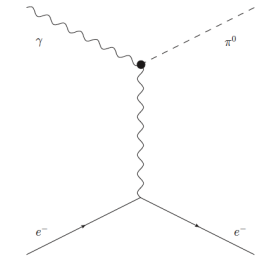
How $\Gamma(\pi^0 \rightarrow \gamma\gamma)$ measurement at IRIDE would compare with Primex?

- Both uses **Primakoff** scattering
- **Electron** (IRIDE) vs **Nuclear** target (Primex)
- $E_\gamma = 10\text{-}20$ MeV (IRIDE) vs $E_\gamma \sim 5$ GeV (Primex)
- Much cleaner environment at IRIDE.
- Higher intensity photon beam at IRIDE compensates for the lower cross section ($d\sigma$ Primakov $\sim Z^2$ (~ 10000)):
 $\approx \sigma \sim 1\text{-}2$ nb (500-750 MeV) at IRIDE.
- With a luminosity of **10^{30} cm⁻² sec⁻¹** and 50% detector efficiency: **$N_{\text{ev}} \sim 10^4$ evts/year**, sufficient to reach 1% stat error in one year.

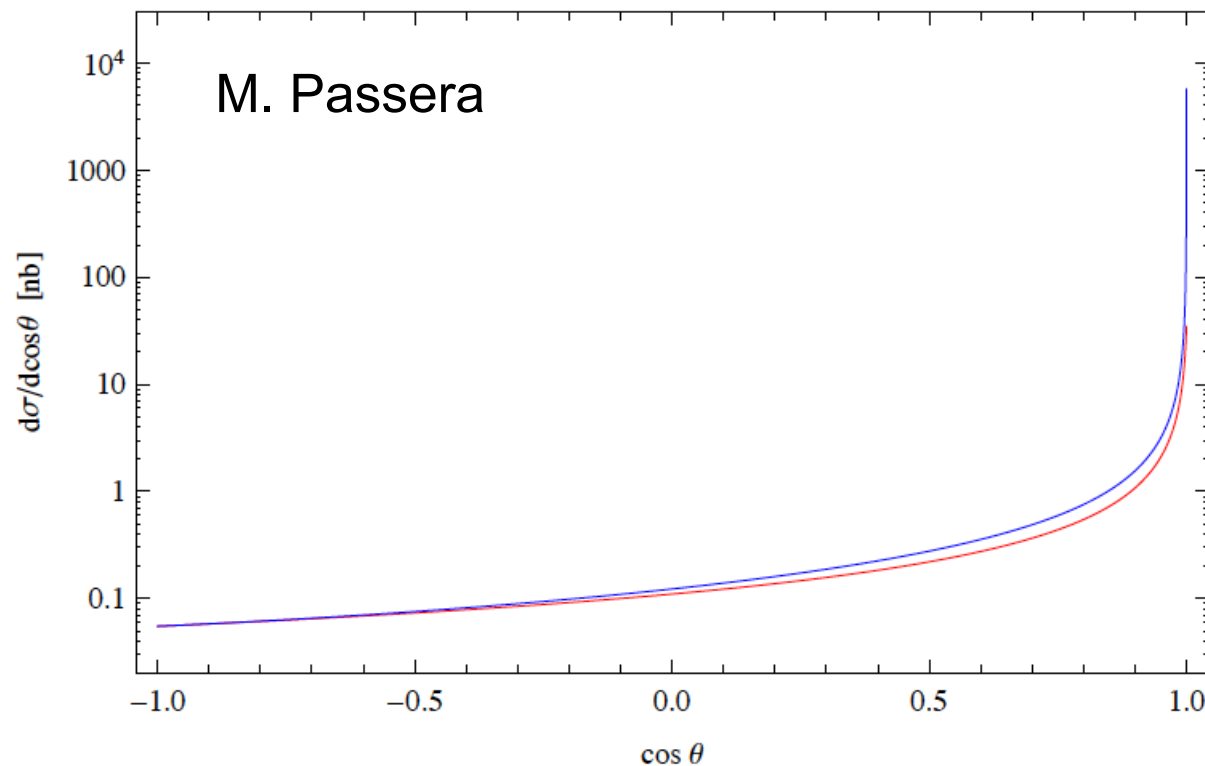
Competitive to Primex but in a much cleaner environment → important for the systematics

$\Gamma(\pi^0 \rightarrow \gamma\gamma)$ important also for HLbL (it fixes $|F_{\pi^0}(0,0)|^2$)

The scattering $\gamma + e^- \rightarrow \pi^0 + e^-$



$$\frac{d\sigma}{d\cos\theta} = \frac{\alpha^3}{32\pi^2 f_\pi^2} \frac{\left[\left((M-m)^2 - s \right) \left((M+m)^2 - s \right) \right]^{\frac{1}{2}}}{st(m^2 - s)} \left[(M^2 - s - t)^2 + s^2 + 2m^2 \left(M^4/t + m^2 - M^2 - 2s \right) \right],$$



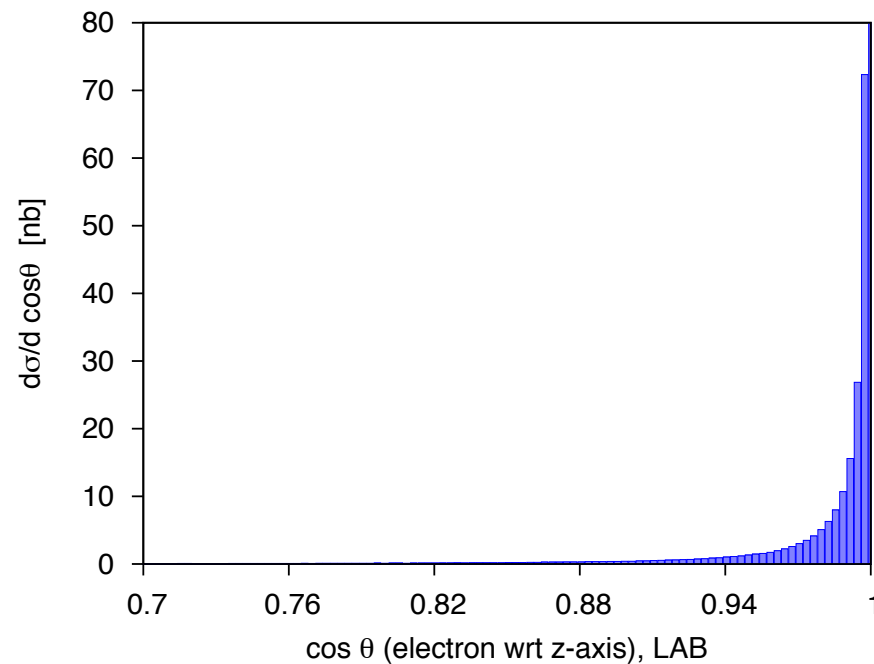
$E_e = 750 \text{ MeV}$
 $E_\gamma = 20 \text{ MeV}$
 $\sigma = 2 \text{ nb}$

$E_e = 500 \text{ MeV}$
 $E_\gamma = 10 \text{ MeV}$
 $\sigma = 0.7 \text{ nb}$

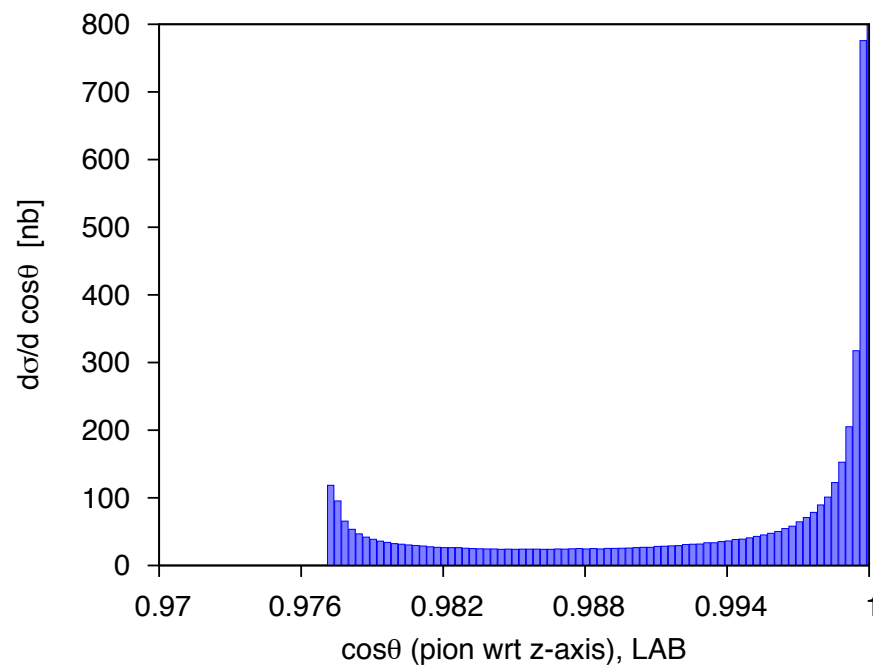
A feasibility study is going on with a MC generator (S. Ivashyn)

“Preliminary” results from MC:

Courtesy of S. Ivashyn

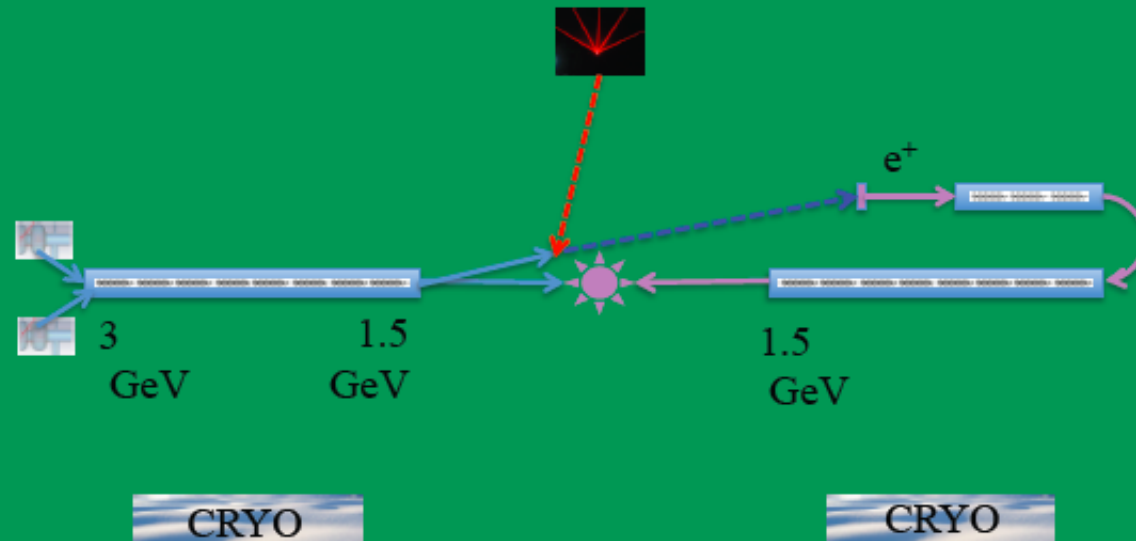


$E_e = 750$ MeV
 $E_\gamma = 20$ MeV
 $\sigma = 2$ nb



$e^+ e^-$ Linear Collider

An electron-positron collider with luminosity of $10^{32} \text{ cm}^{-2}\text{s}^{-1}$ with center of mass energy ranging from the mass of the ϕ -resonance 1 GeV up to $\sim 3.0 \text{ GeV}$, would complement high-energy experiment at the LHC and future linear collider (ILC). Such a machine can easily collect an integrated luminosity of about 5 fb^{-1} in a few years of data taking.



This will allow one to measure the e^+e^- cross section to hadrons with a total fractional accuracy of 1%, a level of knowledge that has relevant implications for the determination of SM observables, like, the $g-2$ of the muon and the effective fine-structure constant at the M_Z scale. The latter are, through quantum effects, sensitive to possible bSM physics at scales of the order of hundred GeV or TeV.

Parameters	Units	Electrons \times Electrons	Electrons \times Positrons	Reduced Positron quality
Beam energy	[GeV]	1	1	1
Beam power	[MW]	1	1	0.4
AC power	[MW]	1.9	1.9	1.3
Charge	[nC]	0.2	2	0.8
Bunch length rms	[μm]	500	675	450
Peak current	[A]	120	888	533
Rep. rate	[MHz]	5	0.5	0.5
Average current	[mA]	1	1	0.4
Transverse rms spot at IR	[μm]	0.5	1.5	1.5
Norm. emittance	[μm]	1	2	10
Beta at IR	[mm]	0.5	2.6	0.45
Aspect ratio	A	1	0.3	1
Disruption parameter	D	-3.5	5.3	1.4
Beam-strahlung parameter	δ_e	$\sim 10^{-7}$	$\sim 10^{-7}$	$\sim 10^{-7}$
Luminosity enhancement factor	H_D	(<) 1	5.8	1.3
Luminosity	$\text{cm}^{-2}\text{s}^{-1}$	$\sim 2.5 \cdot 10^{32}$	$1.6 \cdot 10^{33}$	$\sim 1.1 \cdot 10^{32}$

e^+e^- collider

Physics opportunities with an e^+e^- collider with c.o.m. energy tunable within $[\sim 0.5, \sim 3.0]$ GeV

- ✓ hadronic cross-section meas. $e^+e^- \rightarrow \gamma^* \rightarrow \text{had.}$
 - hadronic contribution to muon a.m.m. a_μ
 - hadronic contribution to α_{em}
- ✓ two-photon physics $e^+e^- \rightarrow e^+e^- \gamma^* \gamma^* \rightarrow e^+e^- + \text{had.}$
 - $\text{had.} \equiv \pi^0, \eta, \eta' \rightarrow$ light-by-light contribution to a_μ^{had}
 - meson spectroscopy
- ✓ exotics
$$\begin{aligned} e^+e^- \rightarrow \gamma \text{ U} &\rightarrow \gamma \ell^+ \ell^-, \\ &\rightarrow \gamma E_{\text{miss.}} \end{aligned}$$
 - possible existence of low-energy ($0.1 \div 1$ GeV) new gauge interactions (dark forces)

e^+e^- collider

LNF-10/17(P)

see also Eur. Phys. J. C **50** (2007) 729

Proposal for taking data with the KLOE-2 detector at the DAΦNE collider upgraded in energy

D. Babusci^a, C. Bini^b, F. Bossi^a, G. Isidori^a, D. Moricciani^c, F. Nguyen^d, P. Raimondi^a,
G. Venanzoni^a, D. Alesini^a, F. Archilli^e, D. Badoni^a, R. Baldini-Ferroli^{a,f},
M. Bellavoglia^a, G. Bencivenni^a, M. Bertani^a, M. Biagini^a, C. Biscari^a, C. Bloise^a,
V. Bocci^d, R. Boni^a, M. Boscolo^a, P. Branchini^d, A. Budano^d, S.A. Bulychjev^g,
B. Buonomo^a, P. Campana^a, G. Capon^a, M. Castellano^a, F. Ceradini^d, E. Chiadroni^a,
P. Ciambione^a, L. Cultrera^a, E. Czerwinski^a, E. Danó^a, G. Delle Monache^a, E. De
Lucia^a, T. Demma^a, G. De Robertis^f, A. De Santis^b, G. De Zorzi^b, A. Di Domenico^b,
C. Di Donato^g, B. Di Micco^d, E. Di Pasquale^a, G. Di Pirro^a, R. Di Salvo^a, D. Domenici^a,
A. Drago^a, M. Esposito^a, O. Erriquez^f, G. Felici^a, M. Ferrario^a, L. Ficcadenti^a,
D. Filippetto^a, S. Fiore^b, P. Franzini^b, G. Franzini^a, A. Gallo^a, G. Gatti^a, P. Gauzzi^b,
S. Giovannella^a, A. Ghigo^a, F. Gonnella^c, E. Graziani^d, S. Guiducci^a, F. Happacher^a,
B. Høistad^h, E. Iarocci^{a,i}, M. Jacewicz^b, T. Johansson^h, W. Kluge^j, V.V. Kulikov^k,
A. Kupec^h, J. Lee Franzini^a, C. Ligti^a, F. Loddo^f, P. Lukin^b, F. Marcellini^a,
C. Marchetti^a, M.A. Martemianov^l, M. Martini^a, M.A. Matsyuk^l, G. Mazzitelli^a,
R. Messi^c, C. Milardi^a, M. Mirazzita^a, S. Miscetti^a, G. Morello^l, P. Moskal^m,
S. Müllerⁿ, S. Pacetti^{a,r}, G. Pancheri^a, E. Pasqualucci^b, M. Passera^o, A. Passeri^d,
V. Patera^{a,i}, A.D. Polosa^b, M. Preger^a, L. Quintieri^a, A. Ranieri^f, P. Rossi^a, C. Sanelli^a,
P. Santangelo^a, I. Sarra^a, M. Schioppa^l, B. Sciascia^a, M. Serio^a, F. Sgammà^a,
M. Silarski^m, B. Spataro^o, A. Stecchi^h, A. Stella^a, S. Stucci^f, C. Taccini^d, S. Tomassini^a,
L. Tortora^d, C. Vaccarezza^a, R. Versaci^p, W. Wislicki^q, M. Wolke^h, J. Zdebik^m,
M. Zobov^a

arXiv:1007.5219v1 [hep-ex] 29 Jul 2010

e^+e^- - collider

Requests:

- ✓ luminosity $\sim 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- ✓ energy $\sqrt{s} = (0.6 \div 3.0) \text{ GeV}$ (in steps of $\sim 25 \text{ MeV}$)
- ✓ tagging systems for $\gamma\gamma$ -physics

Positron source \rightarrow Bethe- $\gamma Z \rightarrow e^+e^- Z$

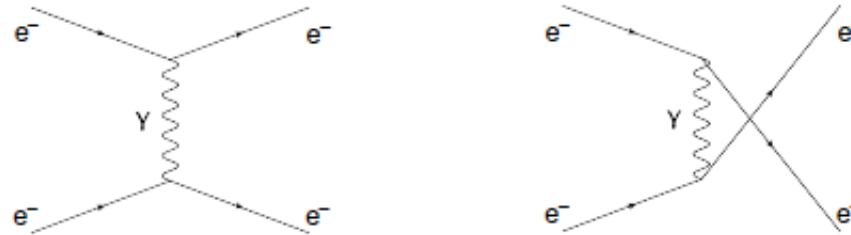
Heitler:
simulation (G4) in progress (collaboration w/ Rm2)

case under study: $E_\gamma = 60 \text{ MeV}$ on Pb ($0.4 X_0$)

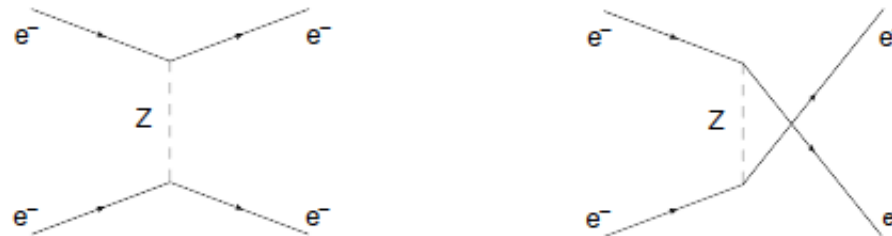
e^-e^- collider

Physics opportunities with an e^-e^- collider have also been explored

- ✓ $\gamma\gamma$ physics \rightarrow as for e^+e^- but w/out the bckg associated to the annihilation channel



- ✓ weak mixing angle $\theta_w \rightarrow$ Moller scattering: γ - Z^0 interference



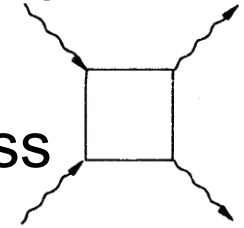
(However required luminosity for a competitive measurement of $\sin^2\theta_w$ looks too high $O(100 \text{ fb}^{-1})$)

Testing QED at IRIDE

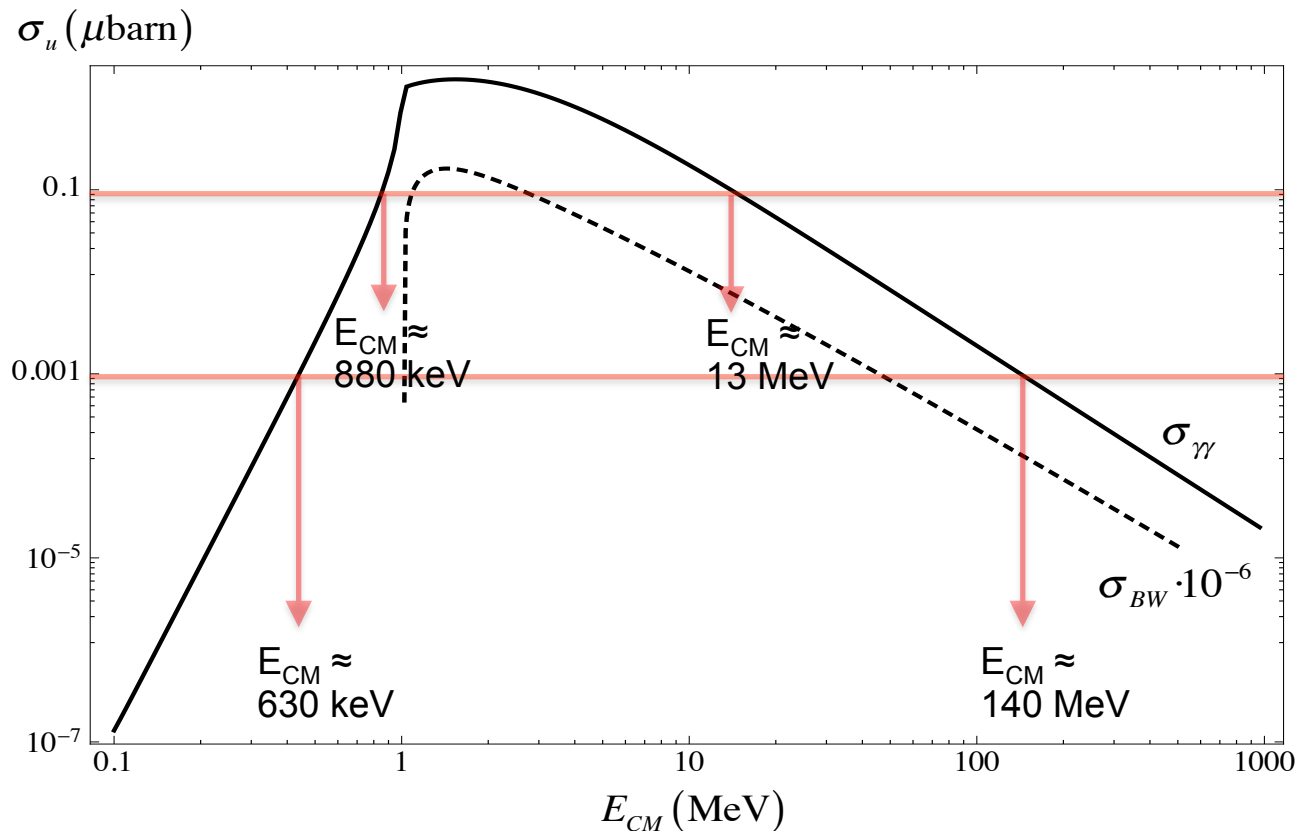
(with photon-photon interaction)



- Photon-photon scattering directly probes the fluctuations of quantum vacuum.
- A photon-photon scattering at $\sqrt{s} \sim 1$ MeV (where the cross section is higher) would be an important test for our understanding of QED Vacuum

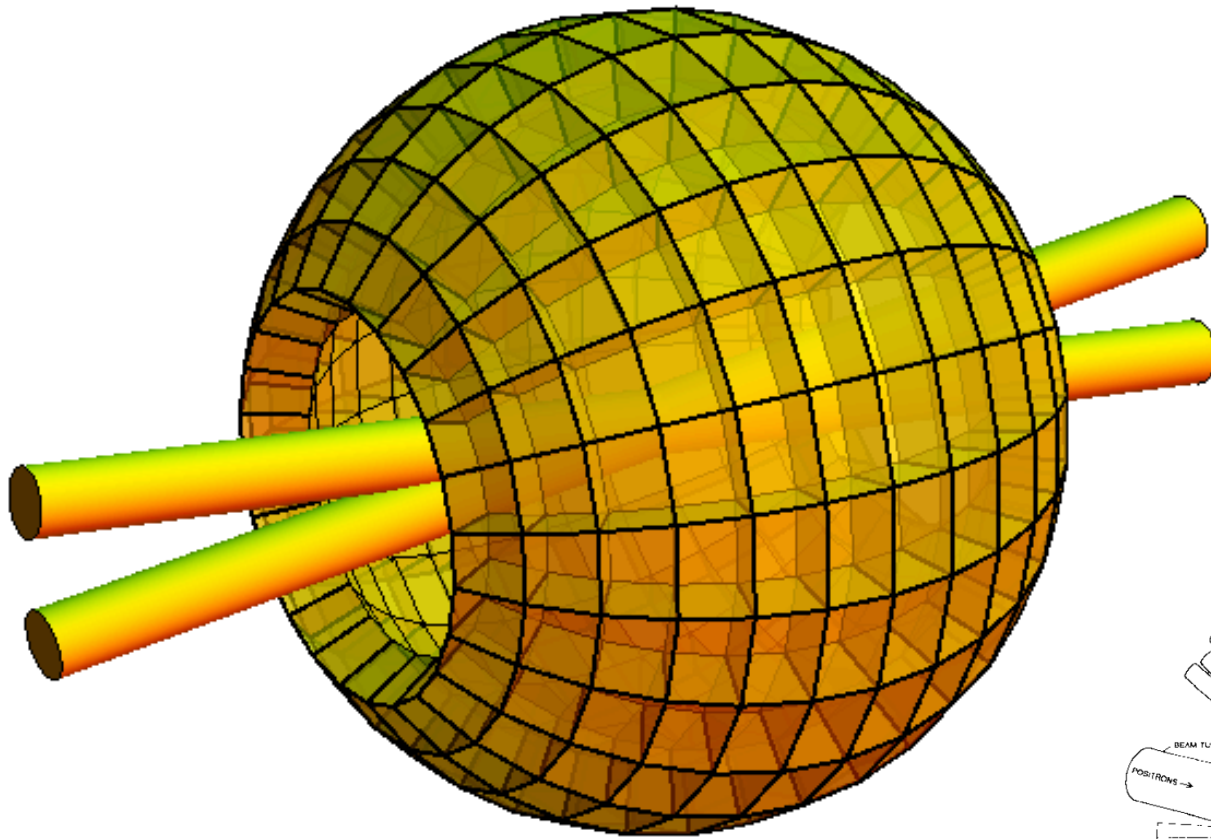


integrated luminosity corresponding to a bare minimum of about 100 scattering events (total).

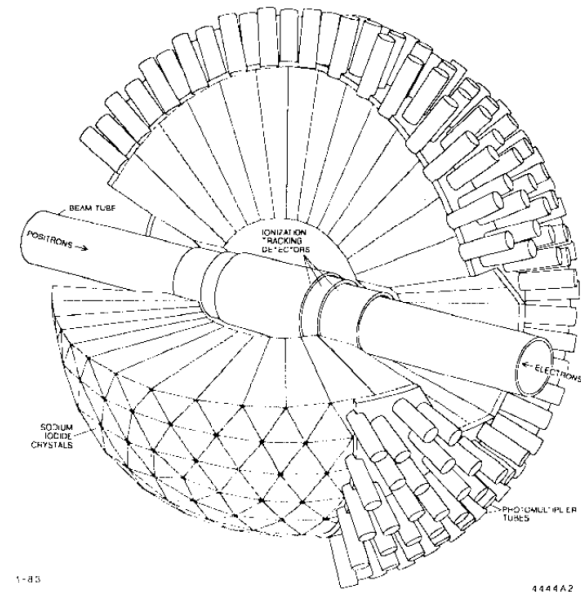


1 nb^{-1}

10 pb^{-1}

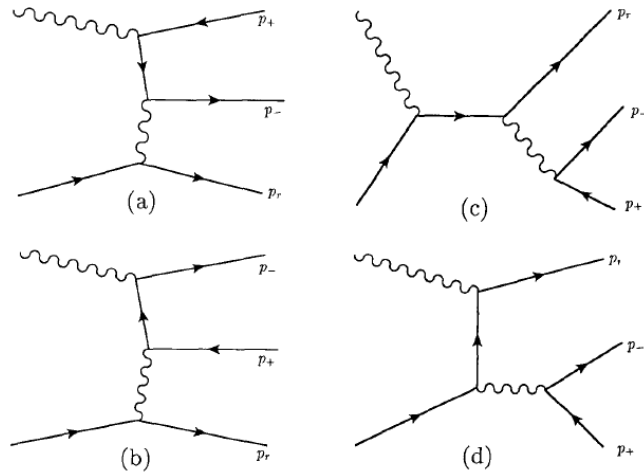


PET-like, segmented detector



... somewhat similar to Crystal Ball

Precision test of QED prediction: Triplet photoproduction $e^- \gamma \rightarrow e^- \gamma^* \rightarrow e^- e^+ e^-$



-This process is very important to determine the linear polarization of the photon (at $E_\gamma > 500$ MeV). It has astrophysical implications (Gamma-rays Polarization)

$$\frac{d\sigma}{d\varphi} = \frac{\sigma_0}{2\pi} (1 + P_\gamma \lambda \cos(2\varphi))$$

λ =analyzing power

- Existing measurements differ from theor

Azimuthal angle of e^-

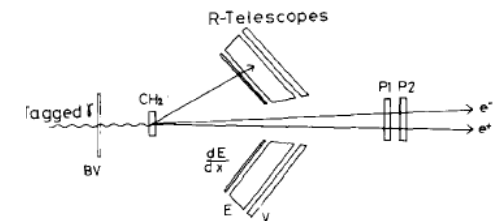
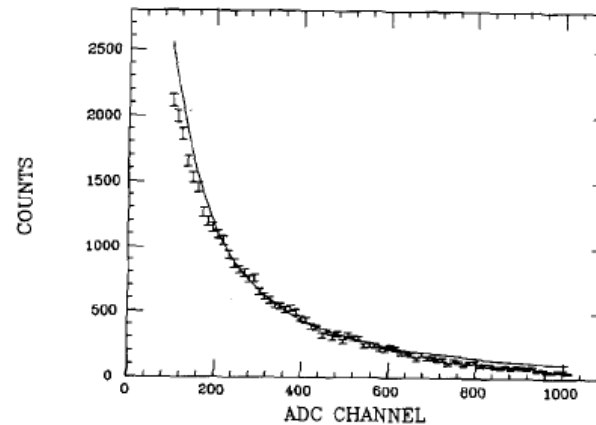
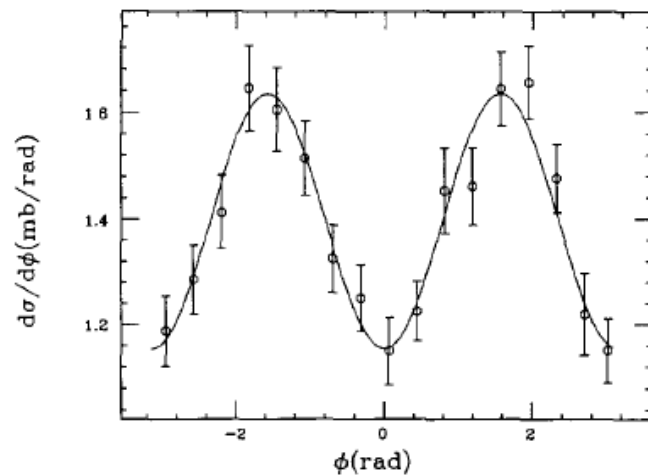


Fig. 1. Experimental layout.

Luminosity and Beam requirements for $\gamma\gamma$ and $e\gamma$

Parameters for ELI-NP case	Units	Thomson Compton Source	$\gamma\gamma$ collider	$e\gamma$ collider
Beam energy	[GeV]	0.1-1	0.1-1	0.1-1
Beam power	[MW]	< 0.003	< 0.003	< 0.003
Charge	[nC]	0.5	0.5	0.5
Bunch length rms	[μm]	300	300	125
Peak current	[A]	200	200	1600
effective Rep. rate	[Hz]	60x100	60x100	60x100
Average current	[μA]	3	3	3
rms spot size at collision	[μm]	5	1	0.25
coll. Laser eff. Power	[kW]	0.1	0.1	0.1
coll. Laser pulse energy	[J]	1	1	1
rms norm. emittance	[μm]	0.5	1	1
beta-funct. at coll. (1 GeV)	[mm]	100	2	0.125
Luminosity	$\text{cm}^{-2}\text{s}^{-1}$	n.d.	$1.6 \cdot 10^{28}$	$1.3 \cdot 10^{30}$

\downarrow
 10^2 nb^{-1}

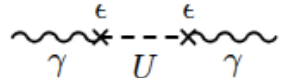
\downarrow
 10^4 nb^{-1}

Parameters for SC-CW case	Units	Thomson Compton Source	$\gamma\gamma$ collider	$e\gamma$ collider
Beam energy	[GeV]	0.1-1	0.1-1	0.1-1
Beam power	[MW]	0.1-1	0.1-1	0.1-1
AC power	[MW]			
Charge	[nC]	0.5	0.5	0.5
Bunch length rms	[μm]	300	300	125
Peak current	[A]	4	4	32
Rep. rate	[MHz]	2	2	2
Average current	[μA]	1000	1000	1000
rms spot size at collision	[μm]	5	1	0.25
coll. Laser eff. Power	[kW]	1000	1000	1000
coll. Laser pulse energy	[J]	0.01	0.01	0.01
rms norm. emittance	[μm]	0.5	1	1
beta-funct. at coll. (1 GeV)	[μm]	100	2	0.125
Luminosity	$[\text{cm}^{-2}\text{s}^{-1}]$	n.d.	$5.4 \cdot 10^{26}$	$4.6 \cdot 10^{30}$

Search for New Physics at IRIDE (e- on target and e- γ interactions)

Search for physics BSM

- In the recent years, the existence of new light weakly interacting bosons (“**u bosons**”) has been proposed to explain “puzzling” astrophysical observations (Integral, Pamela, Atic, Fermi, WMAP, Hess, Dama/Libra)
- This u boson can communicate with the SM through a kinetic mixing term of the form:

$$\mathcal{L}_{\text{mix}} = -\frac{\epsilon}{2} F_{\mu\nu}^{\text{em}} F_{\text{DM}}^{\mu\nu} \quad (\epsilon \ll 1) .$$


- It could explain the **3.6σ deviation between the SM and experimental value of $(g-2)_\mu$**
- This boson is light ($M_U \sim \text{MeV-GeV scale}$) and can be searched in e^+e^- collider and at fixed target experiments

⇒ A lot of experimental activities (and theo. papers)!

arXiv:1205.2709v1

The Muon Anomaly and Dark Parity Violation

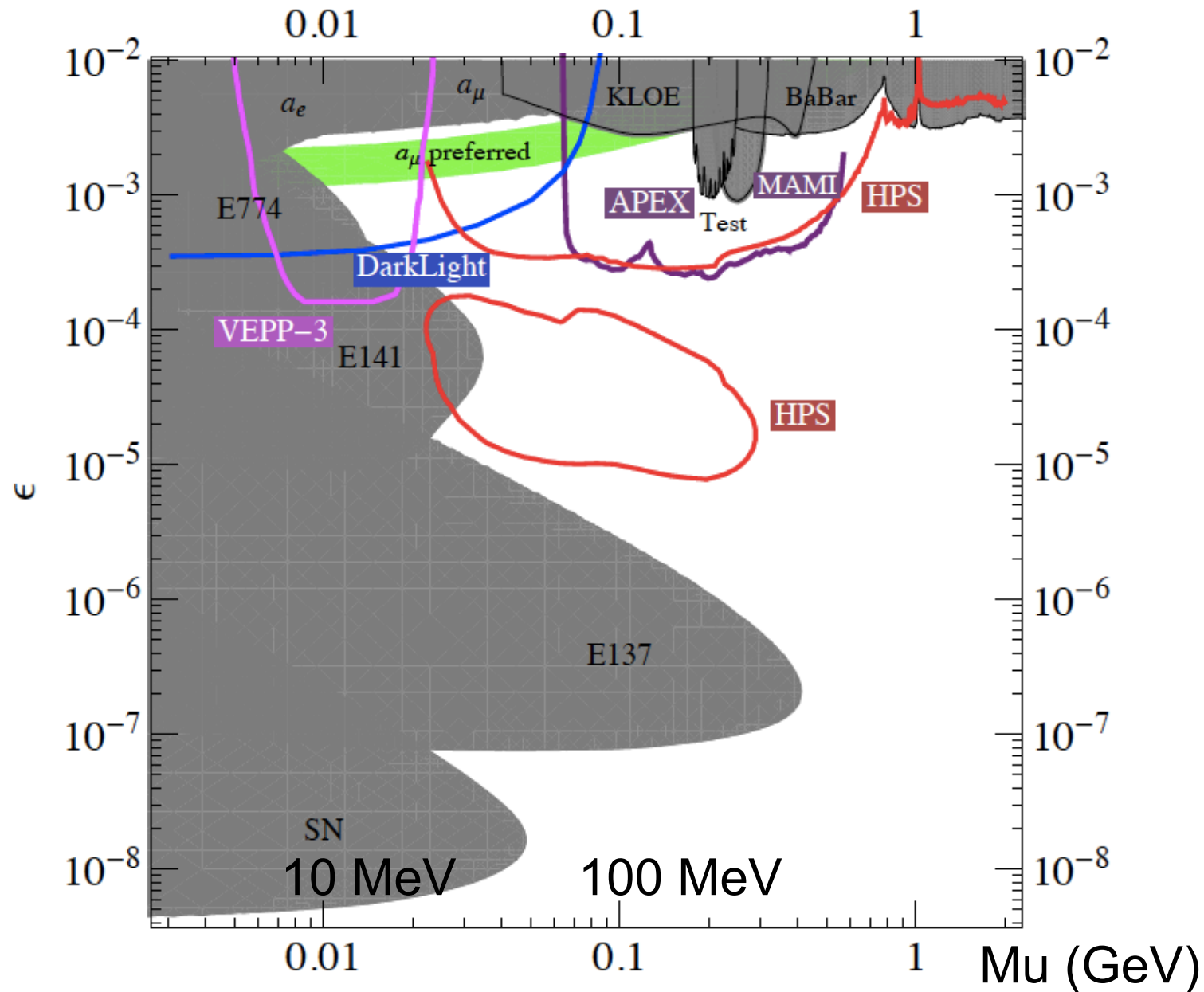
Hooman Davoudiasl*, Hye-Sung Lee[†], and William J. Marciano[‡]

Department of Physics, Brookhaven National Laboratory, Upton, NY 11973, USA

(Dated: May 2012)

The muon anomalous magnetic moment exhibits a 3.6σ discrepancy between experiment and theory. One explanation requires the existence of a light vector boson, Z_d (the dark Z), with mass $10 - 500$ MeV that couples weakly to the electromagnetic current through kinetic mixing. Support for such a solution also comes from astrophysics conjectures regarding the utility of a $U(1)_d$ gauge symmetry in the dark matter sector. In that scenario, we show that mass mixing between the Z_d and ordinary Z boson introduces a new source of “dark” parity violation which is potentially observable in atomic and polarized electron scattering experiments. Restrictive bounds on the mixing $(m_{Z_d}/m_Z)\delta$ are found from existing atomic parity violation results, $\delta^2 < 2 \times 10^{-5}$. Combined with future planned and proposed polarized electron scattering experiments, a sensitivity of $\delta^2 \sim 10^{-6}$ is expected to be reached, thereby complementing direct searches for the Z_d boson.

90% Exclusion plots: dashed are published meas.;
lines are new projects (arXiv:1205.2671v1)



U bosons can be searched at flavor factories and fixed target experiment

JHEP 0907 (2009) 051

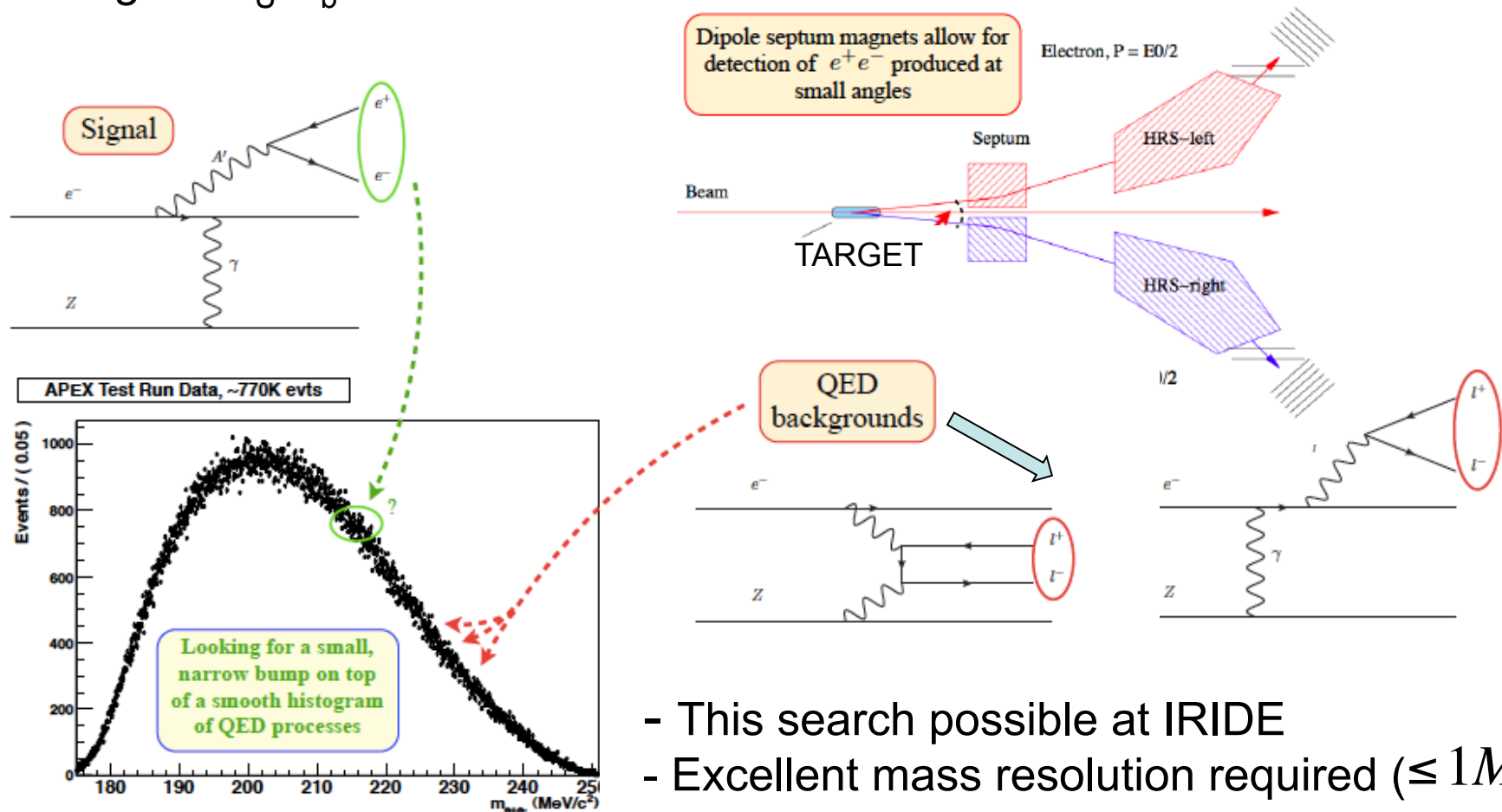
Searching for the light dark gauge boson in GeV-scale experiments

Matthew Reece^{1,*} and Lian-Tao Wang^{2,†}

We study current constraints and search prospects for a GeV scale vector boson at a range of low energy experiments. It couples to the Standard Model charged particles with a strength $\leq 10^{-3} - 10^{-4}$ of that of the photon. The possibility of such a particle mediating dark matter self-interactions has received much attention recently. We consider searches at low energy high luminosity colliders, meson decays, and fixed target experiments. Based on available data, searches both at colliders and in meson decays can discover or exclude such a scenario if the coupling strength is on the larger side. We emphasize that a dedicated fixed target experiment has a much better potential in searching for such a gauge boson, and outline the desired properties of such an experiment. Two different optimal designs should be implemented to cover the range of coupling strength $10^{-3} - 10^{-5}$, and $< 10^{-5}$ of the photon, respectively. We also briefly comment on other possible ways of searching for such a gauge boson.

U bosons search at IRIDE with e- beam on fixed target: Experimental signature

- Produce low mass hidden gauge bosons with weak coupling to SM via high intensity electron beam incident on fixed high-Z target
- U decays to e^+e^- pair with opening angle $\sim m_U/E_b$



U bosons can be searched in e-gamma collisions?

JHEP 0907 (2009) 051

Searching for the light dark gauge boson in GeV-scale experiments

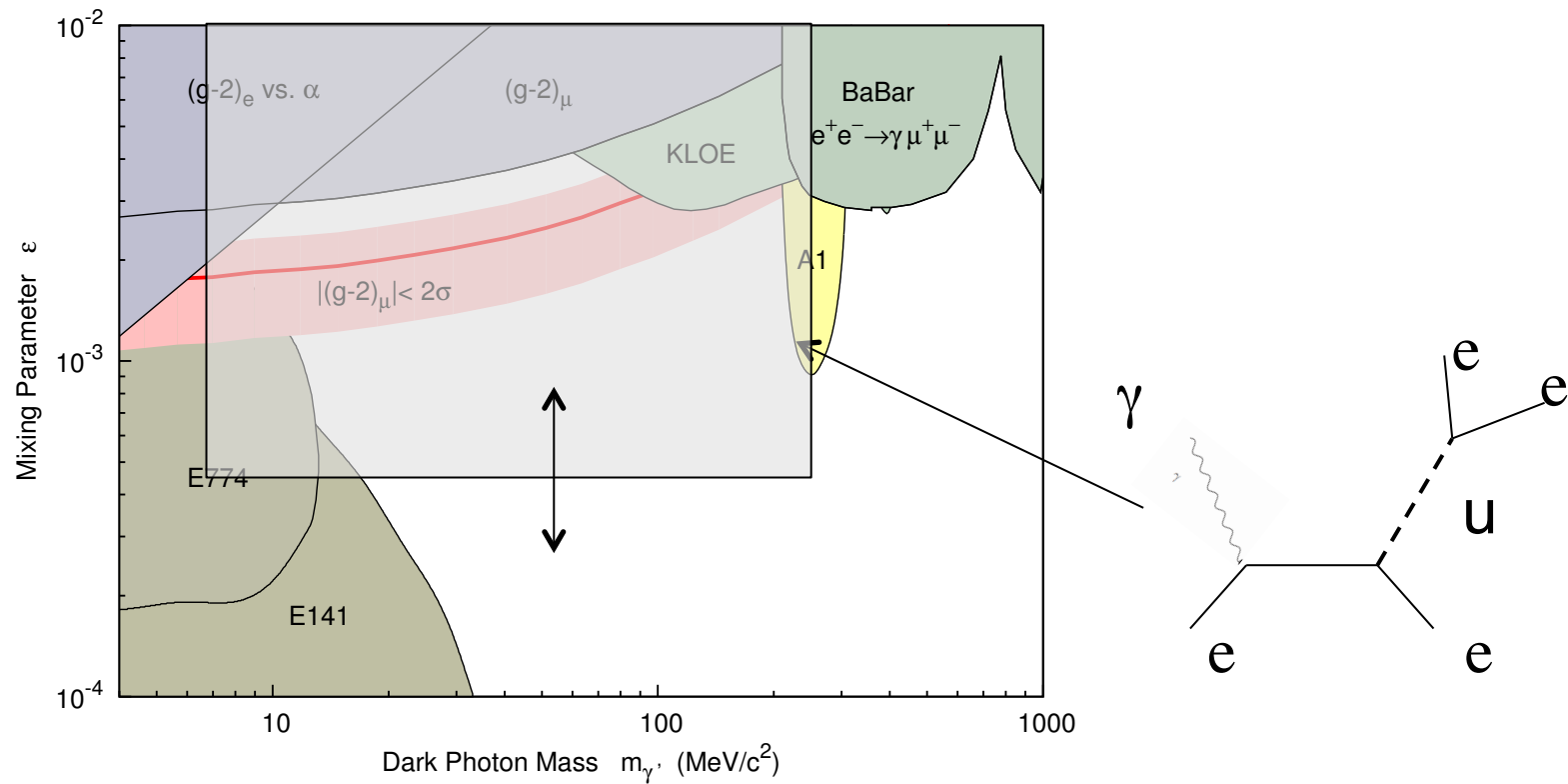
Matthew Reece^{1,*} and Lian-Tao Wang^{2,†}

Another option is to consider the process $e^- \gamma \rightarrow e^- U$. However, it is easy to see that current facilities do not offer a reasonable chance to probe this channel. Because we want a center of mass energy on the order of hundreds of MeV or a few GeV, light sources that supply hard X-rays are insufficient; one would need a gamma ray source. Gamma rays are at Brookhaven [66] and the HI γ S facility at Duke [67], at rates on the order of 10^6 to 10^8 photons per second collimated in spots of about 1 cm. Such beams are insufficient for our purposes.

At IRIDE we could achieve some order of magnitude better, making this search realistic

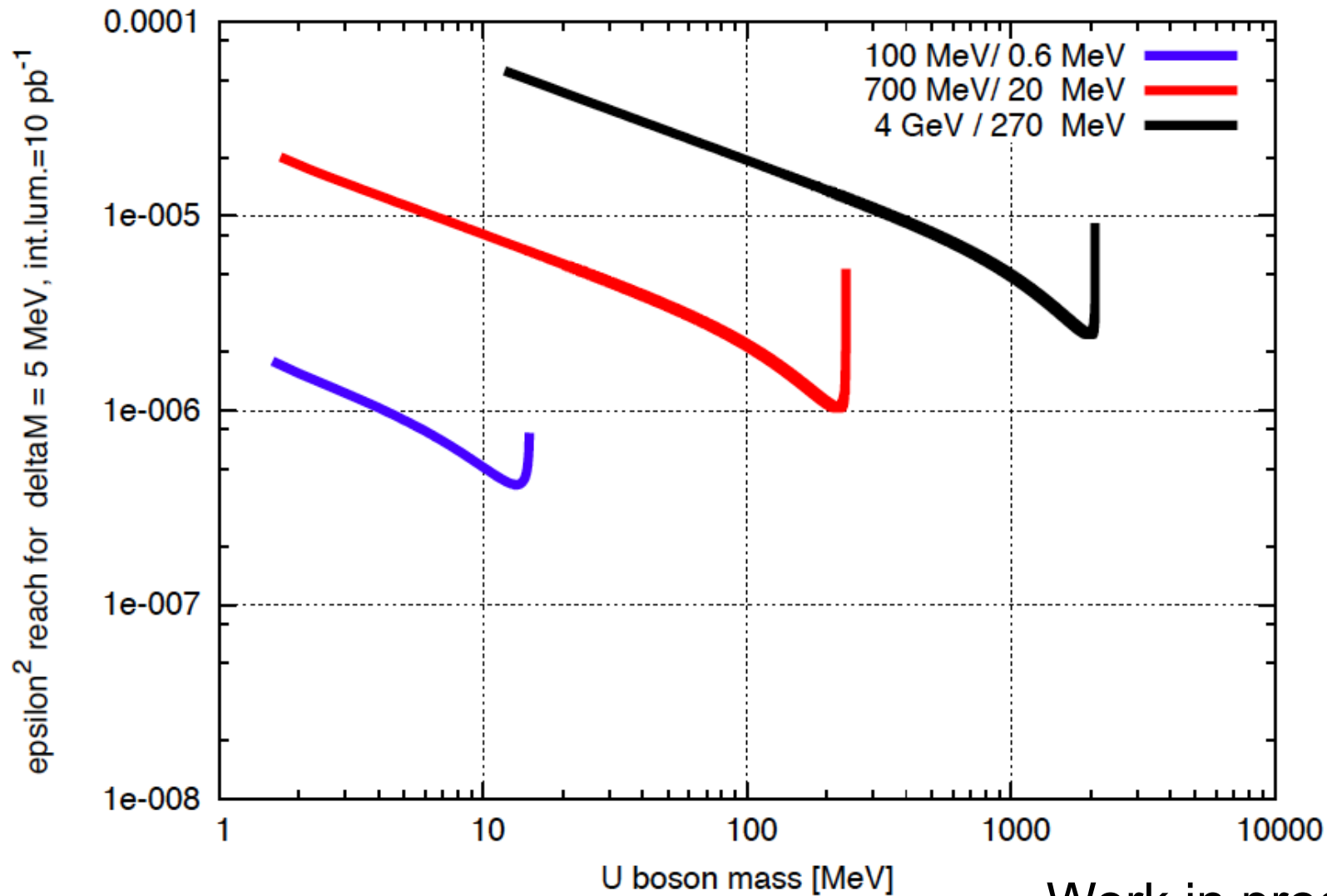
Search for u boson at IRIDE ($M_u < 250$ MeV)

$$\gamma + e^- \rightarrow u + e^- \quad E_e = 100-3000 \text{ MeV and } E_\gamma = 10-50 \text{ MeV,}$$



Sensitivity on ϵ must be estimated (work is in progress)

Very preliminary: sensitivity with e- γ collisions
(courtesy of Ivashyn and Shekhovtsova)



$L > 10^{30}$ needed

Work in progress

Testing QM at IRIDE

Test of QM at IRIDE?

Triple Compton effect:

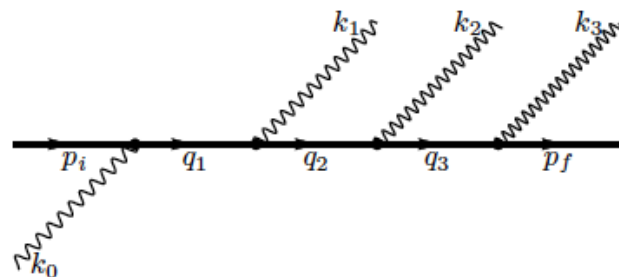
A photon splitting into three upon collision with a free electron

Erik Lötstedt* and Ulrich D. Jentschura

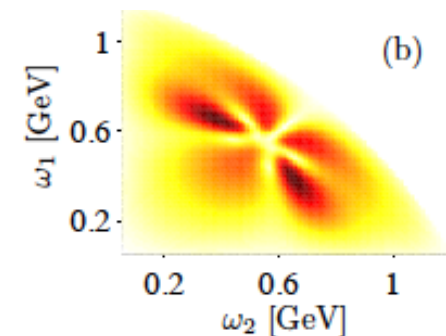
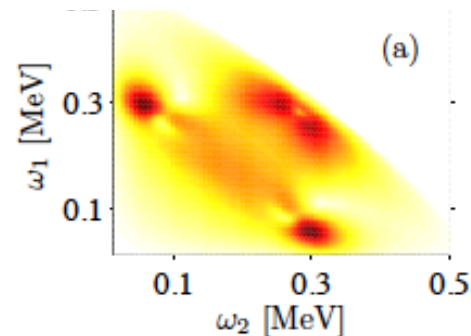
Phys.Rev.Lett. 108 (2012) 233201

The process in which a photon splits into three after the collision with a free electron (triple Compton effect) is the most basic process for the generation of a high-energy multi-particle entangled state composed out of elementary quanta. The cross section of the process is evaluated in two experimentally realizable situations, one employing gamma photons and stationary electrons, and the other using keV photons and GeV electrons of an x-ray free electron laser. For the first case, our calculation is in agreement with the only available measurement of the differential cross section for the process under study. Our estimates indicate that the process should be readily measurable also in the second case. We quantify the polarization entanglement in the final state by a recently proposed multi-particle entanglement measure.

$$e^- + \gamma \longrightarrow e^- + \gamma + \gamma + \gamma.$$



$$\langle \lambda_1 \lambda_2 \lambda_3 | \varrho | \lambda'_1 \lambda'_2 \lambda'_3 \rangle = N \sum_{r_i, r_f} M(\lambda_1 \lambda_2 \lambda_3) M^*(\lambda'_1 \lambda'_2 \lambda'_3),$$



Conclusion (I)

- The physics case offered by IRIDE is very compelling. It would allow to test EW and QCD sectors of the SM, QED, MQ and search for New Physics.
- IRIDE parameters (current, luminosity) look very suited for these precision measurements, making these searches competitive with existing and planned experiments.
- The $e\text{-}\gamma$ and $\gamma\text{-}\gamma$ collider would be an unique feature of this facility

Conclusion (I)

- Realistic studies are in progress. Request on precision (machine, detector) very demanding.
- We are studying in details this physics program. It is very promising with strong opportunities for involvement.

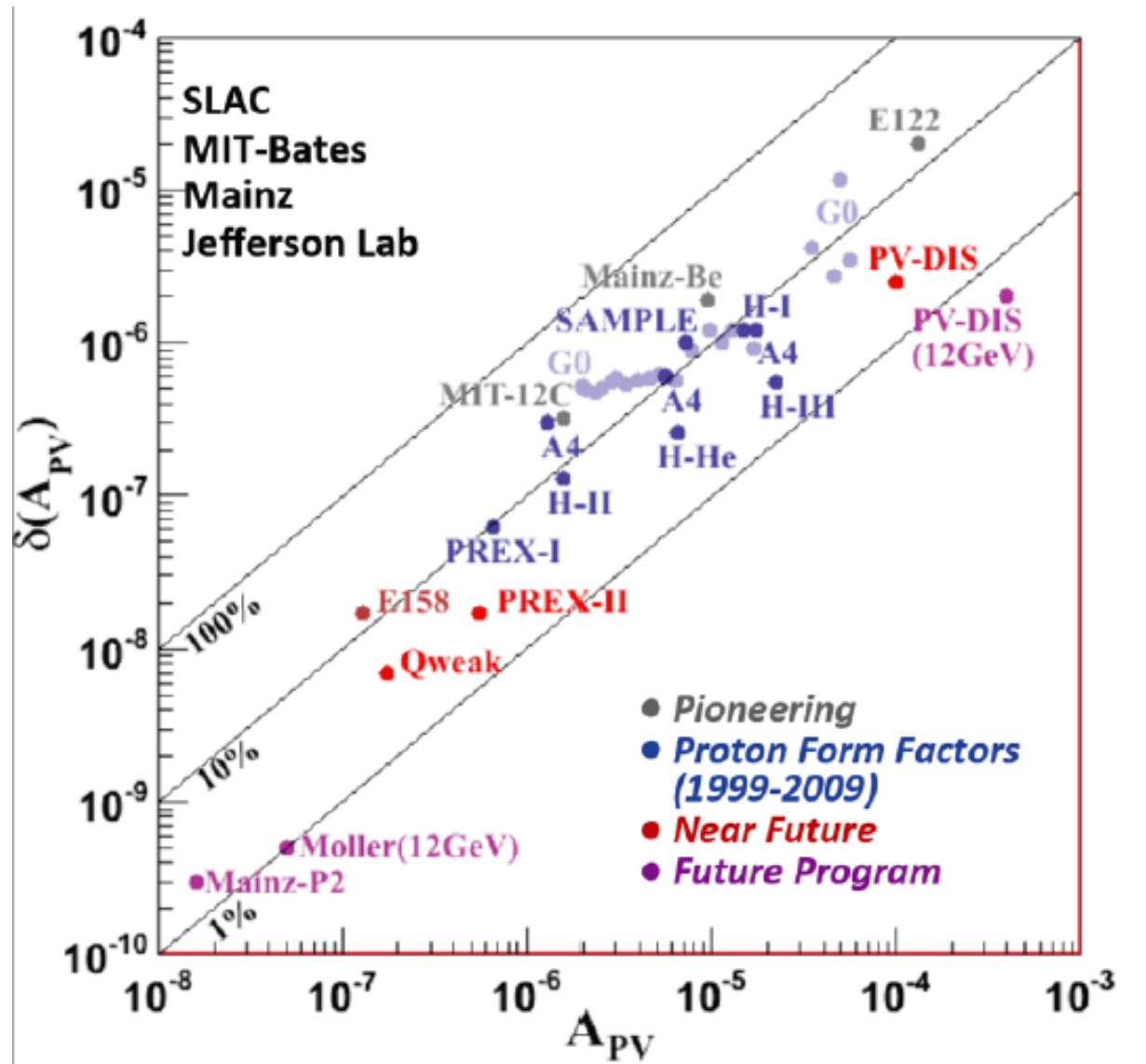
If you are interested you are welcome!

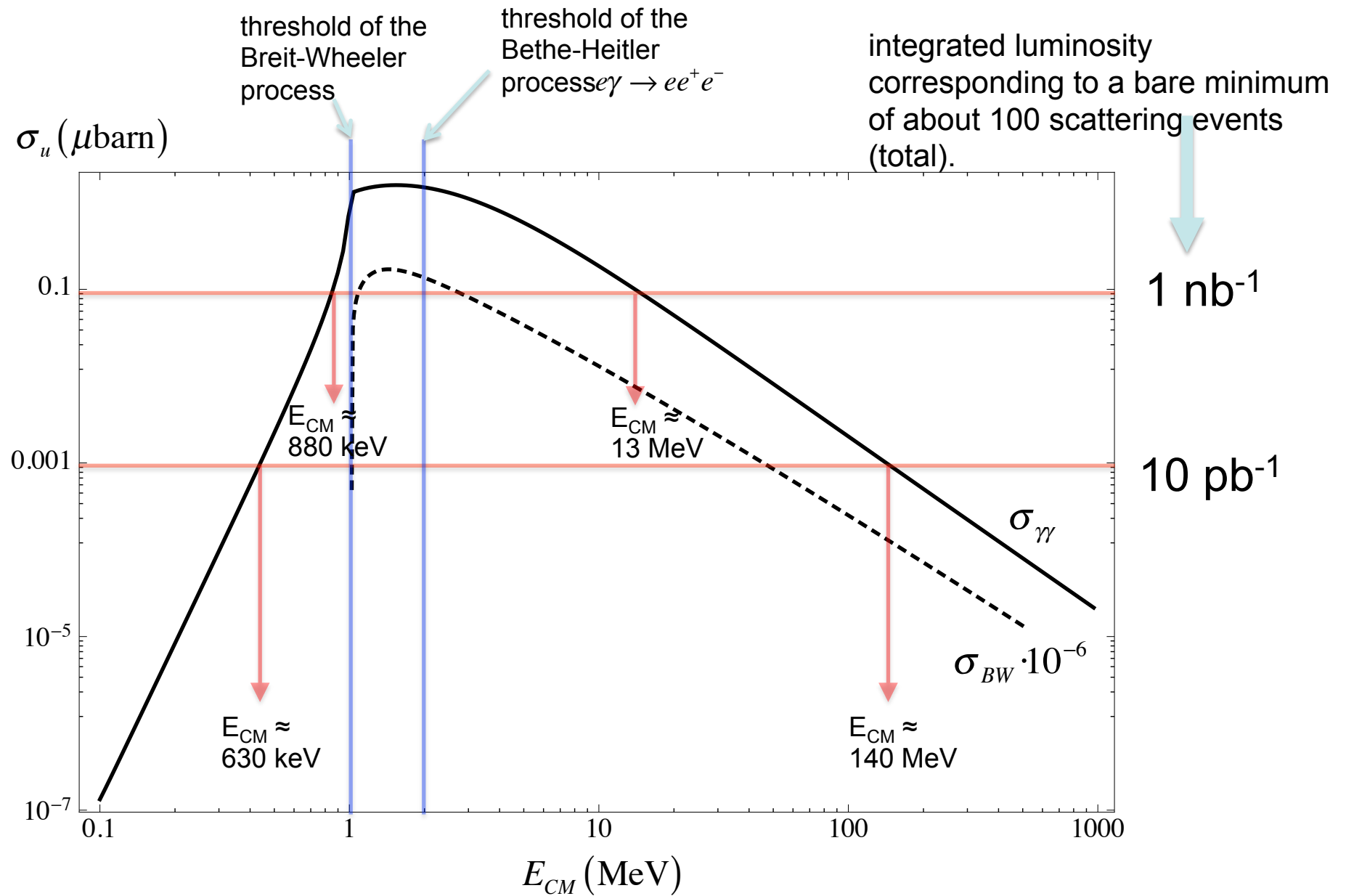
Iride Roadmap

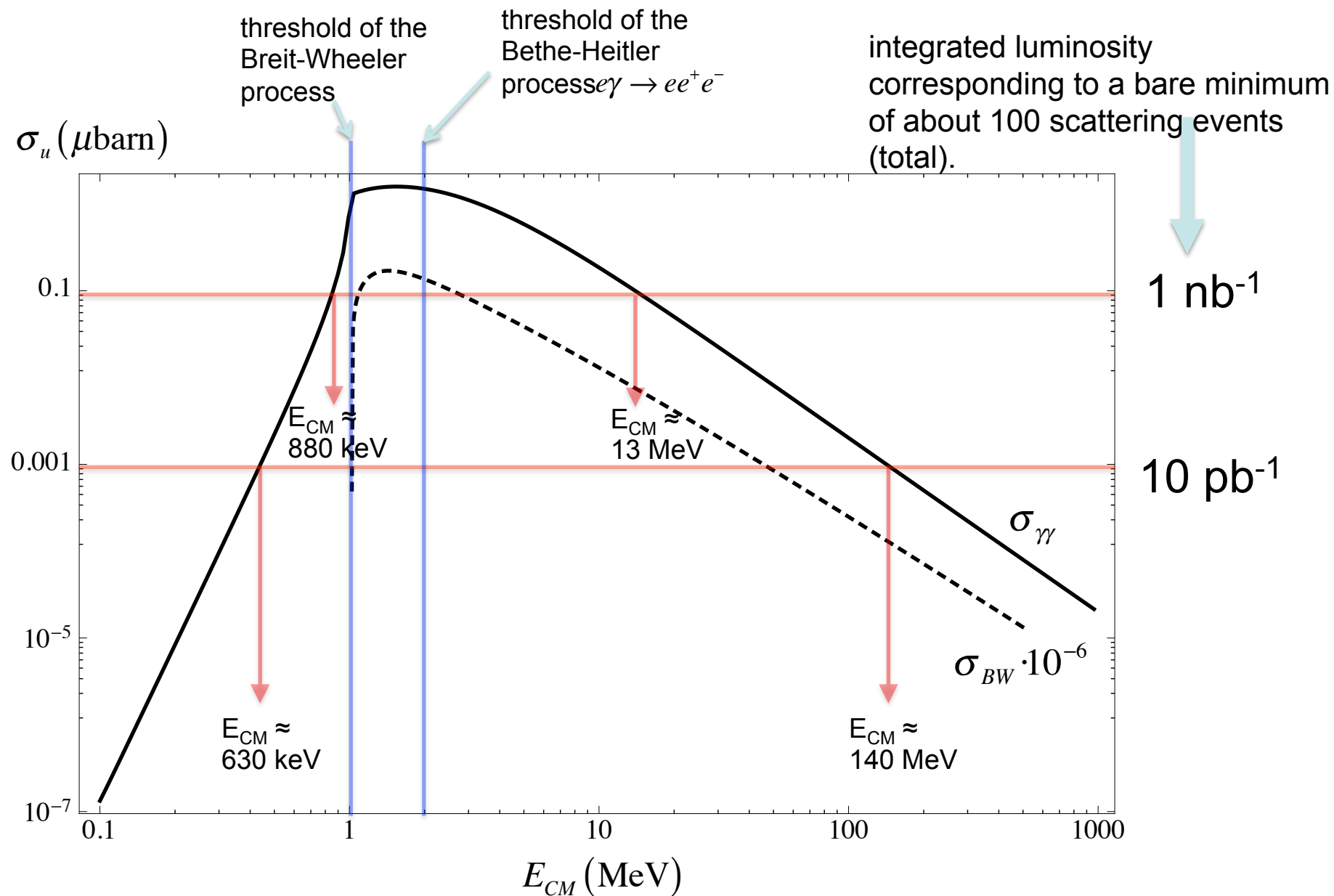
- 
- **March → June – Working Groups Meeting with int. experts**
 - **July 31 - Conceptual Design Report ready**
 - **By the end of 2013 IRIDE approval?**

Thank you!!!

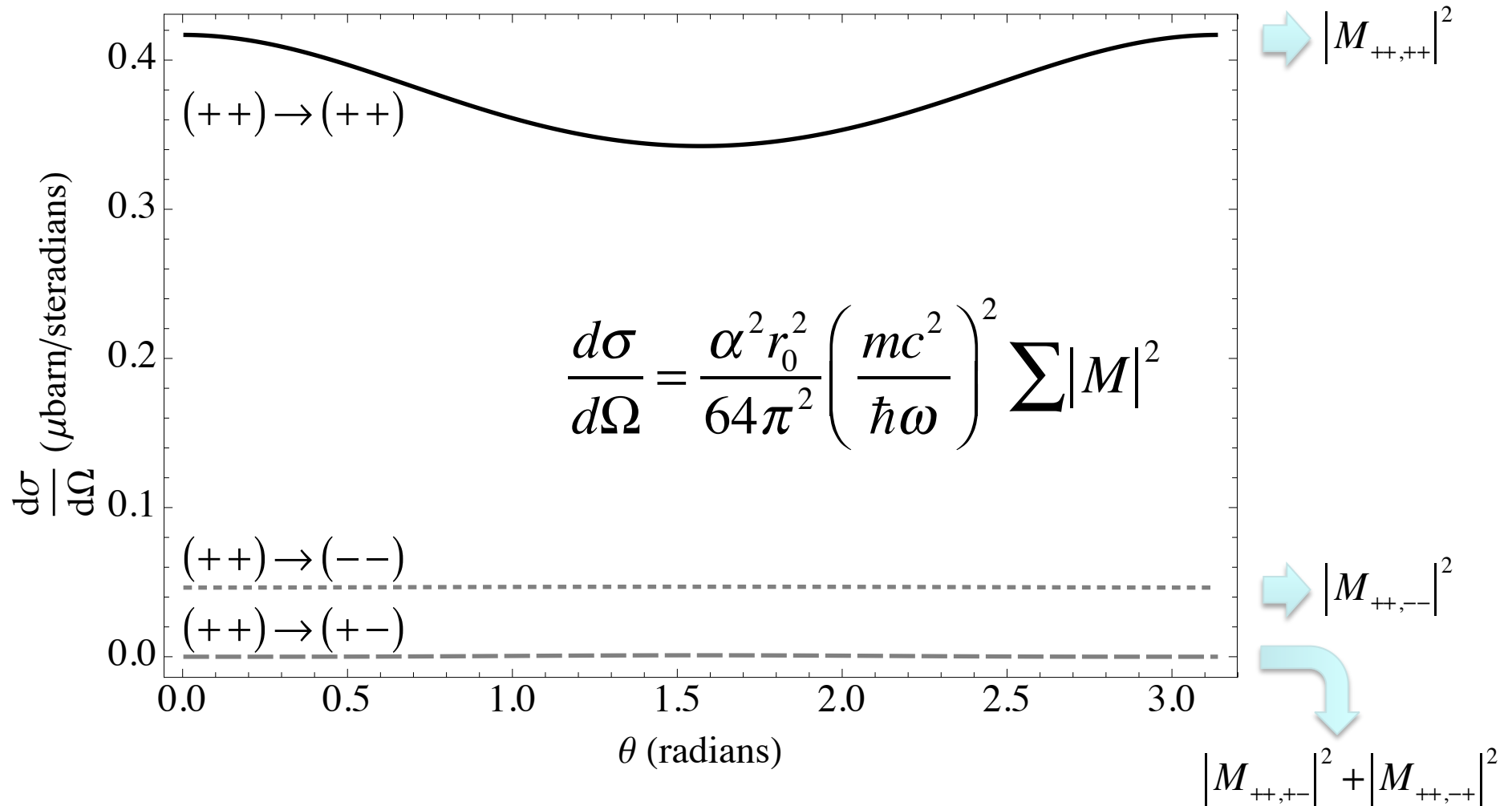
Past, Current and future experiments





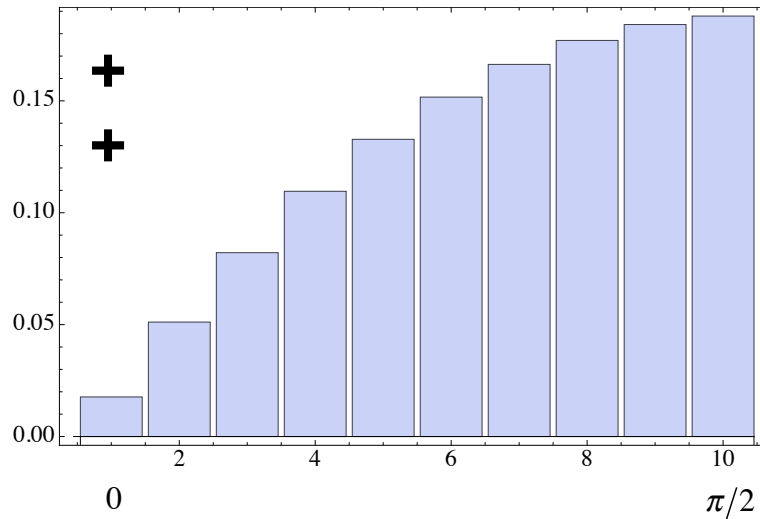


Variable beam polarization and final state polarization discrimination, useful for disentangling contributions from different matrix elements

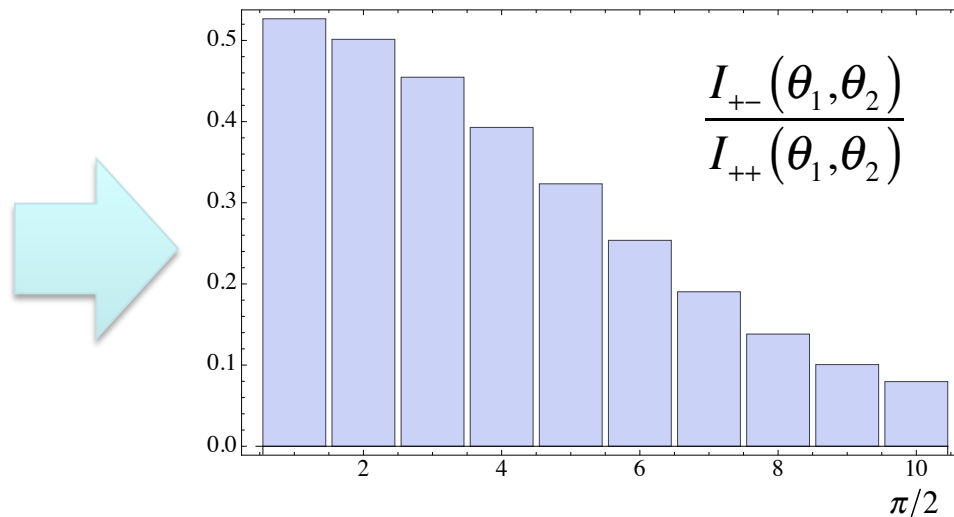
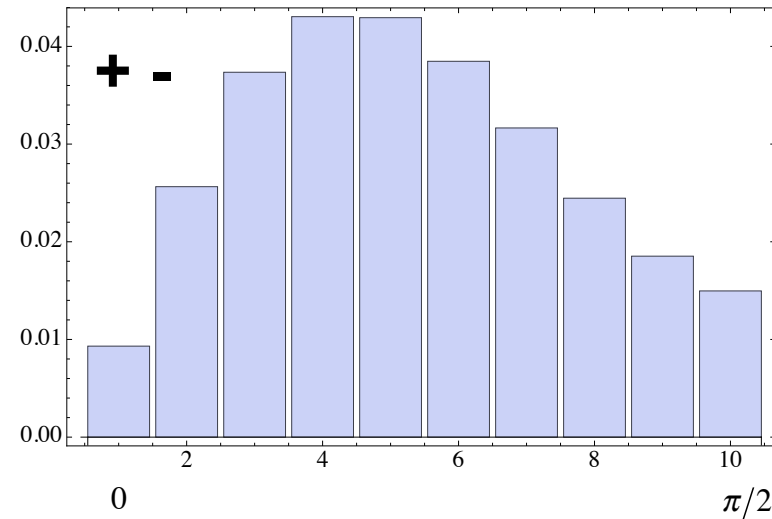


Event rate calculation (at 1.6 MeV CM)

$$I_{++}(\theta_1, \theta_2) = \int_0^{2\pi} d\varphi \int_{\theta_1}^{\theta_2} \sin\theta d\theta \frac{d\sigma_{++}}{d\Omega}$$



$$I_{+-}(\theta_1, \theta_2) = \int_0^{2\pi} d\varphi \int_{\theta_1}^{\theta_2} \sin\theta d\theta \frac{d\sigma_{+-}}{d\Omega}$$



At least 13 events in the last bin for I_{+-}

(cross-section $\approx 0.015 \mu\text{barn}$)

$$L\Delta t \approx \frac{N}{\sigma} \geq \frac{13}{15 \text{ nbarn}} \approx 0.87 \text{ nbarn}^{-1}$$

THEN, Luminosity must be

17/04/13 0

Edoardo Milotti - LNF/IRIDE

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Background from the Breit-Wheeler process (straightforward process, however still unobserved!)

