IRIDE: a new way to see

Proposal for e-γ experiments at IRIDE accelerator

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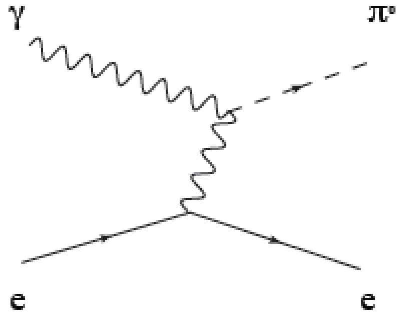
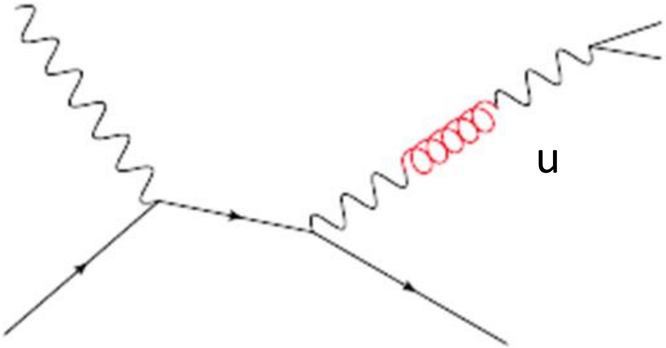
Our opportunities for e-γ phisics on IRIDE are ultimately 2:

π^o (and possibly η and η’) width measurement

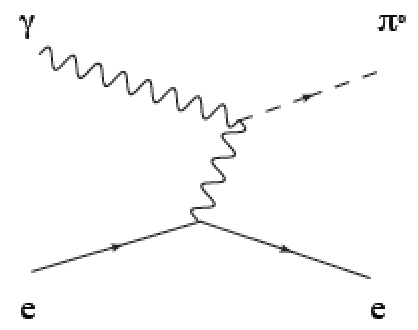


Search for dark forces



These measurements will provide important tests of the Standard Model, but they are not possible at present electron-photon colliders due to the low photon intensities of the machines.

In this presentation we will focus just on the π^o width measurement



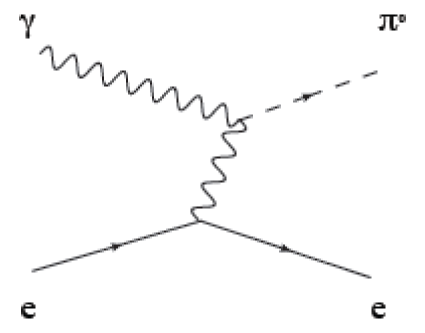
The axial anomaly of Adler, Bell and Jackiw (non-conservation of the axial vector current) is responsible for the decay of the neutral pion into two photons. It bridges in QCD the strong dynamics of infrared physics at low energies (pions) with the perturbative description in terms of quarks and gluons at high energies. The anomaly allows to gain insights into the strong interaction dynamics of QCD and has received great attention from theorists over many years.

In IRIDE we propose a measurement of π^o width via Primakoff effect using just an e-γ collision instead of electron collision on a nuclear target. In this way we will reduce the uncertainty due to nuclear gamma background and to the uncertainties from the hadronic vacuum polarization and the hadronic light-by-light scattering contribution.

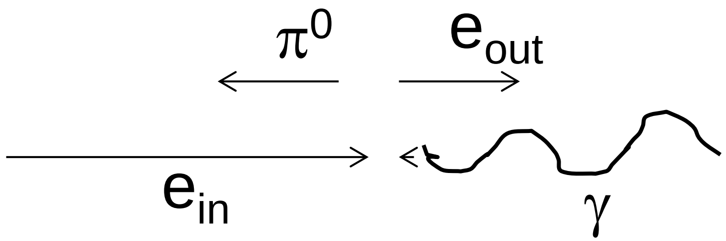
Some numbers

- the π^o decay width is predicted with a 1.4% accuracy
- the most precise measurement of π^o decay width has been done by the PrimEx Collaboration with a precision of 2.8%
- using e-γ collisions instead of nuclear targets we lost a Z^2 factor on luminosity;
- A rough calculation shows that by colliding photons of 20 MeV against electrons of 750 MeV the cross section of π^o production is about 1-2 nb

In order to achieve a 1% uncertainty we need an integrated luminosity of 10^{30} cm^{-2} s^{-1} (in one year of data taking).

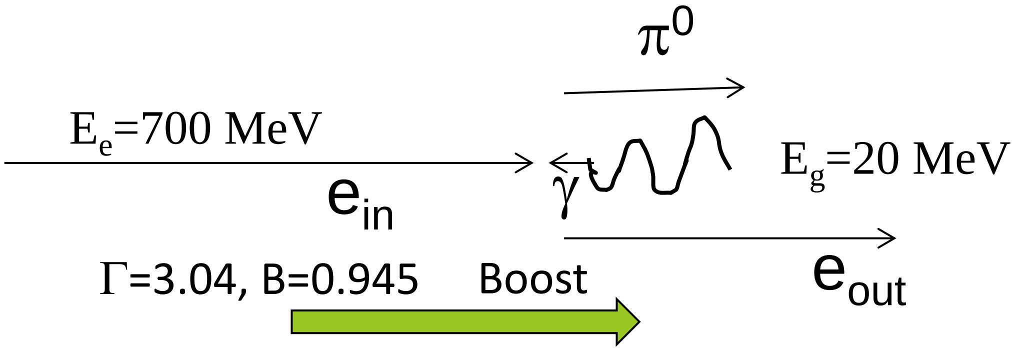


About kinematics



$\sqrt{s}$=236 MeV, $P^*_{\pi 0}=P^*_e$=79.8 MeV, $E^*_{\pi 0}$=156.8 MeV

In CMS the π° is preferentially emitted in the direction of photon.
But in LAB system the effect due to Lorentz boost lead the π° to be emitted at a large angle θ (respect to the direction of the photon), in almost the same direction of the electron.

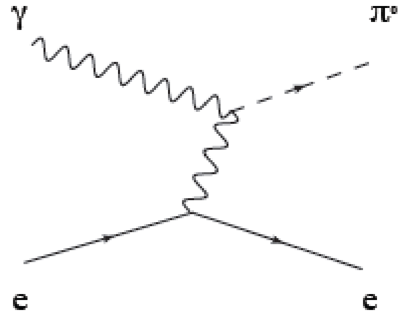


E_e=700 MeV

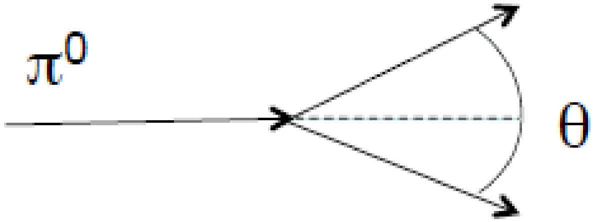
E_g=20 MeV

Γ=3.04, B=0.945

$P_{\pi 0}$=207.8 MeV, $E_{\pi 0}$=247.8 MeV, P_e=472.2 MeV

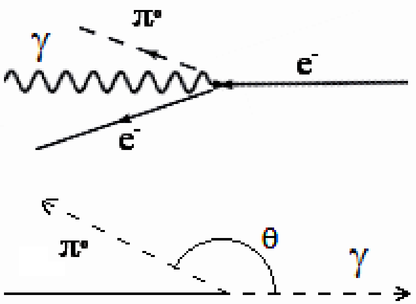


About kinematics



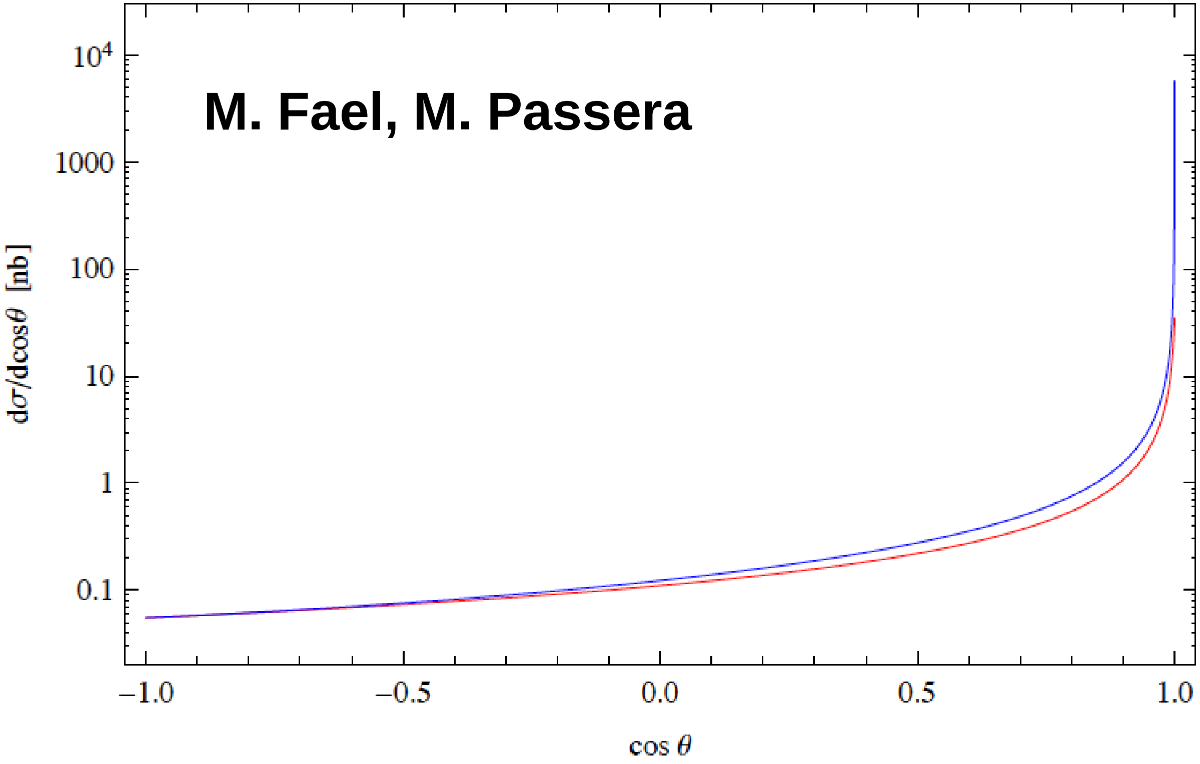
Let’s consider the decay of the π^o into 2 γ.
In this case, θ is the (minimum) angle at which the differential cross section is peaked.

$$\sin\left(\frac{\vartheta}{2}\right) \sim \frac{1}{\gamma} \qquad \theta \sim 65^o$$

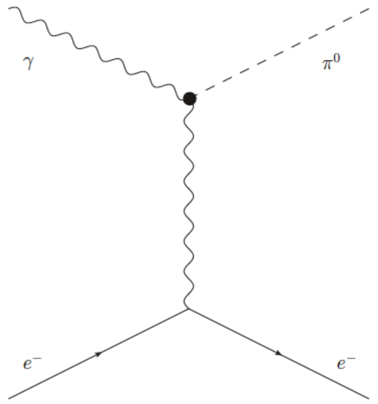


The scattering $\gamma + e^- \rightarrow \pi^0 + e^-$

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



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



E_e=750 MeV

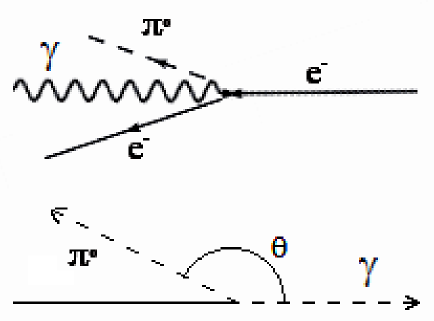
E_γ=20 MeV

σ=2nb

E_e=500 MeV

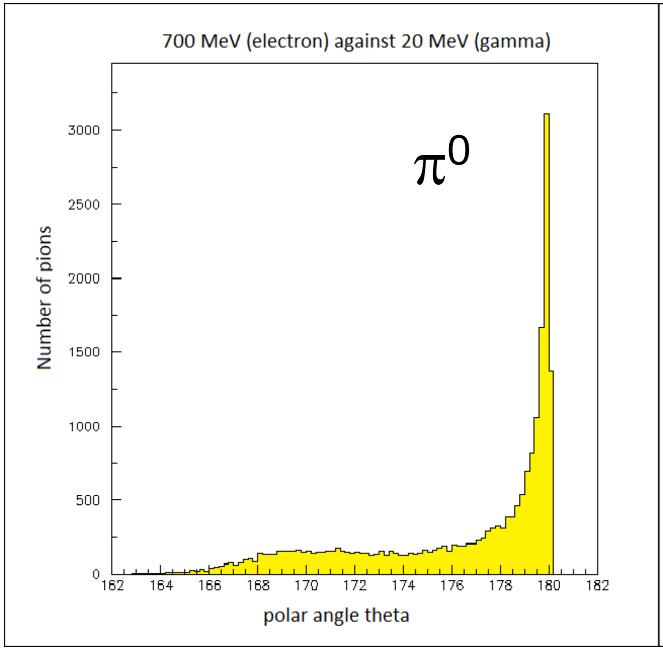
E_γ=10 MeV

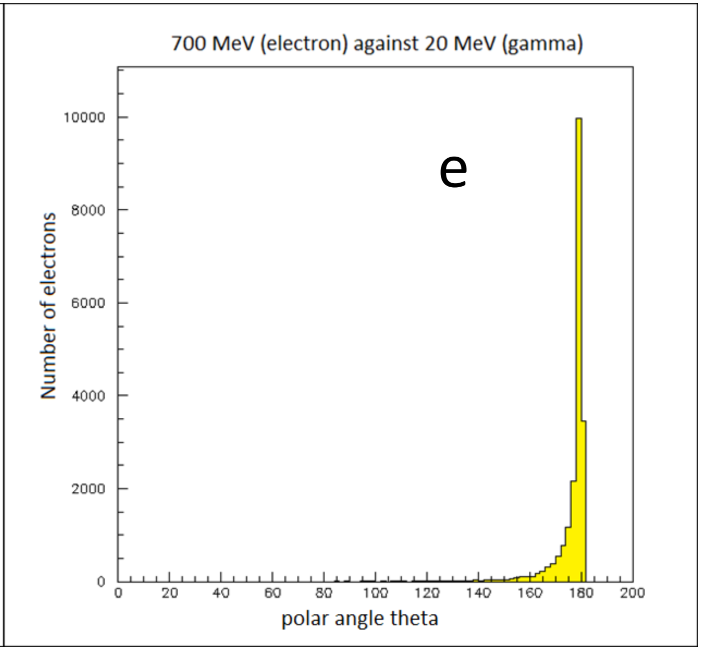
σ=0.7 nb



Results from generator (courtesy of S. Ivashyn):

$$\cos\theta \equiv < p_{\gamma}, p_{\pi 0} >$$

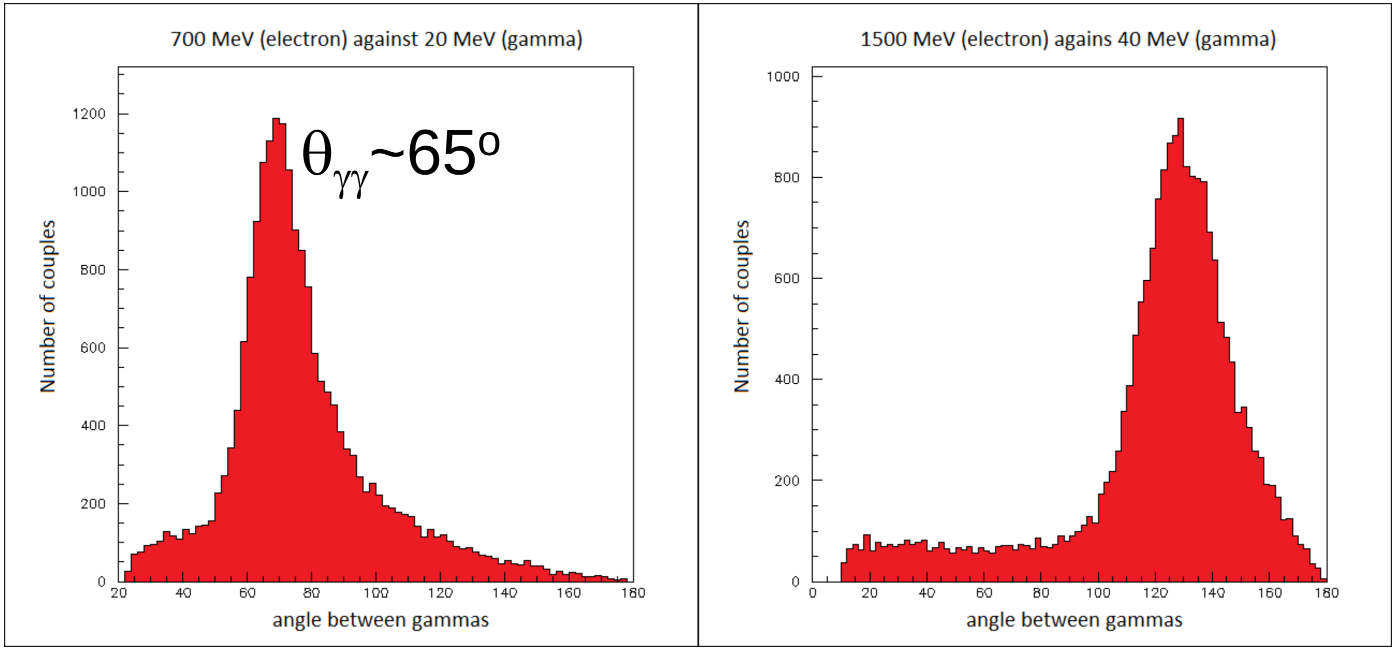




As we can see, the polar angle of the pion and the electron is almost the same.

Cross section at 700-20: 2.014537E+00 [nb]

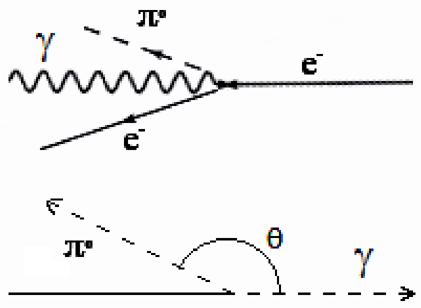
Results from generator (courtesy of S. Ivashyn):



700 MeV (electron) against 20 MeV (gamma)

1500 MeV (electron) agains 40 MeV (gamma)

$\theta_{\gamma\gamma}$~65°

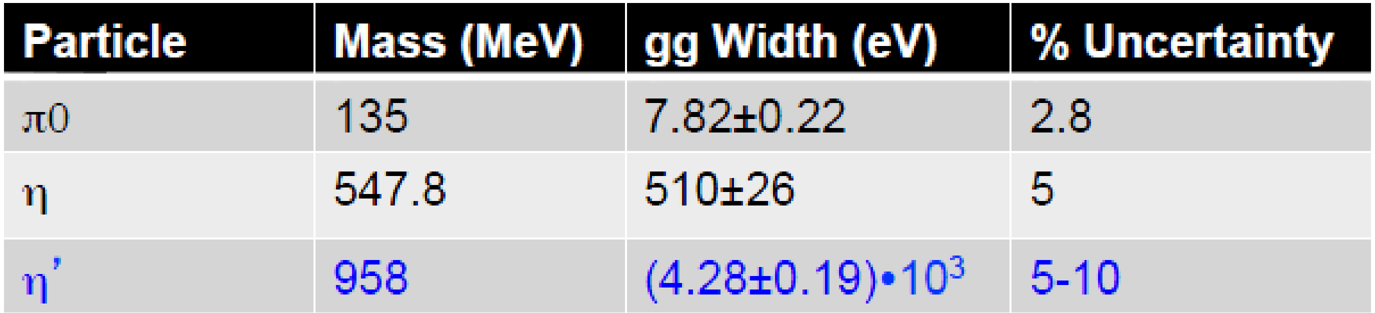


When we increase the energy the angle where the differential cross section is peaked changes.

Very clear signature with one energetic electron along the beam and 2 photons at ~30° each

Going beyond?

Can we reach the energy threshold for η an η’?



Particle	Mass (MeV)	gg Width (eV)	% Uncertainty
π0	135	7.82±0.22	2.8
η	547.8	510±26	5
η’	958	$(4.28\pm0.19)\cdot10^3$	5-10

This measures are the most difficult of our proposal, but they are so interesting to upgrade the machine in order to get the energies and the luminosities we need.

Always trying to go beyond!

First evaluations

First valuation of the cross section of η and η‘ at different energies and luminosity needed for a measure the γγ width at 1% in one year:

- 2000 (E_e) MeV vs 65 MeV (E_γ) → √s=720 MeV;
  $\sigma_{e\gamma \rightarrow \eta e \rightarrow \gamma\gamma e}$ ~ 0.6 nb
- 2500 (E_e) MeV vs 100 MeV (E_γ) → √s= 1 GeV;
  $\sigma_{e\gamma \rightarrow \eta' e \rightarrow \gamma\gamma e}$ ~ 0.04 nb

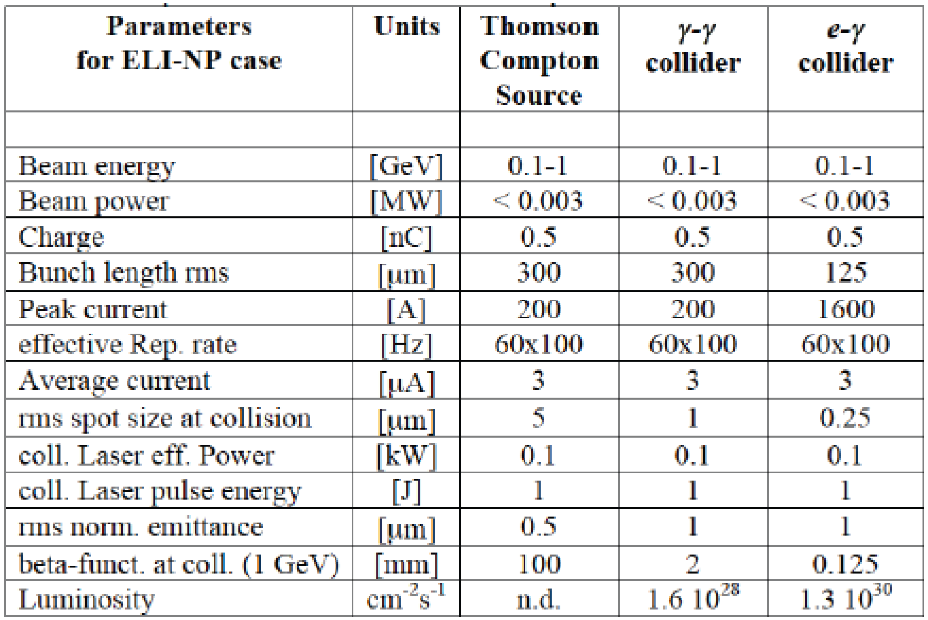
At least, to reach 1% we need (assuming 50% eff.):
- 40pb^{-1} for η (i.e. 1 year at $L \sim 4 \cdot 10^{30}\ cm^{-2}\ sec^{-1}$)
- 500pb^{-1} for η’ (i.e. 1 year at $L \sim 5 \cdot 10^{31}\ cm^{-2}\ sec^{-1}$).

Difficult but possible(?)

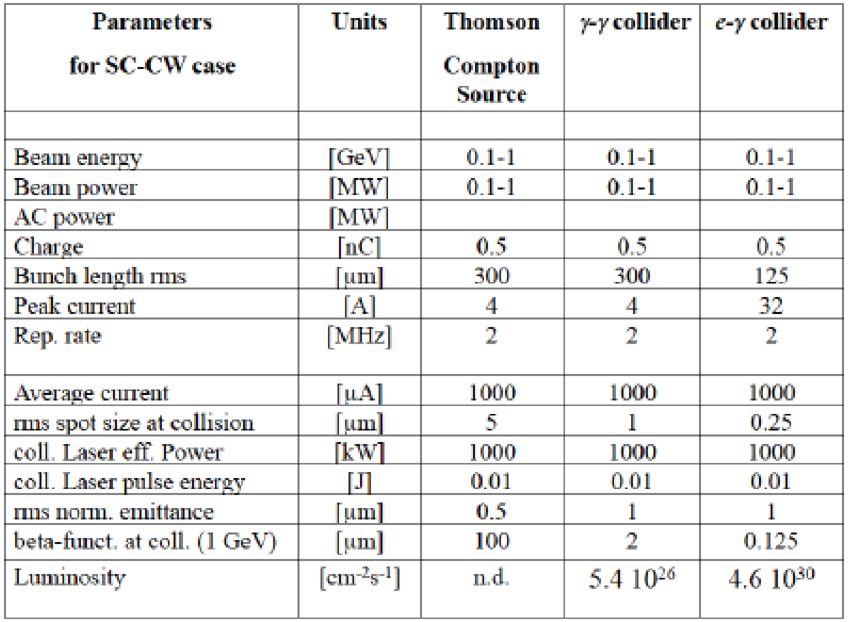
$4\ 10^{30}\ cm^{-2}\ s^{-1}$ @ 2GeV for η
$5\ 10^{31}\ cm^{-2}\ s^{-1}$ @ 2.5GeV for η’

$L>10^{31}\ cm^{-2}\ s^{-1}$ necessary also for U boson searches in eγ→ue process

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



Parameters for ELI-NP case	Units	Thomson Compton Source	γ-γ collider	e-γ 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	$cm^{-2}s^{-1}$	n.d.	$1.6\ 10^{28}$	$1.3\ 10^{30}$



Parameters for SC-CW case	Units	Thomson Compton Source	γ-γ collider	e-γ 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	$[cm^{-2}s^{-1}]$	n.d.	$5.4\ 10^{26}$	$4.6\ 10^{30}$

$\downarrow$

$5\ 10^{31}$

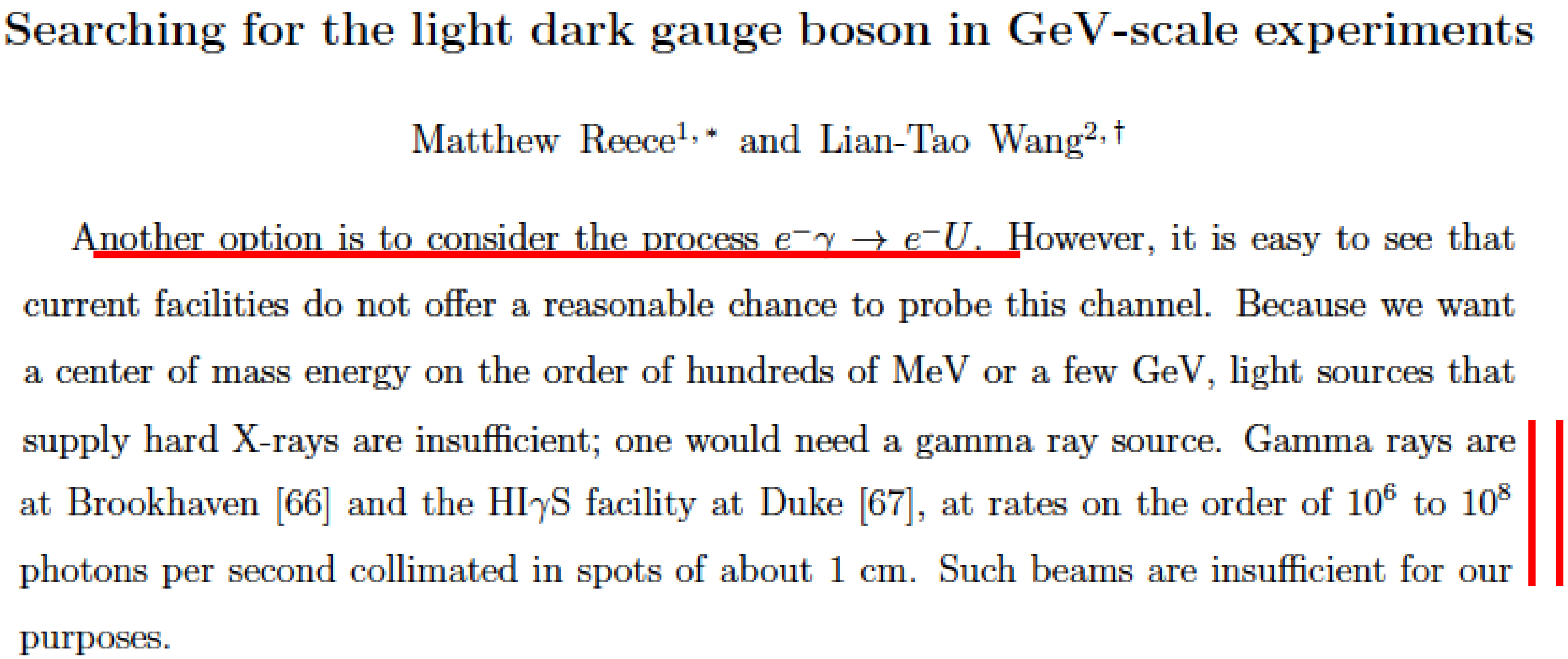
We need to increase a luminosity of one order of magnitude (with Ee~2-2.5 GeV).

With the designed luminosity ($L=10^{30}$) → $\delta\Gamma(\eta \rightarrow \gamma\gamma)$= 4%. Still a factor 2 better than the accuracy of the full widht by COSY-11 measurement ($\Gamma_{\eta'} = 0.226 \pm 0.017$(stat.) ± 0.014(syst.) MeV)

E. Czerwinski et al. PRL 105 (2010) 122001 δ~10%

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,†]

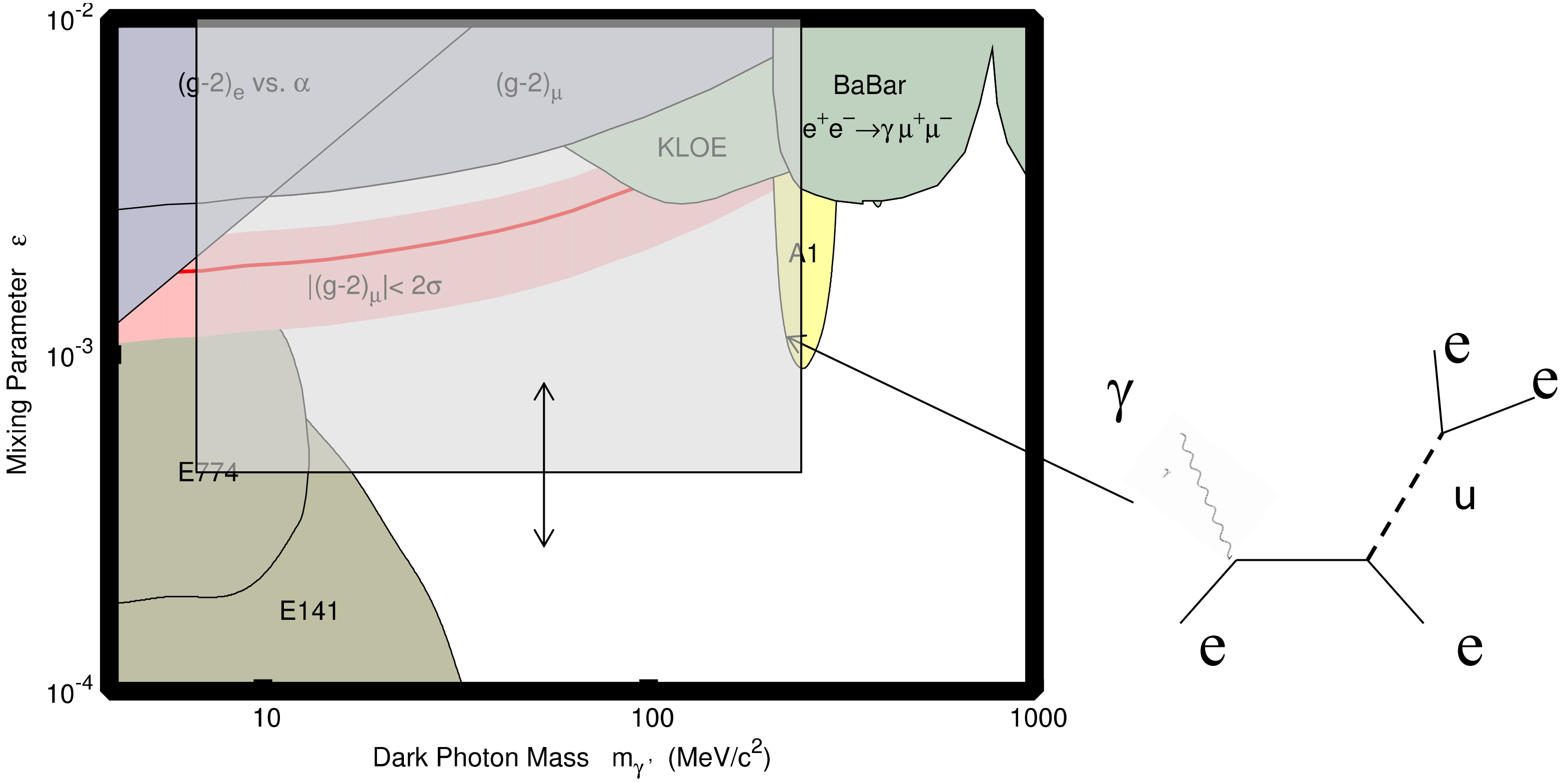
Another option is to consider the process $e^-\gamma \rightarrow e^-U$. However, it is easy to see that current facilities do not offer a reasonable chance to probe this channel. Because we want a center of mass energy on the order of hundreds of MeV or a few GeV, light sources that supply hard X-rays are insufficient; one would need a gamma ray source. Gamma rays are at Brookhaven [66] and the HIγS 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 (Mu<250 MeV)

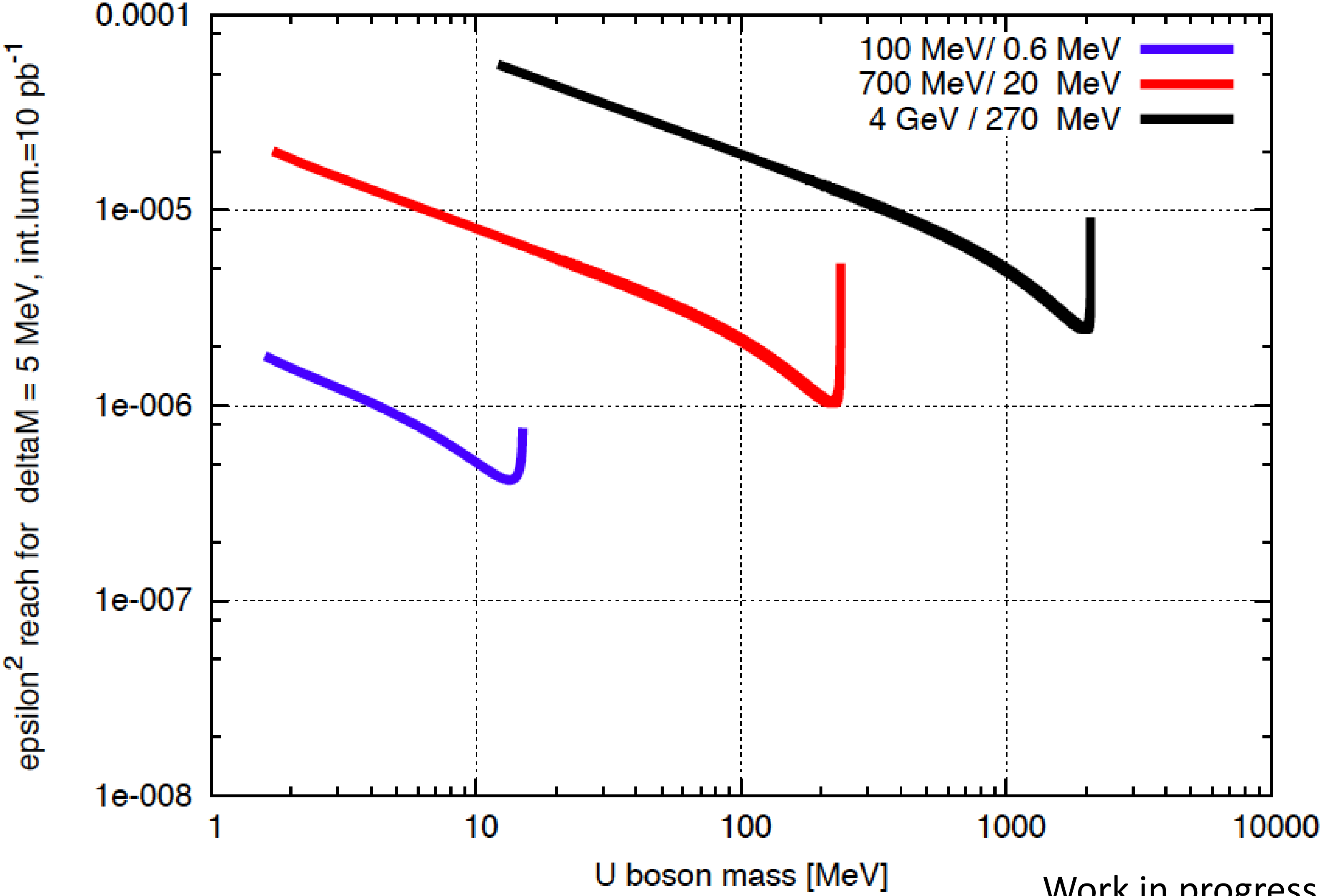
$\gamma + e^- \rightarrow u + e^-$

E_e=100-3000 MeV and E_γ=10-50 MeV



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

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



Work in progress

L>10^{31} needed

Conclusion (I)

- The e-γ (and γ–γ collider) is an unique feature of IRIDE
- The physics case offered by e-γ is the precise measurement of the partial and full widths of P(S) mesons (and search for u bosons).
- At IRIDE we can measure the γγ width of the π^0 at 1% with 1 year of data taking at 10^{30} cm^{-2} s^{-1} . By increasing the luminosity to 4 10^{30} cm^{-2} s^{-1} @ 2GeV and 5 10^{31} cm^{-2} s^{-1} @ 2.5GeV the widths of η,η' would be measured at 1%.
- I didn't discuss the measurement of the Transition Form Factor of π^0, η, η' at $q\neq0$ which could be possible.
- A possibility to measure the full width by exploring the missing mass is under study. In this case $L\sim10^{30}$ is sufficient to measure the full width of of η,η' at 1% uncertainty.

Stay tuned!

Thank you very much for the attention