Comparison Physics Generators:

or modern life of MC calculations of QED processes by Tobias Beranek for HPS

Ani Simonyan

Michel Guidal & Raphael Dupre

Institut de Physique Nucléaire d'Orsay

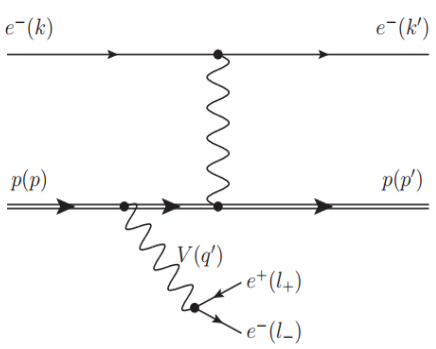
CNRS-IN2P3
Université Paris-Sud

Unité mixte de recherche
CNRS-IN2P3
Université Paris-Sud
91406 Orsay cedex
Tél. : +33 1 69 15 73 40
Fax : +33 1 69 15 64 70
http://ipnweb.in2p3.fr

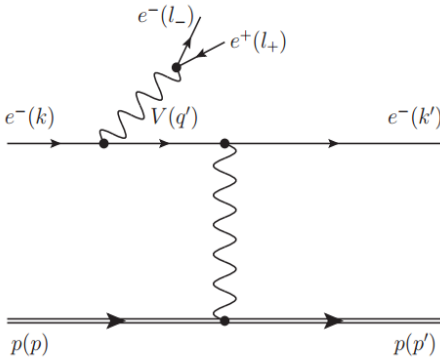
QED processes and cross section calculations

Feynman diagrams contributing to $ep \to epl^+l^-$

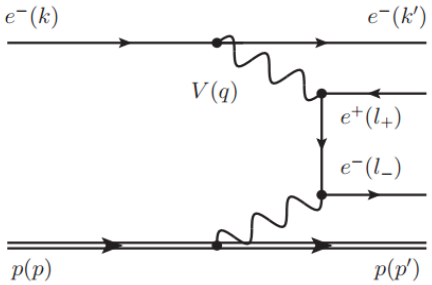
1. Direct Diagrams (D)



(VVCS)



(TL)



(SL)

2. + same diagrams with e^-_{beam} , e^-_{pair} exchange term (X)

Some processes neglected

- *VVCS –neglected for nucleon target*

Acceptance for HPS

$$|\varphi_{horizontal}| < 50\ [mrad]$$
$$-60 < \theta_{out\ of\ plane} < -15[mrad]$$
$$60 < \theta_{out\ of\ plane} < 15[mrad]$$

Differential Cross-Section

$$d\sigma = \frac{1}{4\sqrt{(k\cdot p)^2 - m^2M^2}}\,(2\pi)^4\delta^{(4)}\left(k+p-k'-p'-l_- - l_+\right)$$
$$\times \frac{d^3\vec{k}'}{(2\pi)^3\,2\,E'_e}\,\frac{d^3\vec{p}'}{(2\pi)^3\,2\,E'_p}\,\frac{d^3\vec{l_-}}{(2\pi)^3\,2\,E_-}\,\frac{d^3\vec{l_+}}{(2\pi)^3\,2\,E_+}\,\overline{|\mathcal{M}|^2},$$

QED background cross section integrated by the acceptance

$$\Delta\sigma_\gamma \propto \left|\mathcal{M}^{TL}_{D,\gamma^*} + \mathcal{M}^{SL}_{D,\gamma^*} - \mathcal{M}^{TL}_{X,\gamma^*} - \mathcal{M}^{SL}_{X,\gamma^*}\right|^2$$

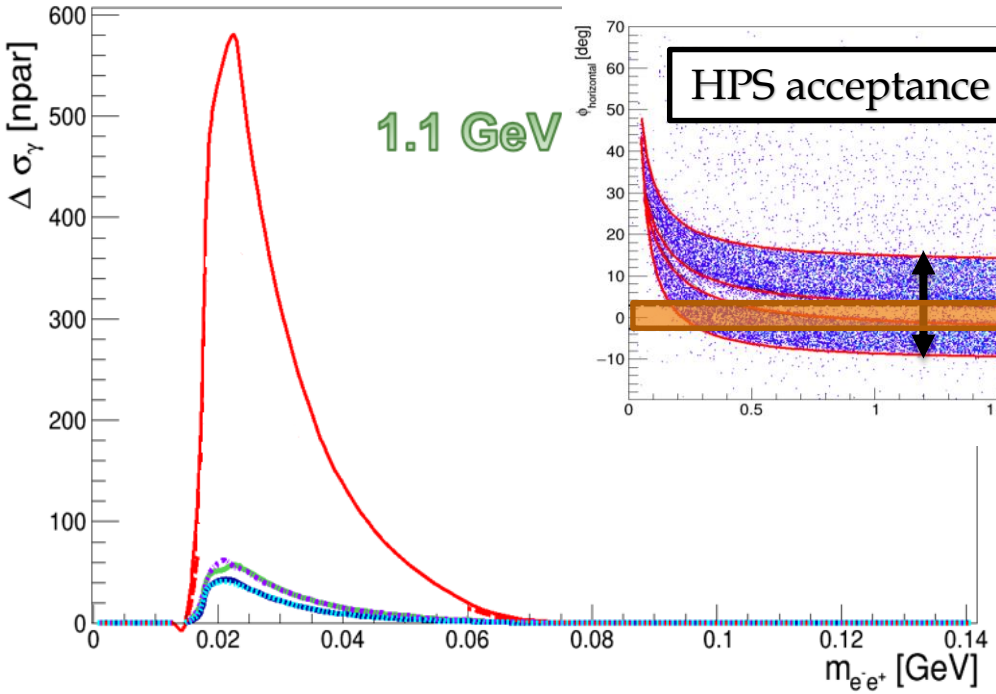
QED background estimation in the phase space selected by Beranek

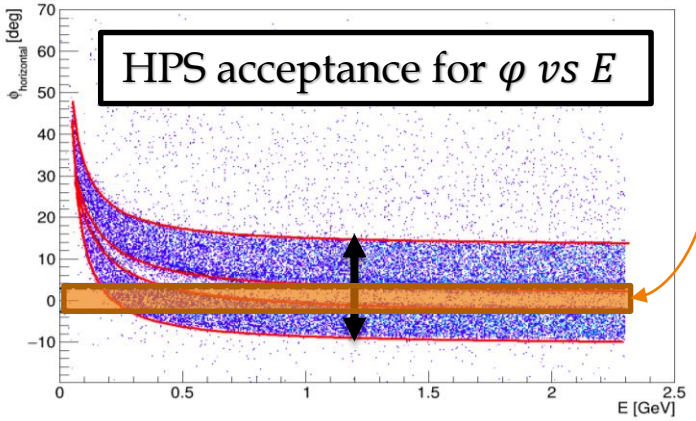
8 dimensional phase space

E_{e^+}	ϑ_{e^+}	φ_{e^+}
$m_{e^+e^-}$	ϑ_{e^-}	φ_{e^-}
ϑ'_{e^-}	φ'_{e^-}	

phase space selected (not Polar Coo Sys)

Beranek's calculation			
	$E_{min} < E_{e^+} < E_b - E_{e^-}$ $0.5 < E_{e^+} < 1.1 - 0.5$ [GeV]	$-60 < \vartheta_{e^\pm} < -15$ $15 < \vartheta_{e^\pm} < 60$ $[mrad]$	$-50 < \varphi_{e^\pm} < 50$ $[mrad]$
	$m_{e^+e^-}$ [0.0, 0.2 GeV]	Esum>0.8Ebeam	Ebeam = 1.1 GeV
	$-\frac{\pi}{2} < \vartheta'_{e^-} < \frac{\pi}{2}$	$0 < \varphi'_{e^-} < 2\pi$	



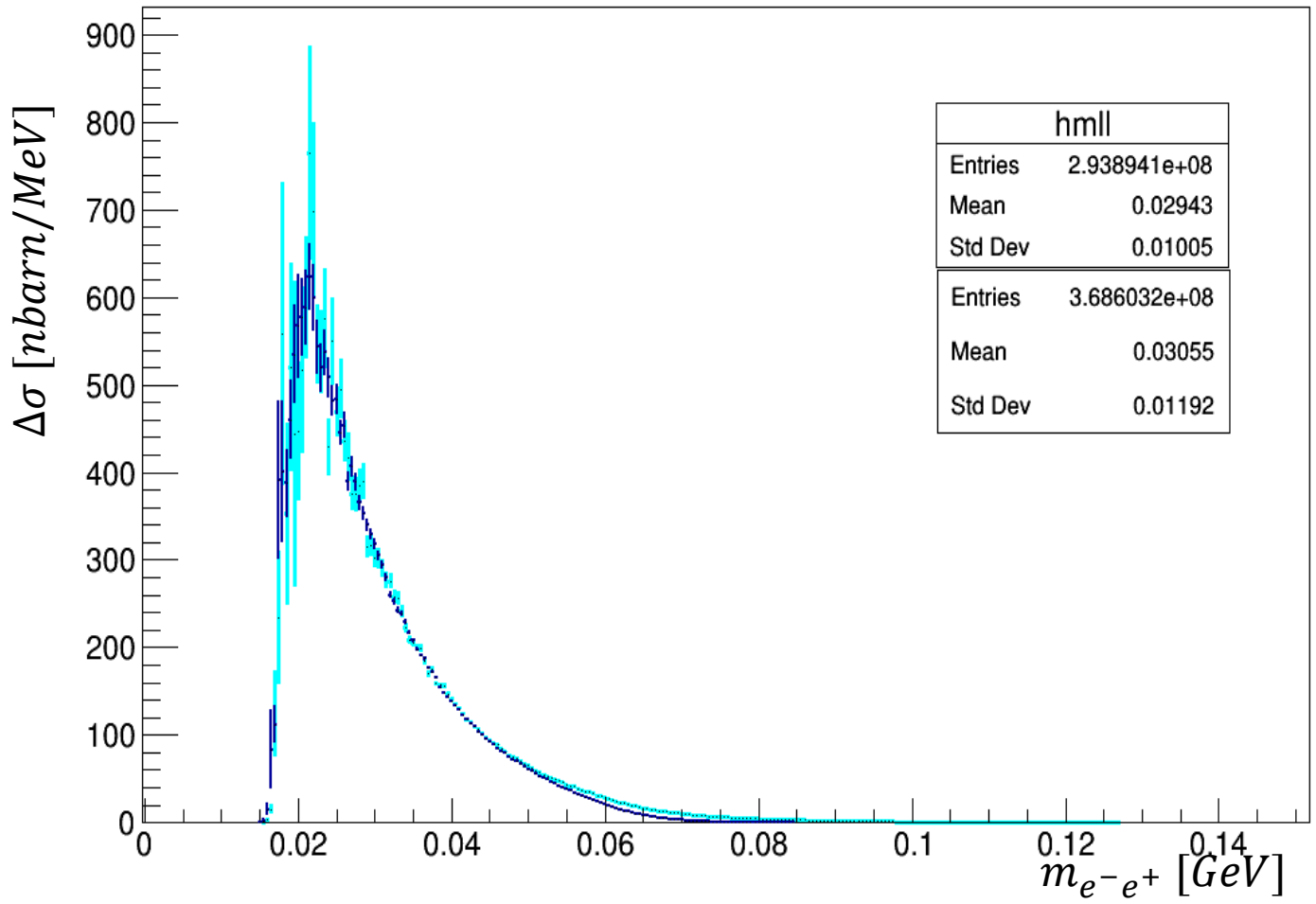


Beranek selection φ

phase space in MadGraph5 model by Rouven,Yiming (Polar Coo Sys)

HPS MG 5 simulation			
	$E_{min} = 0.05$ GeV	$\vartheta_{e^\pm}$ *open*	$\varphi_{e^\pm}$ *open*
	Esum>0.5GeV		Ebeam = 1.056 GeV
	ϑ'_{e^-} *open*	φ'_{e^-} *open*	

Cross-section within $2\Delta\varphi$ interval



- Blue –in phase space selected by Beranek [1],[2] $(\Delta\theta, \Delta\varphi, \Delta E)$
- Azure – in phase space twice bigger in horizontal angle $(\Delta\theta, 2\Delta\varphi, \Delta E)$

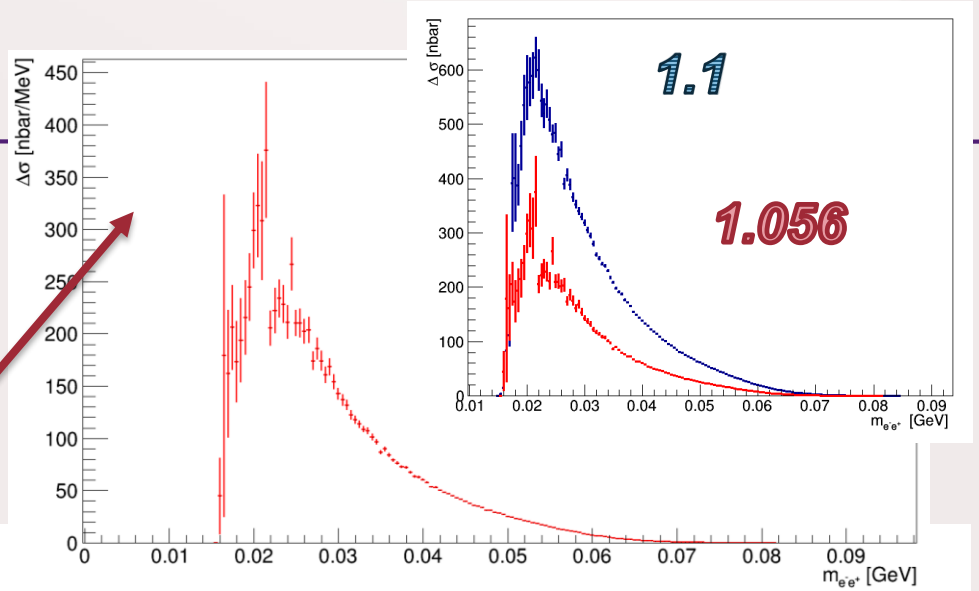
@Note that efficiency drops very fast

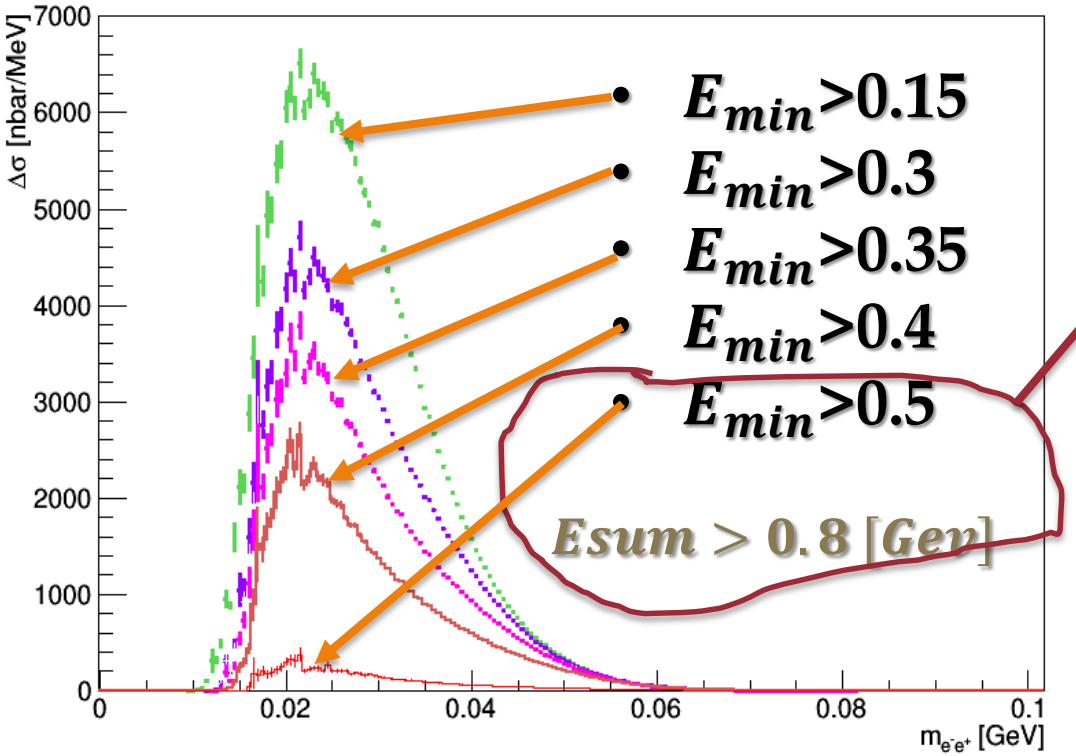
$E_{min} < E_{e^+} < E_b - E_{e^-}$ $0.5 < E_{e^+} < 1.1 - 0.5$ [GeV]	$m_{e^+e^-}$ [min, max] [0.0, 0.2 GeV]
Esum>0.8Ebeam	Ebeam = 1.1 GeV

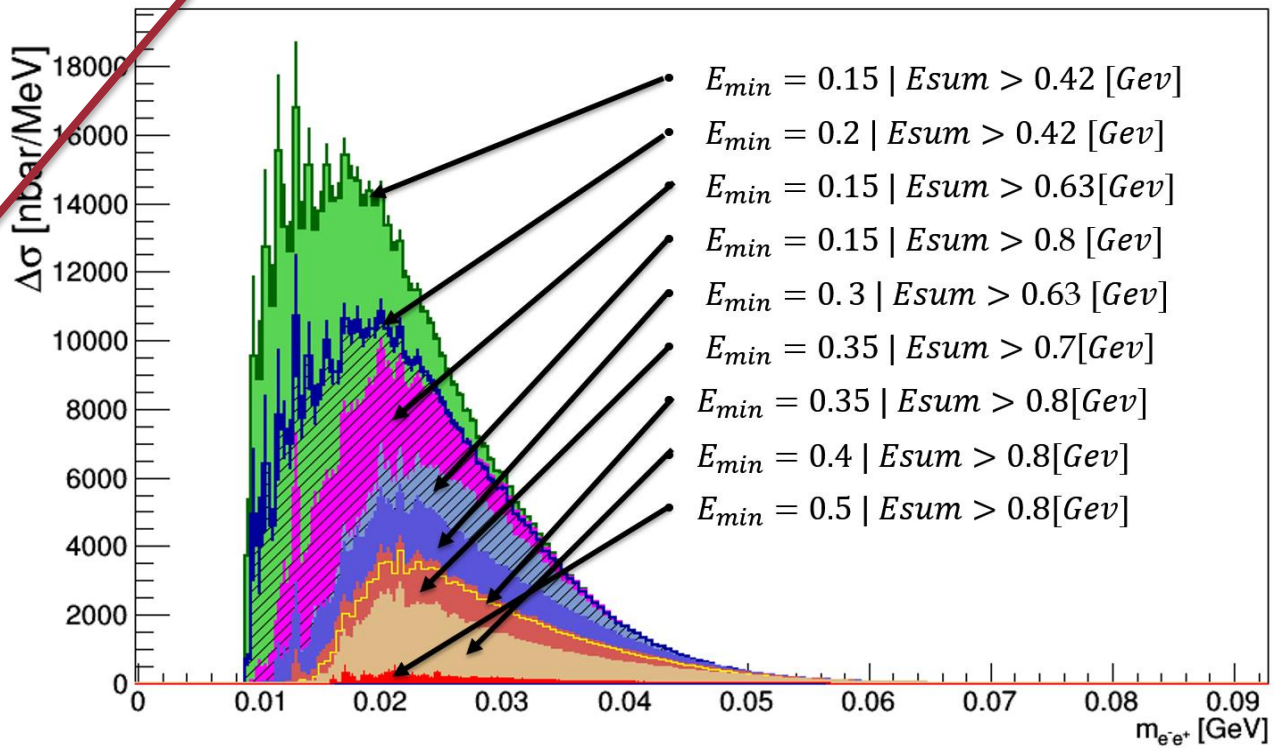
$-60 < \vartheta_{e^\pm} < -15$ $15 < \vartheta_{e^\pm} < 60$ $[mrad]$	Blue$\{-50 < \varphi_{e^\pm} < 50\}$ Azure$\{-100 < \varphi_{e^\pm} < 100\}$ $[mrad]$
$-\frac{\pi}{2} < \vartheta'_{e^-} < \frac{\pi}{2}$	$0 < \varphi'_{e^-} < 2\pi$

Cross-section vs Energy cuts

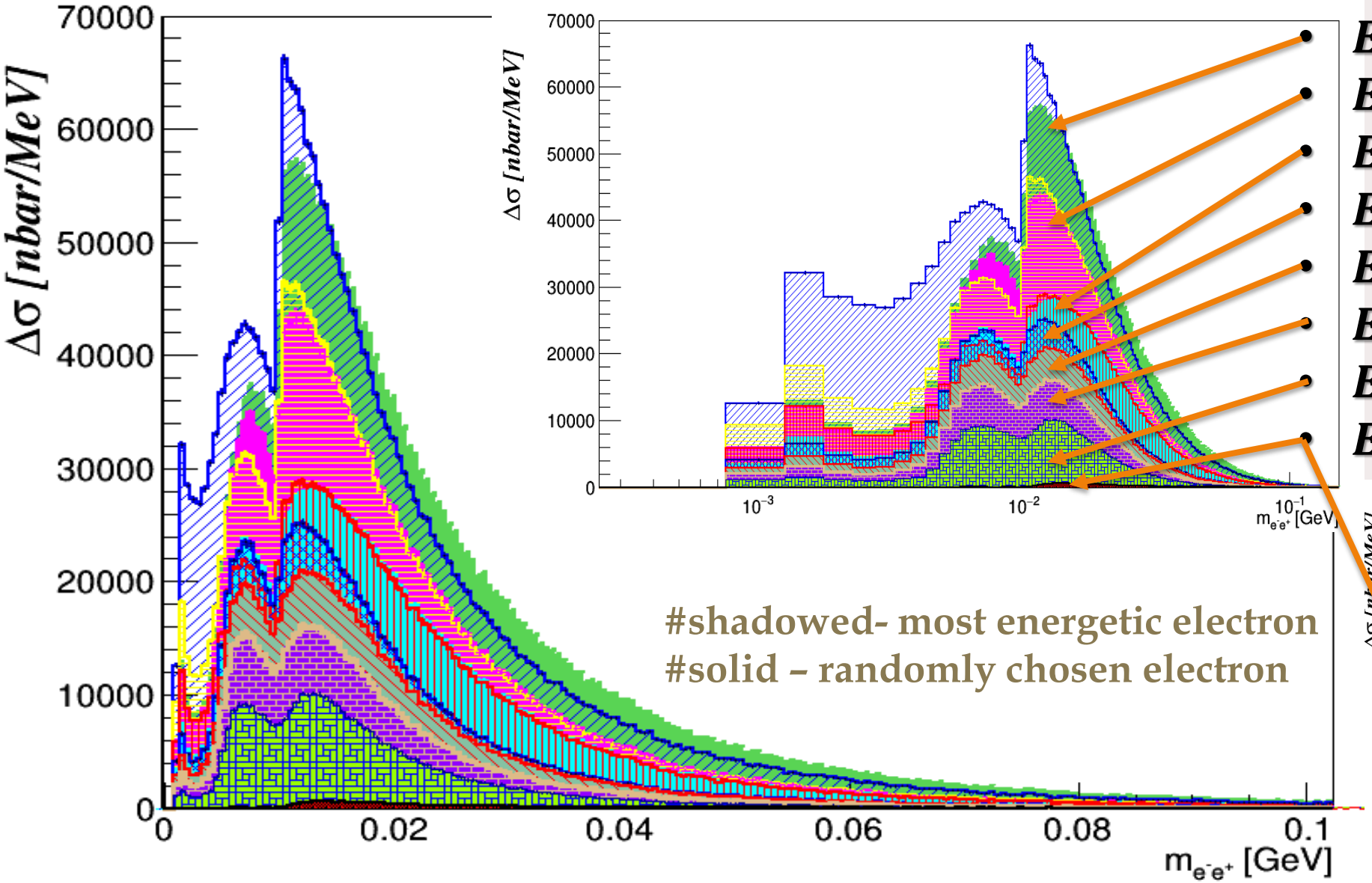
$-60 < \vartheta_{e^\pm} < -15$ $15 < \vartheta_{e^\pm} < 60\ [mrad]$	$-50 < \varphi_{e^\pm} < 50$ $[mrad]$
E_{min}>0.15 | Esum<0.4	Ebeam = 1.056 GeV
$-\frac{\pi}{2} < \vartheta'_{e^-} < \frac{\pi}{2}$	$0 < \varphi'_{e^-} < 2\pi$





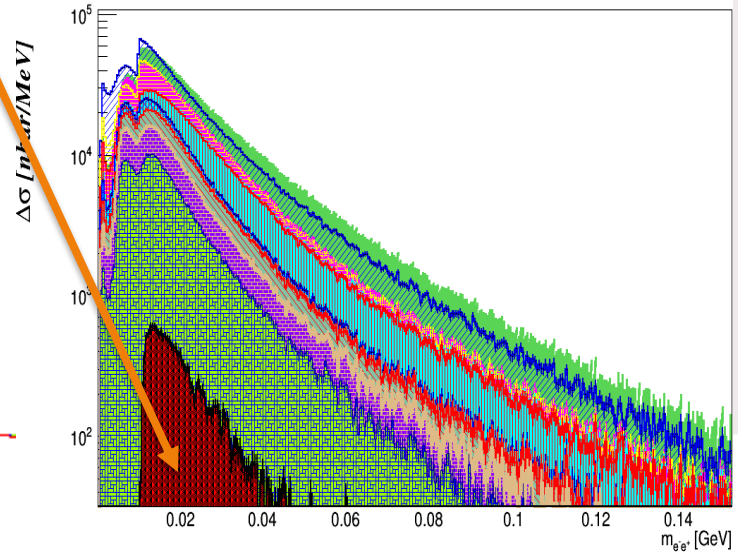


MG5: most energetic vs random pick of pair electron

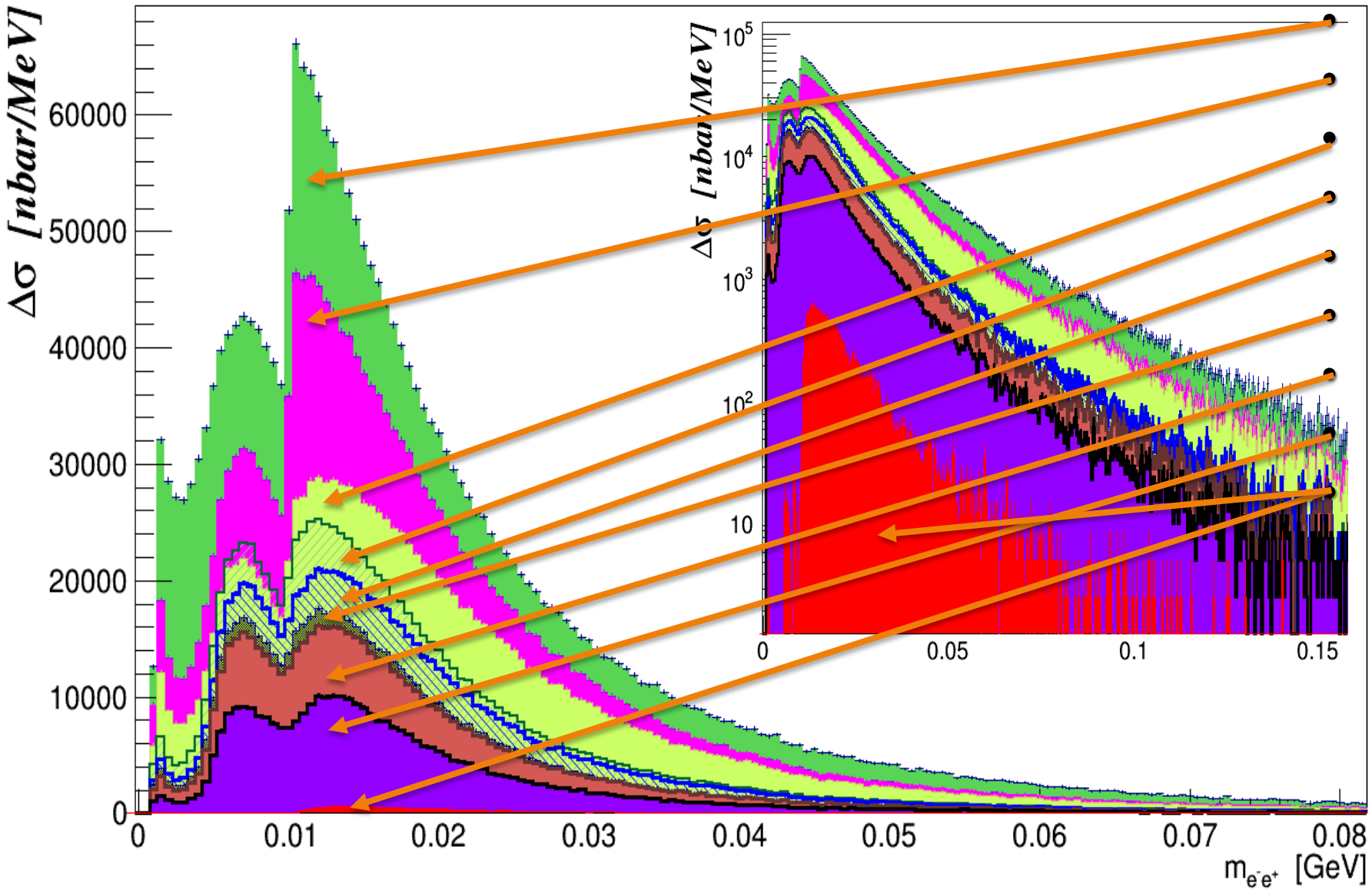


#shadowed- most energetic electron
#solid – randomly chosen electron

E_{min}>0.05 | $E_{sum} > 0.0$
E_{min}>0.15 | $E_{sum} > 0.42$
E_{min}>0.15 | $E_{sum} > 0.8$
E_{min}>0.3 | $E_{sum} > 0.6$
E_{min}>0.3 | $E_{sum} > 0.8$
E_{min}>0.35 | $E_{sum} > 0.7$
E_{min}>0.4 | $E_{sum} > 0.8$
E_{min}>0.5 | $E_{sum} > 0.8$



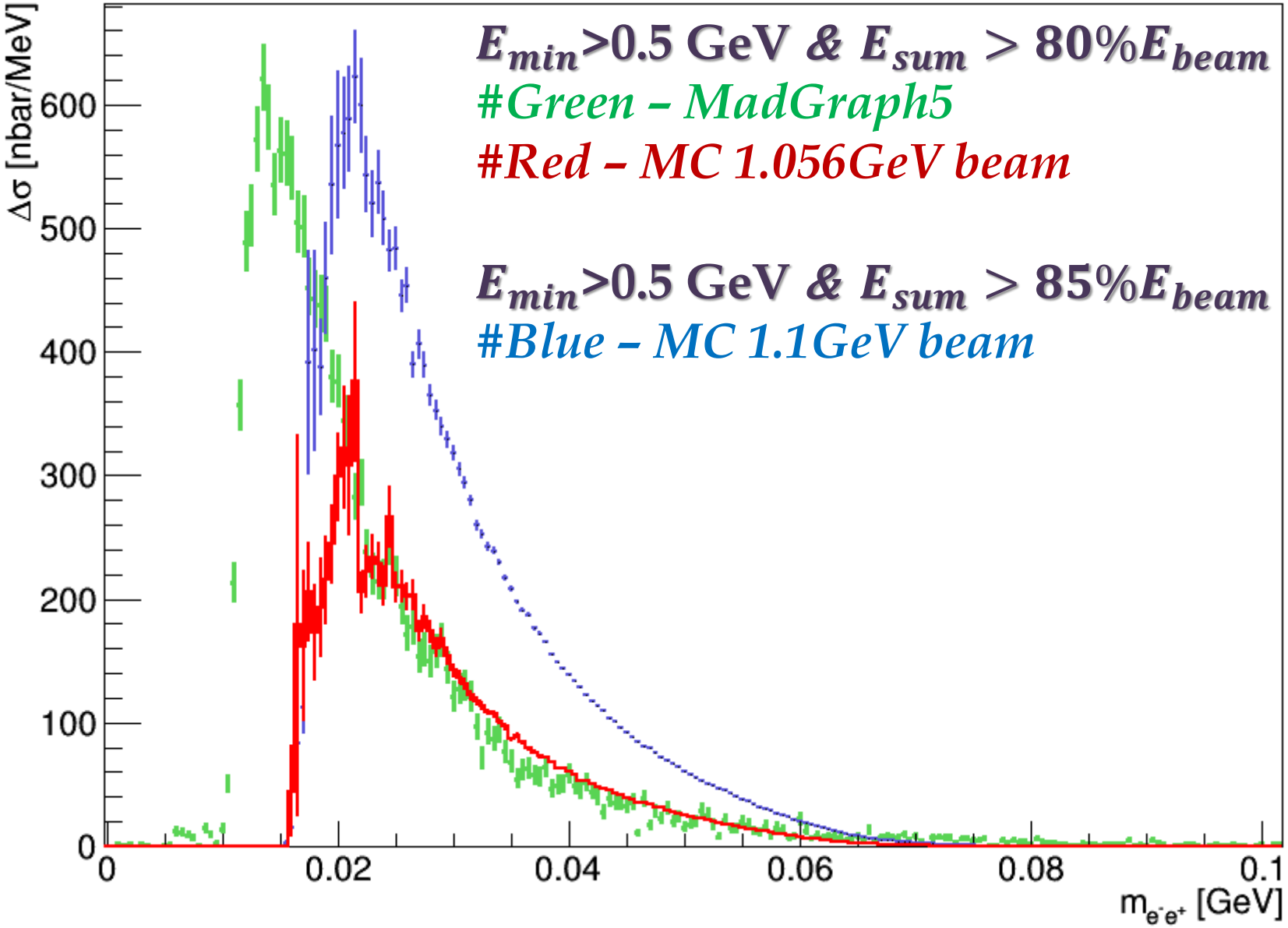
MG5: cross-section vs energy cuts

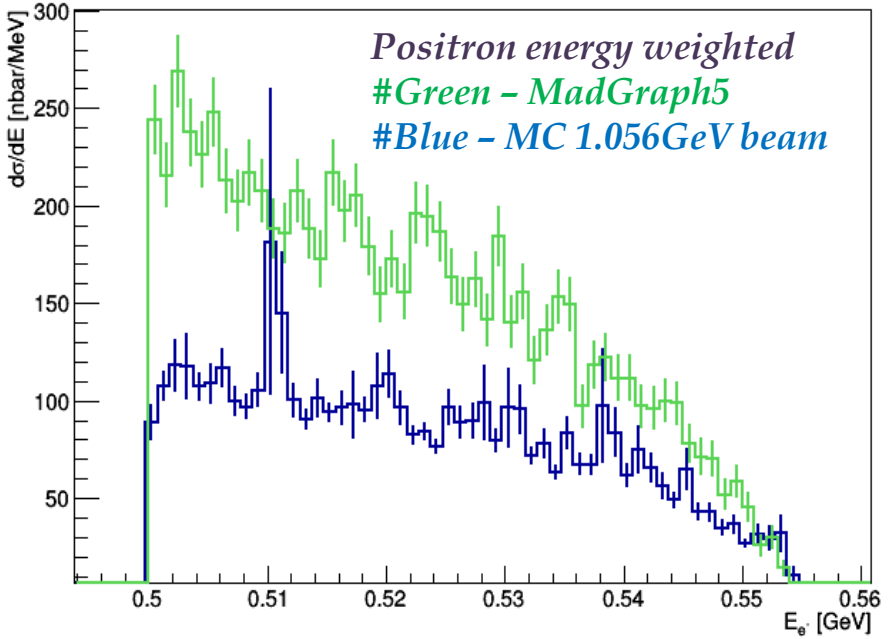


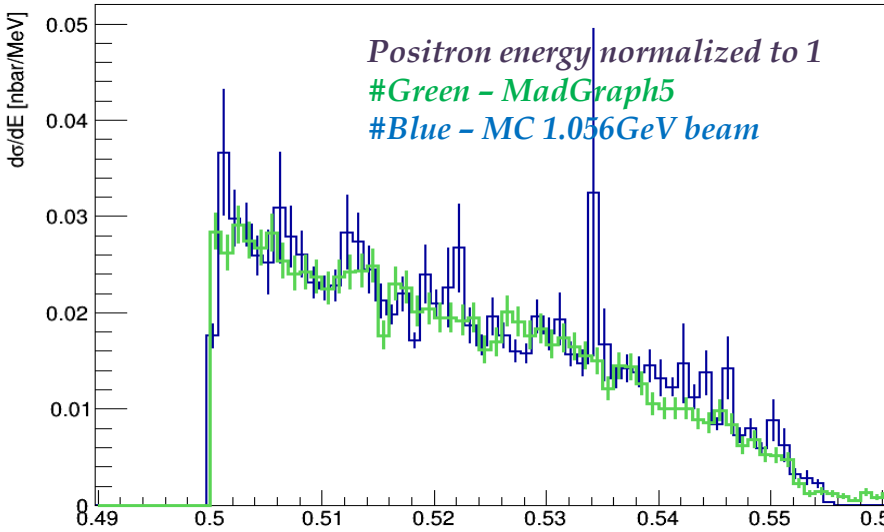
E_{min}>0.05 | $E_{sum} > 0.5$
E_{min}>0.15 | $E_{sum} > 0.42$
E_{min}>0.15 | $E_{sum} > 0.8$
E_{min}>0.3 | $E_{sum} > 0.42$
E_{min}>0.3 | $E_{sum} > 0.62$
E_{min}>0.35 | $E_{sum} > 0.7$
E_{min}>0.3 | $E_{sum} > 0.8$
E_{min}>0.4 | $E_{sum} > 0.8$
E_{min}>0.5 | $E_{sum} > 0.8$

Both simulations with MadGraph5 and with Monte Carlo technique show similar behavior depending on kinematic range.

MG5 vs MC by Beranek



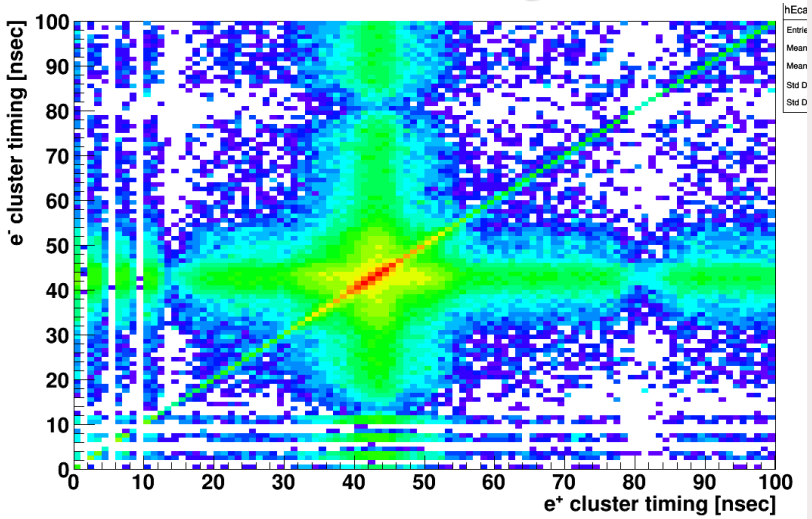




Comparison with Data: Event Selection

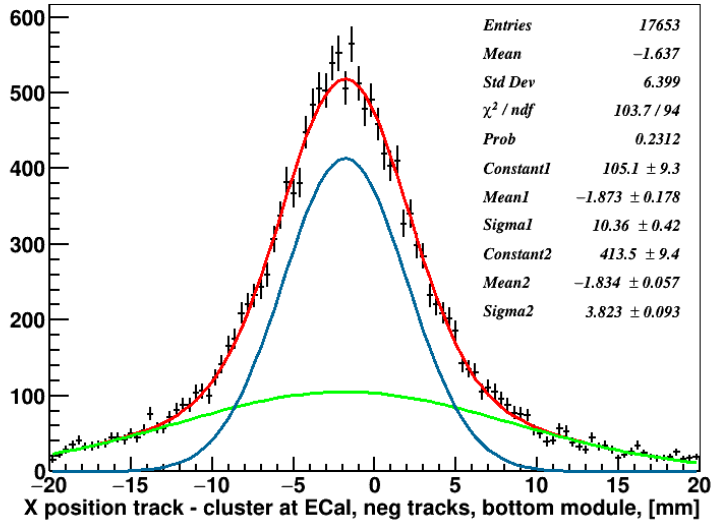
- Data sample – files from 5772, 5779 run
  2015 (pass6, recon, slcio format)
- Track selection:
  - Track type
  - Track Chi2
- Cluster selection
  - dt <3nsec
  - > 0.15GeV

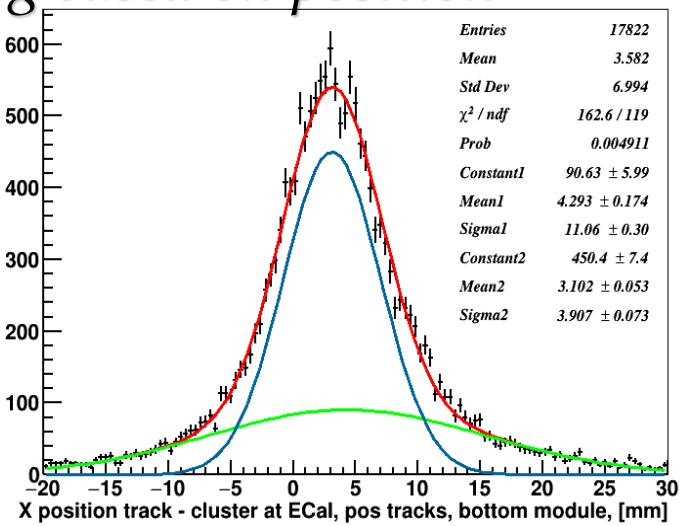
Positron cluster timing vs electron cluster timing

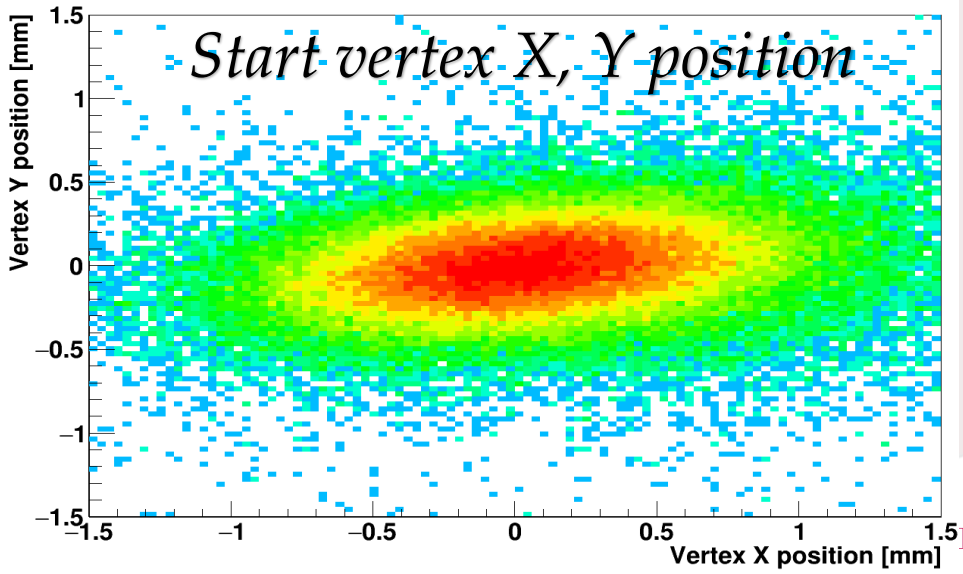


- Track-Cluster Matching:
- Vertex cut is not implemented yet
- Coulumb scattered beam electrons
- Radiative cut

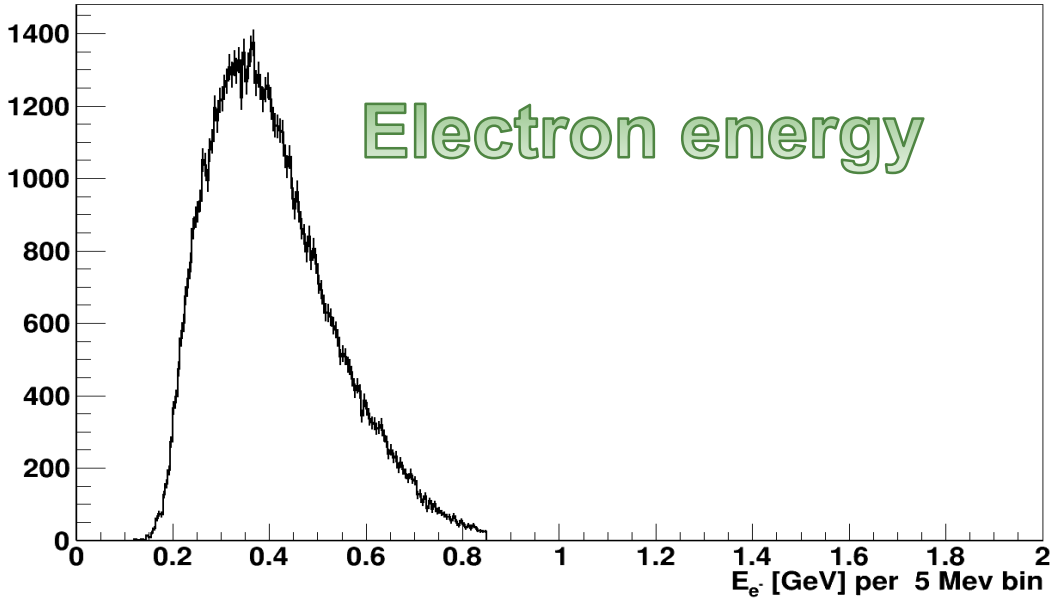
Track-cluster matching based on position

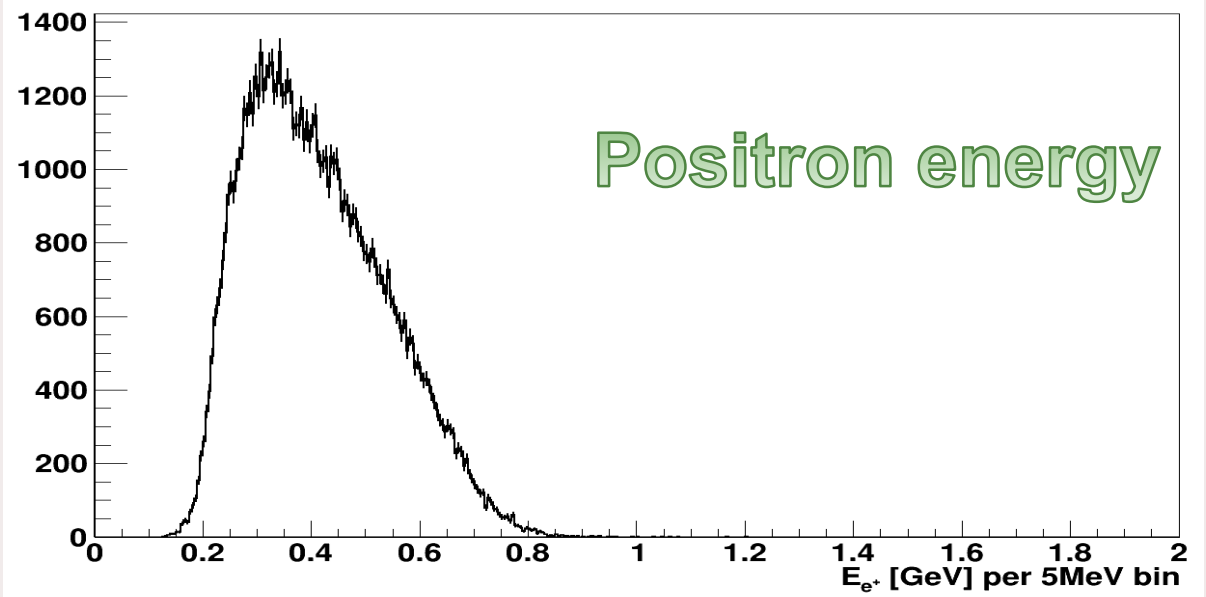


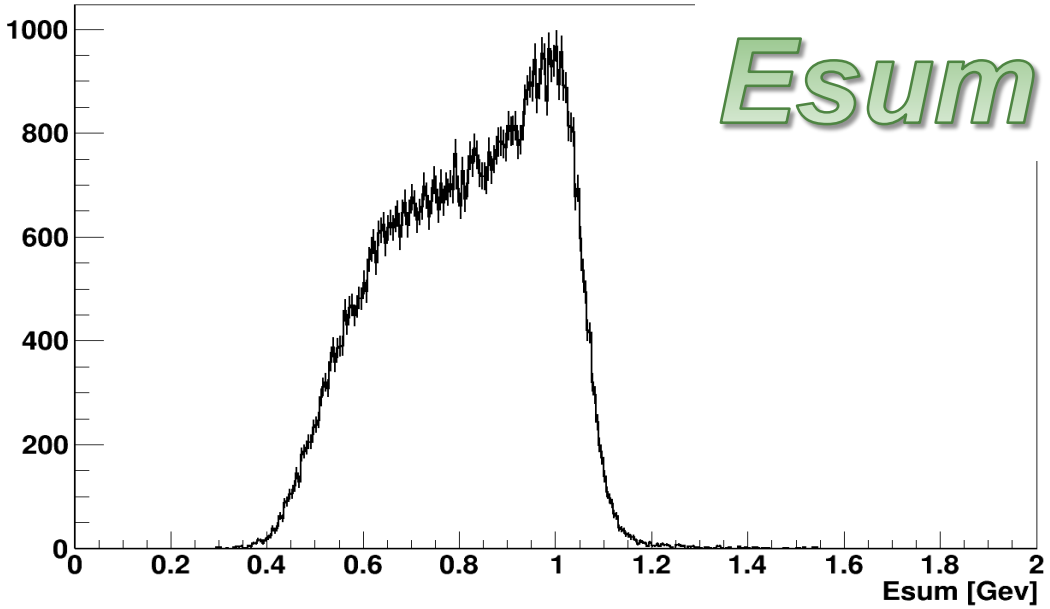


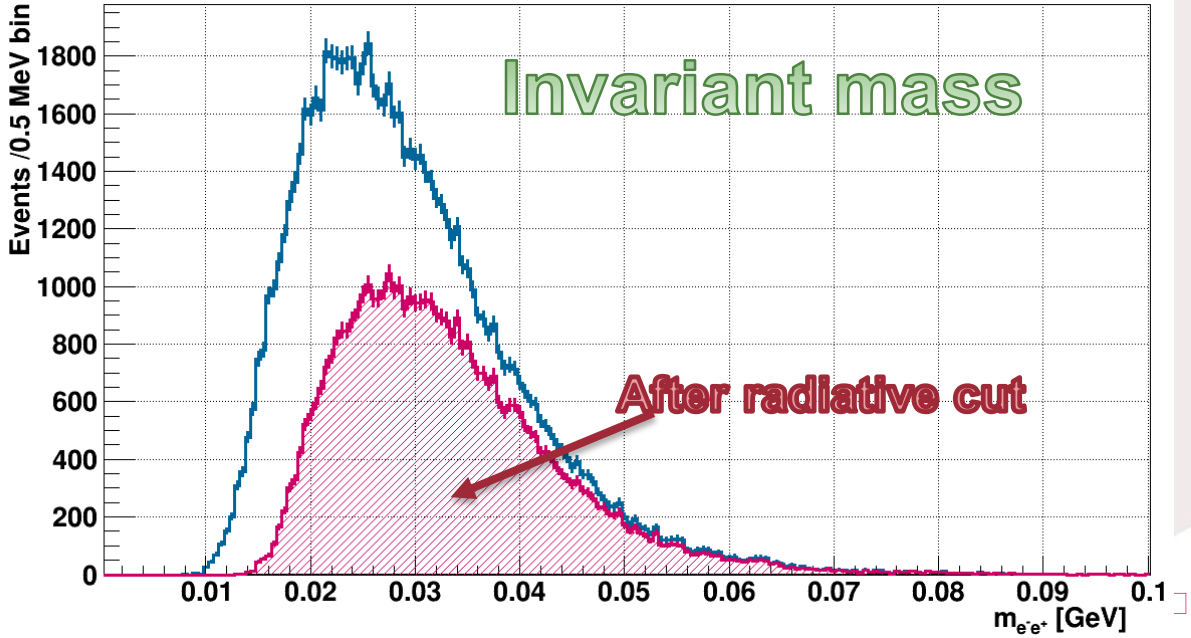


Data: Invariant mass, Esum, lepton energy



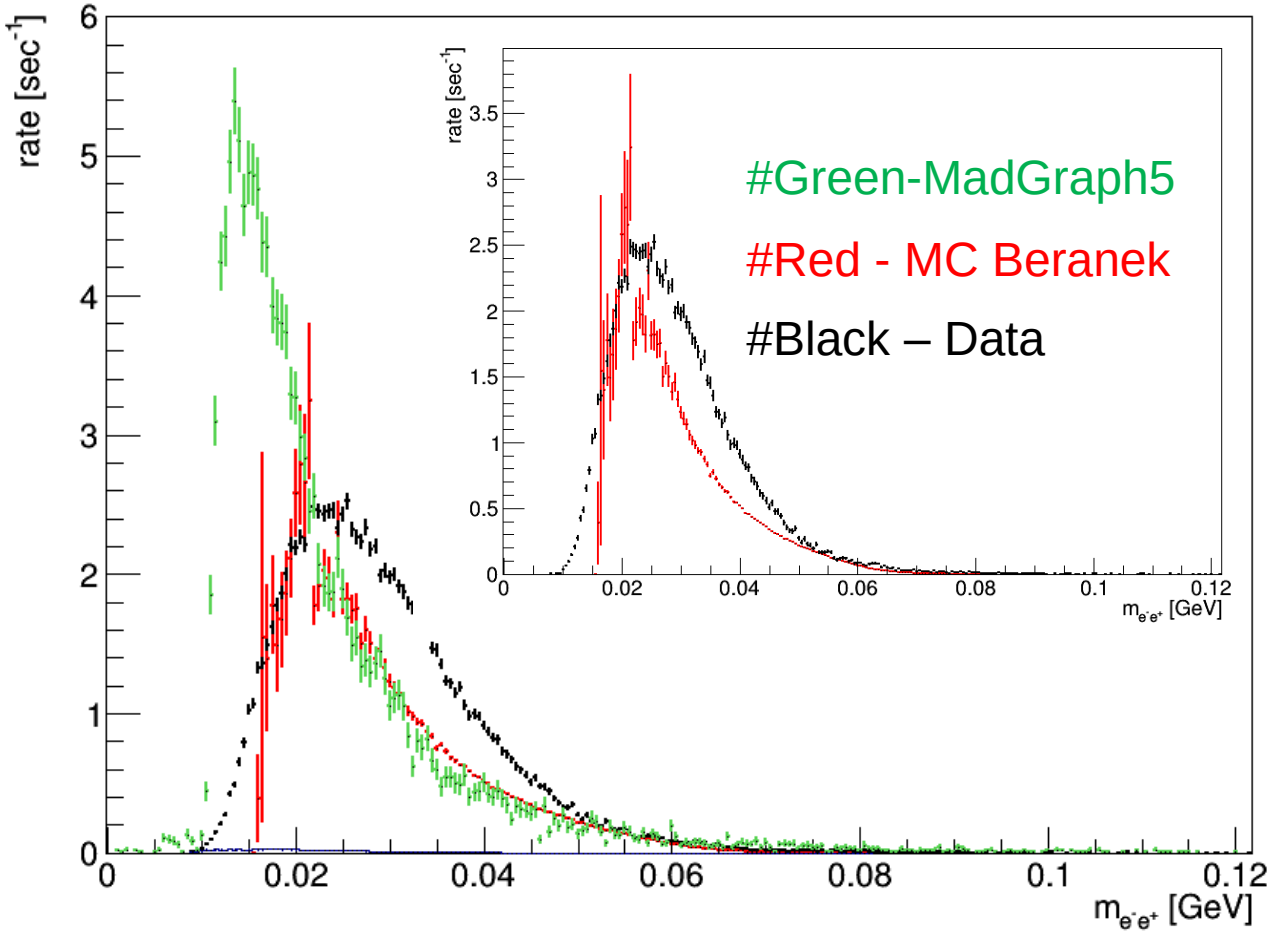


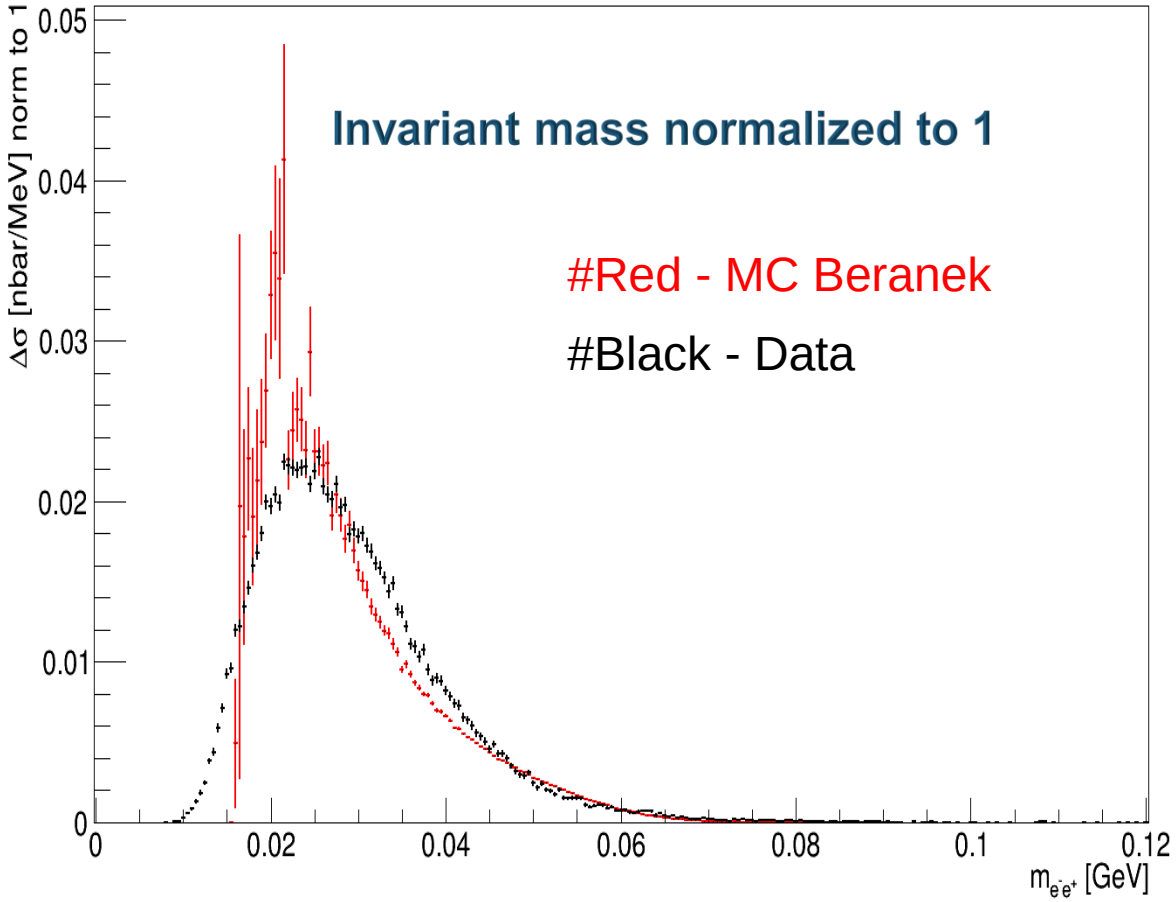




Invariant mass distribution : comparison with MG5, Data, MC Beranek

Invariant mass normalized to rate calc. for data = 110.8 sec^{-1}
For simulations scaled by luminosity = 0.00863 $nb^{-1}sec^{-1}$





Summary

- QED background estimation with Beranek's MC calculation
  - It is setup properly for HPS
- This method has complications
  - Right now the MC integration does not converge with full HPS acceptance
- Comparison with MG5 in small phase space is satisfactory
- Comparison to Invariant mass distribution extracted from data gives reasonable normalization

References

- *[1] "Study of the discovery potential for hidden photon emission at future electron scattering fixed target experiments"*
  T. Beranek and M. Vanderhaeghen
  Phys. Rev. D ***89****, – Published 10 March 2014*

- *[2] "Theoretical framework to analyze searches for hidden light gauge bosons in electron scattering fixed target experiments"*
  T. Beranek, H. Merkel, M. Vanderhaeghen
  Phys. Rev. D ***88****, 015032 – Published 29 July 2013*