Electromagnetic processes at PANDA
TL form factors - Hard exclusive processes - Drell Yan
current activities

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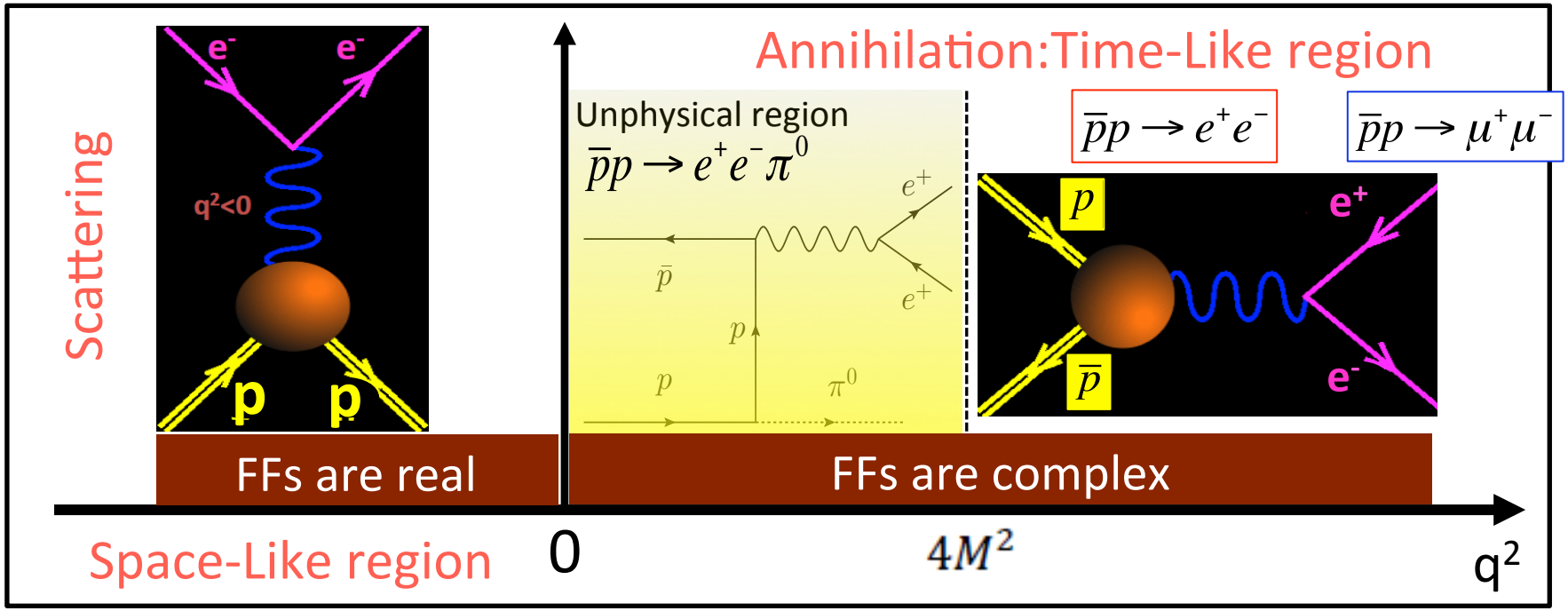
Outline

Publications/release notes in progress

Monte Carlo event generators

Ongoing analyses

Electromagnetic Form Factors of the Proton



Publications/release notes in progress

Feasibility studies for the measurement of time-like proton electromagnetic form factors from $\bar{p}p \to \mu^+\mu^-$ at $\overline{\mathrm{P}}$ANDA at FAIR

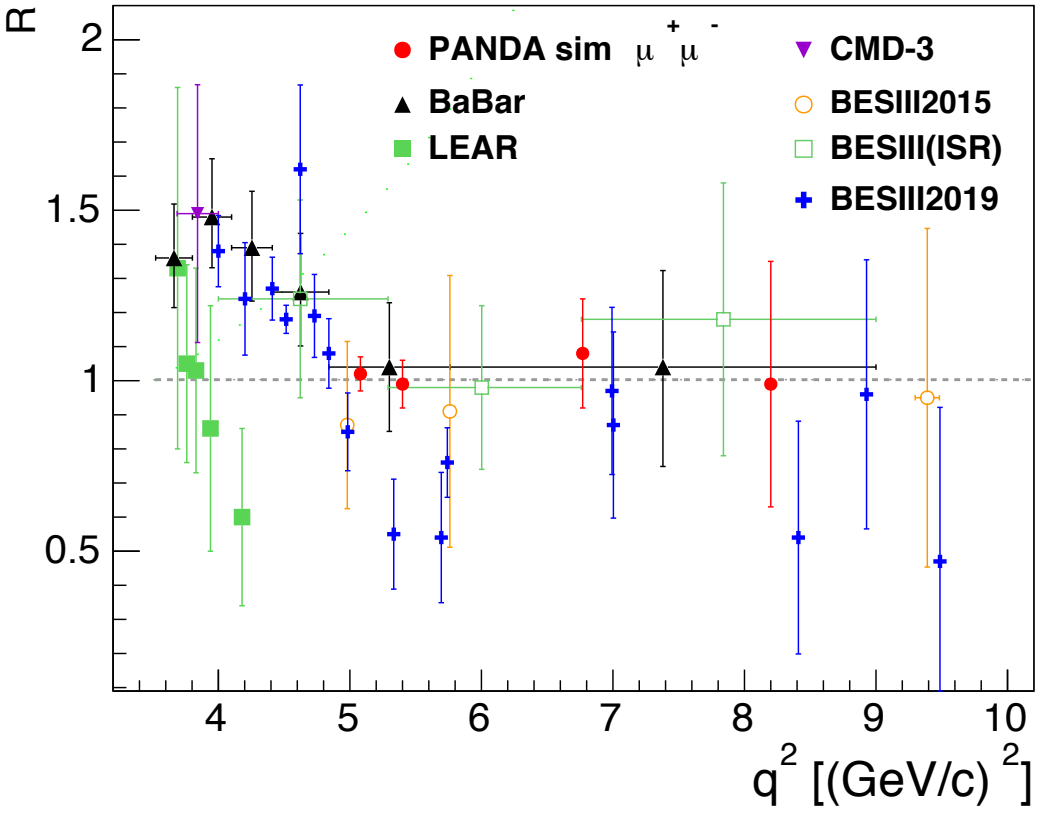
The $\overline{\mathrm{P}}$ANDA Collaboration

$$\bar{p}p \to \mu^+\mu^-$$

- Results are approved
- Journal paper has been finalized (currently under internal review)
- To be submitted to the PANDA Pub. Com. within the next weeks
- Target journal: EPJA

Iris Zimmermann at al., HIM

Results for Phase-3 (L=2 fb^{-1})



Publications/release notes in progress

PANDA Phases1,2 (0.1 fb^{-1}) - Proton form factors

$\bar{p}p \rightarrow e^+e^-$ $\bar{p}p \rightarrow \mu^+\mu^-$

- Muon case: results are approved
- Electron case: comments from referees have been answered and accepted

$\bar{p}p \rightarrow e^+e^-$	*revision 25544*		*DEV2019*	
Cut	Signal	Background	Signal	Background
Reconstruction	86	85	84.5	84
Kinematical cuts (θ, ϕ)	94	96	94	96
dE/dx_{STT}	81	2.5×10^{-1}	81	2.9×10^{-1}
E_{EMC}/p, EMC LM, EMC E1	79	6×10^{-3}	74	7×10^{-3}
$\mathrm{PID}_{STT} > 0.1$	95	1.3	95	1.2
$\mathrm{PID}_{EMC} > 0.1$	82	8.3×10^{-2}	80	3×10^{-1}
$\mathrm{PID}_{MVD} > 0.1$	87	65	93	89
$\mathrm{PID}_{DRC} > 0.1$	96	79	87	79
$\mathrm{PID}_{c} > 0.99$	82	5×10^{-3}	80	2.7×10^{-2}
Reconstruction + all cuts	39.5	6.1×10^{-6}	35	1 event

P=1.5 GeV/c

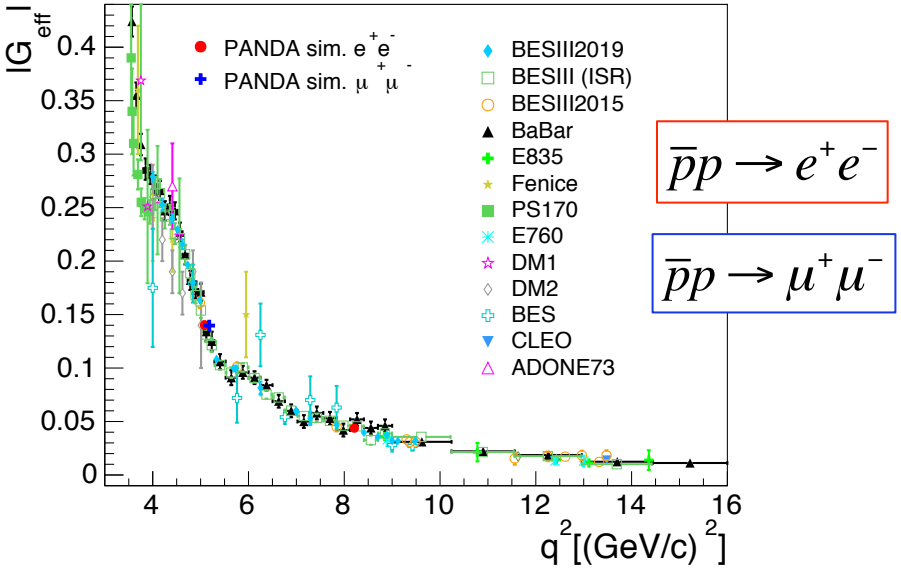
PandaRoot	R	$R \pm \Delta R$
revision 25544	1	1.02 ± 0.040
DEV2019	1	0.96 ± 0.042

The 2 PandaRoot versions provide the same results on the determination of the proton form factors

- Nucleon structure part in the PANDA Phase-1 paper has been updated and ready for review

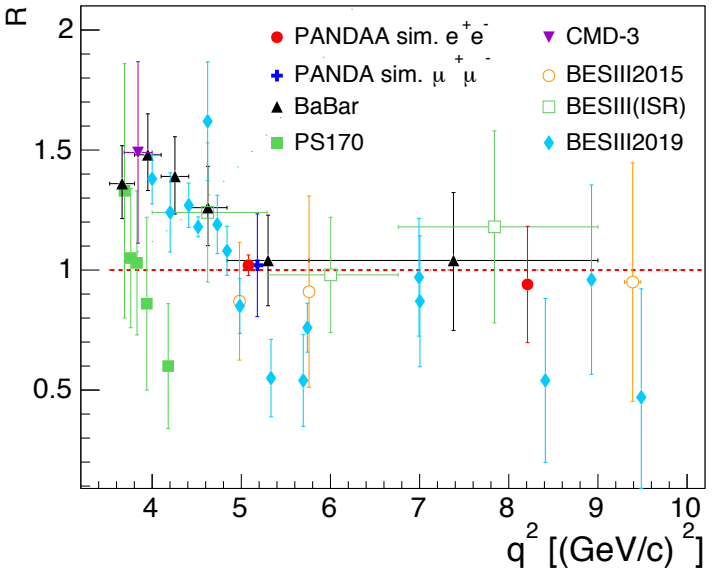
Publications/release notes in progress

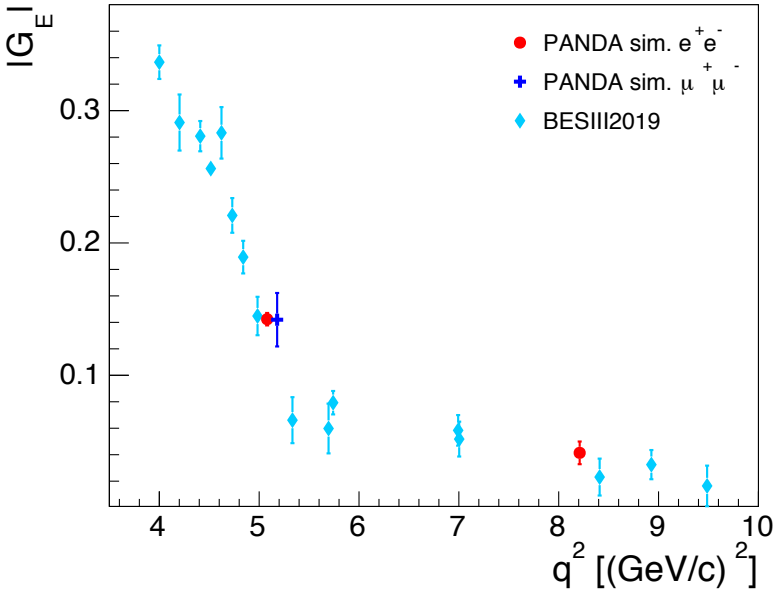
PANDA Phases1,2 (0.1 fb^{-1}) - Proton form factors

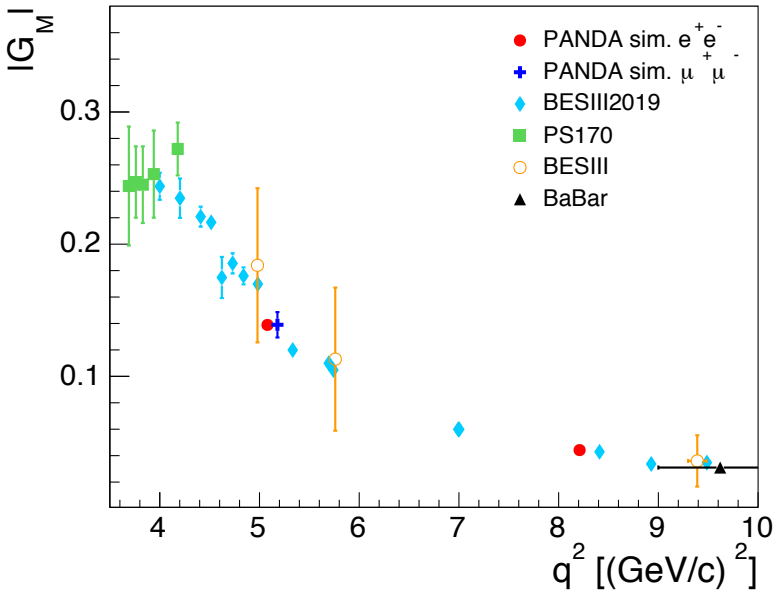


$\bar{p}p \rightarrow e^+e^-$

$\bar{p}p \rightarrow \mu^+\mu^-$





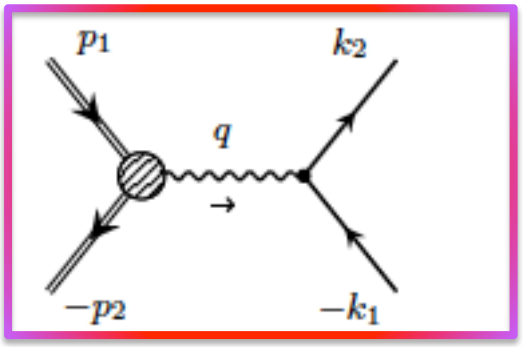


Radiative corrections on $\bar{p}p \to e^+e^-$ at PANDA - Monte Carlo event generator

Yu.M. Bystritskiy , V.A. Zykunov (JINR, Dubna)
M. Zambrana, E. Tomasi-Gustafsson, F. Maas and A. Dbeyssi

Frits A. Berends, K. J. F. Gaemer, and R. Gastmans. Nucl. Phys. B75, 546 (1974).
Frits A. Berends, K. J. F. Gaemers, and R. Gastmans. Nucl. Phys. B63,381–397 (1973).
A.I. Ahmadov et al. Phys. Rev. D 82, 094016 (2010)
A. G. Aleksejevs, S. G. Barkanova, and V. A. Zykunov, Phys. Atom. Nucl. 79, 78 (2016)

Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

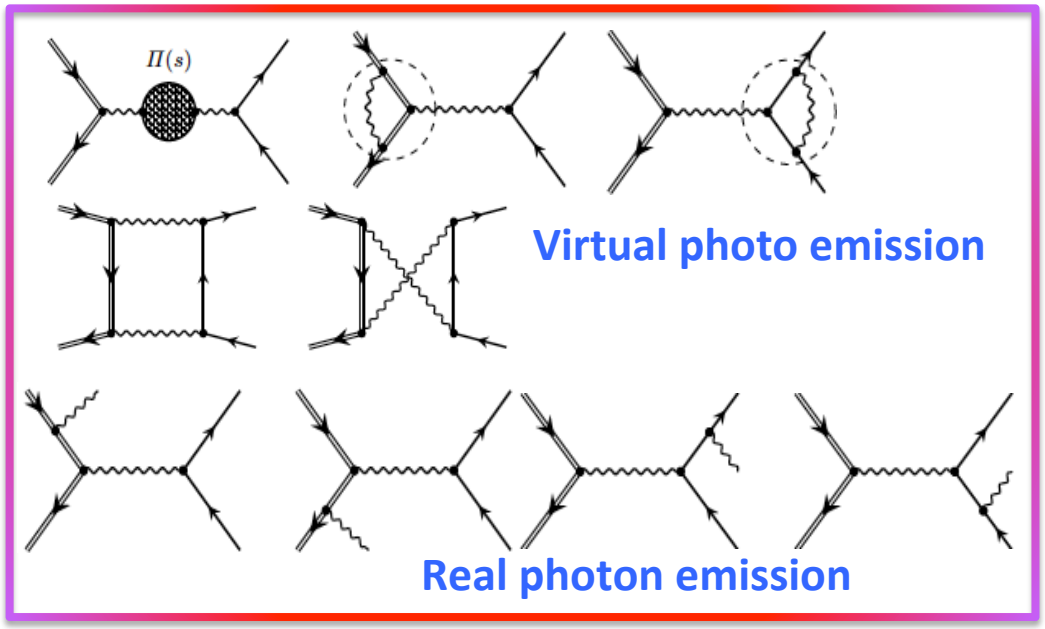


Born differential cross section:

$$\frac{d\sigma_B}{d\cos\theta} = \frac{\pi\alpha^2}{2\beta s}\left[(1+\cos^2\theta)|G_M|^2 + \frac{1}{\tau}\sin^2\theta|G_E|^2\right]$$

- Extraction of the proton form factors

+



QED radiative corrections:

- Modify the value of the cross section

$$\sigma = \sigma_B\,(1+\delta_V+\delta_\gamma)\,.$$

- Modify the value of the experimental signal efficiency (e.g. hard photon)

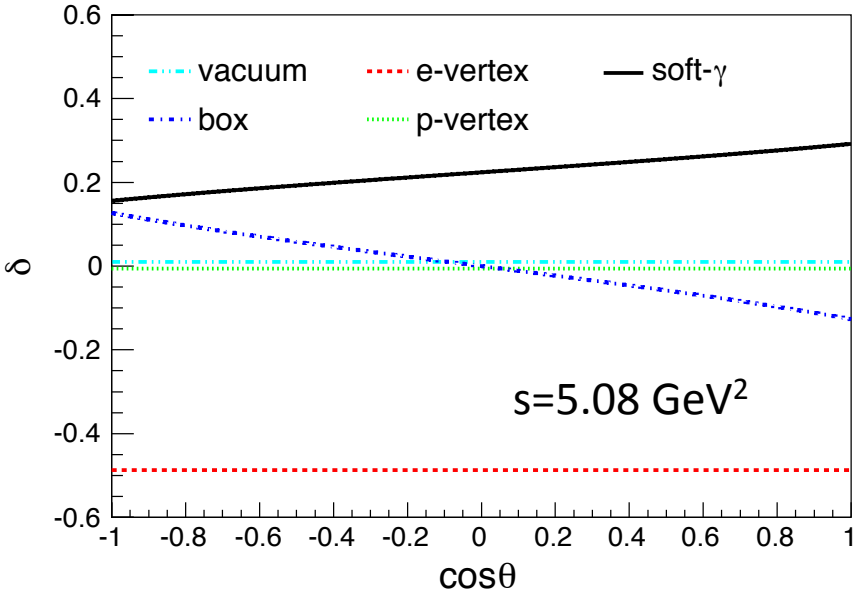
- **Monte Carlo event generator with dedicated calculations is needed**

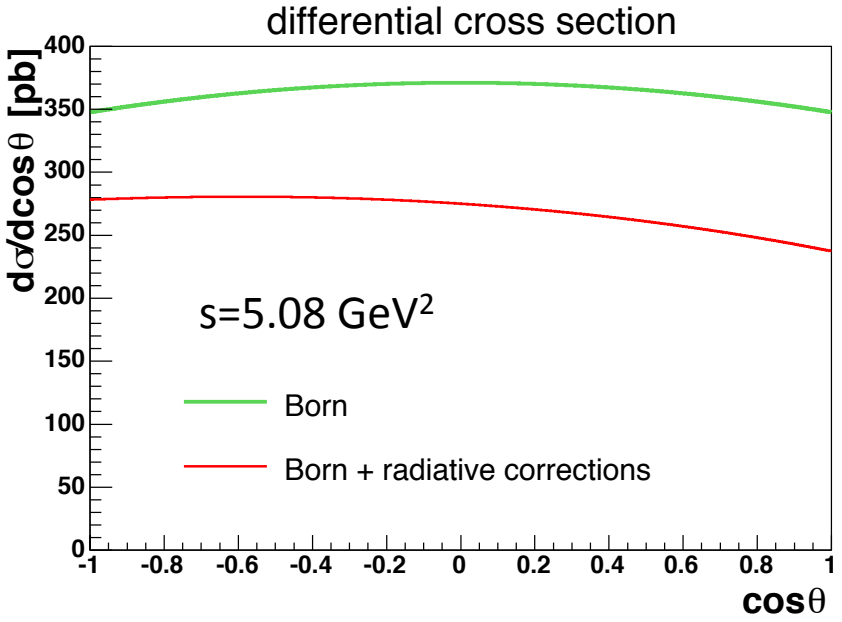
+ higher orders

Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

Virtual and real soft photon emission

- Real soft photon emission: $E_\gamma < \Delta E$ ($< 10^{-2}\sqrt{s}/2$), no experimental detection of the photon
- Two body final state (e^+e^-) : same kinematics as Born process but with a modified cross section





Talk by E. Tomasi, EMP session, PANDA CM June 2019

Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

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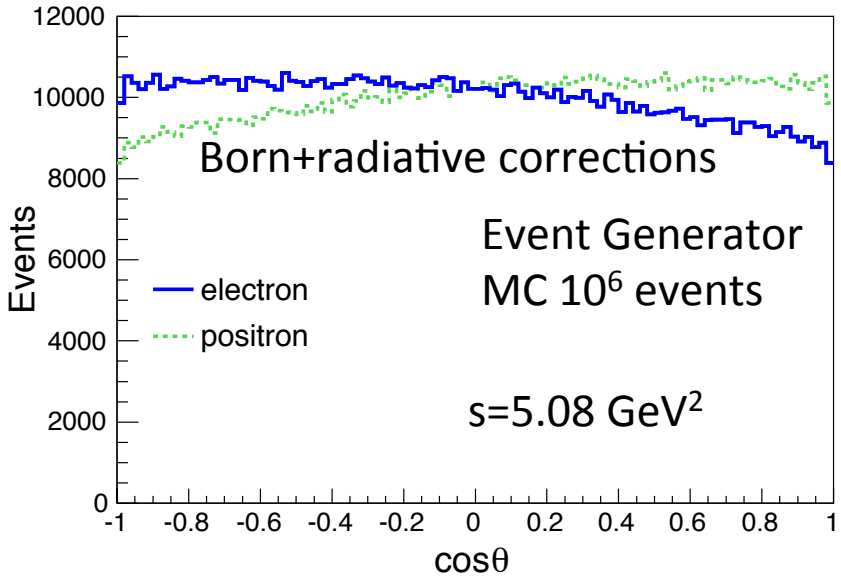
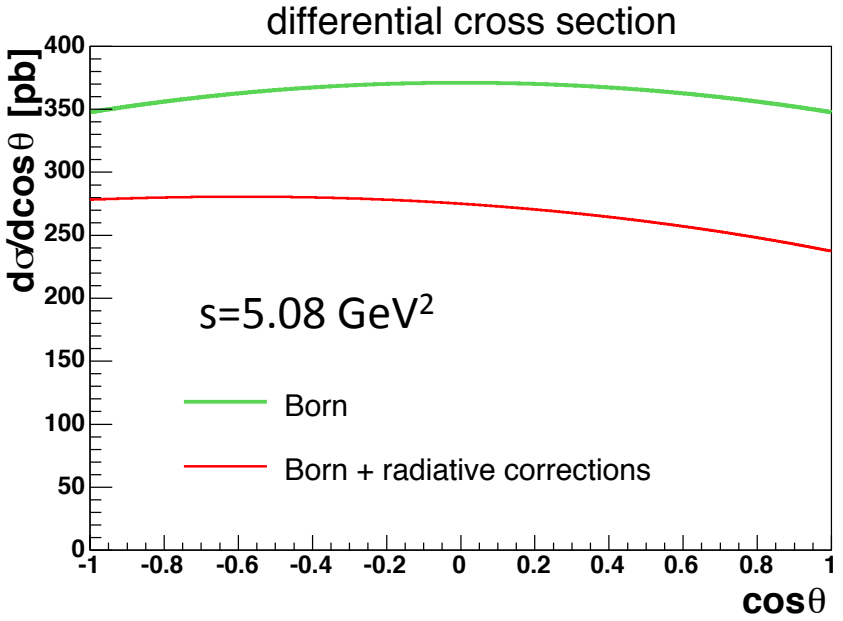




Talk by E. Tomasi, EMP session, PANDA CM June 2019

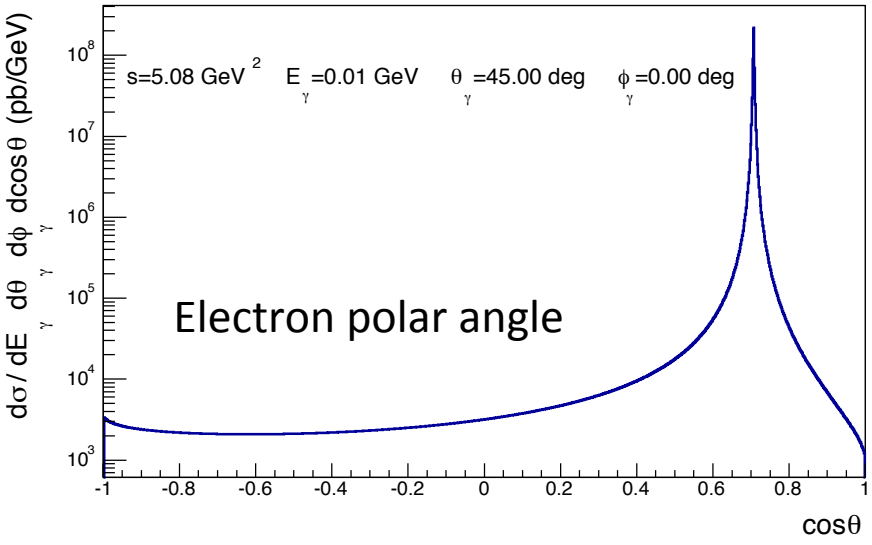
Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

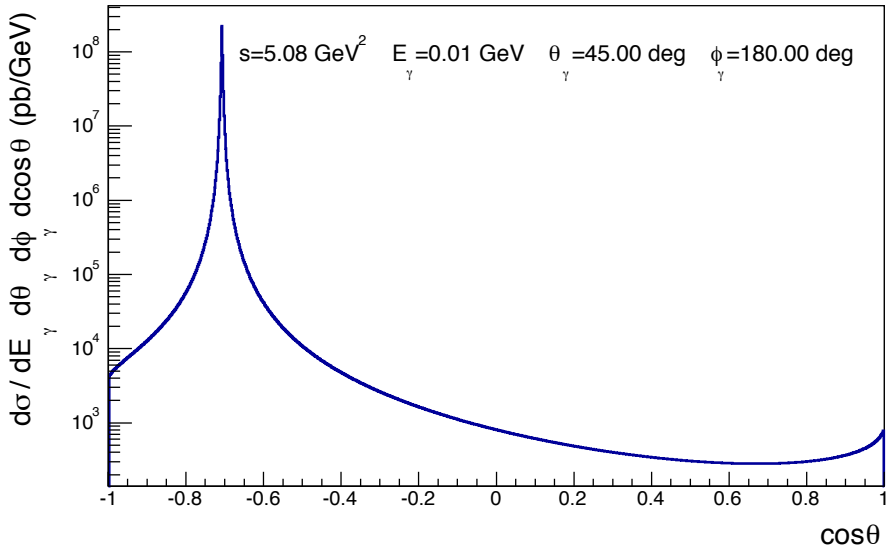
Real soft+hard photon emission

$$p(p_1) + \bar{p}(p_2) \rightarrow e^+(k_1) + e^-(k_2) + \gamma(k),$$

- Differential cross section as function of 5 variables in the CMS:

$$d\sigma_R = (\Sigma)\, dE_\gamma\, d\theta_\gamma\, d\phi_\gamma\, d\cos\theta$$





- Collinear kinematics: photon emitted collinear to the direction of the electron or positron:
  - **Peaks which leads to a reduction in the efficiency and in the accuracy of the of the Monte Carlo event generator**

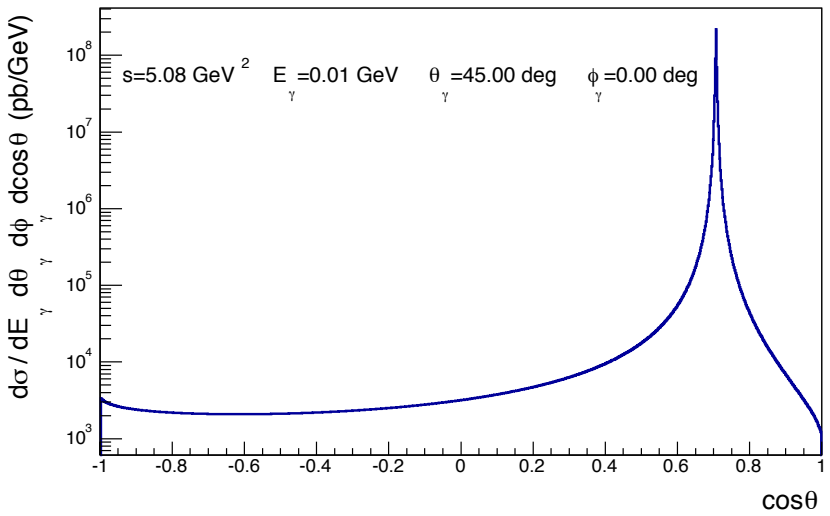
Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

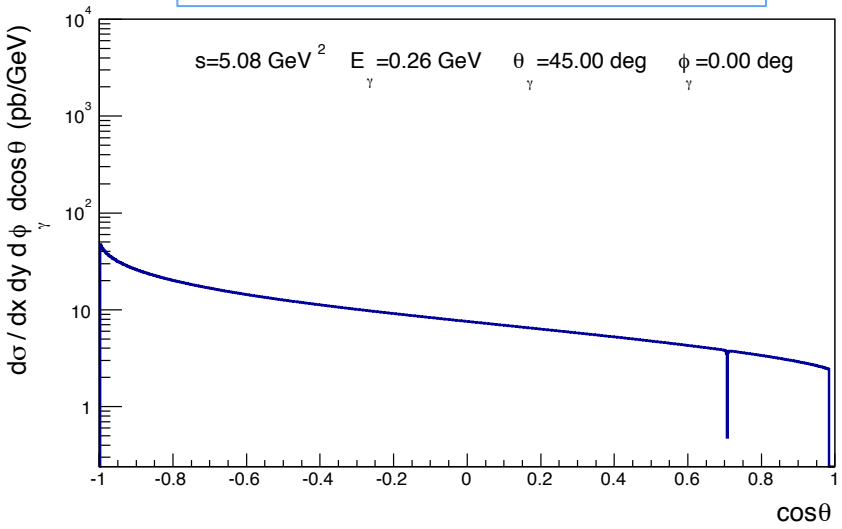
Real soft+hard photon emission

Importance Sampling method (F. james, rep. Prog. Phys. 43 (1980) 1145; M. Caffo and H. Czyz, Comput. Phys. Commun., 100:99–118, 1997):

Photon polar angle θ_γ

$$y(\theta_p) = -\ln(a + 2\sin^2\frac{\theta_p}{2}),$$
$$\theta_p = \angle(\vec{k}_2, \vec{k}),\ a = \frac{2m_e^2}{2s}$$

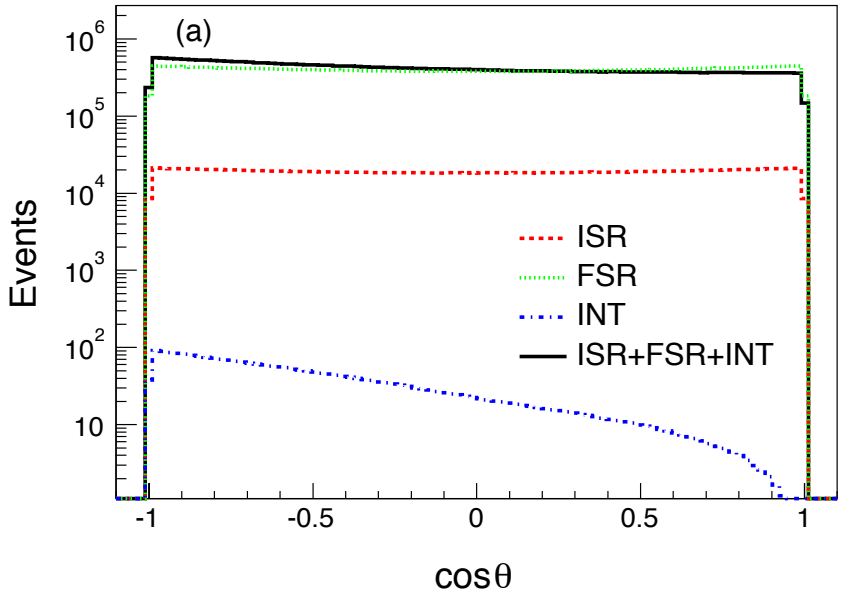


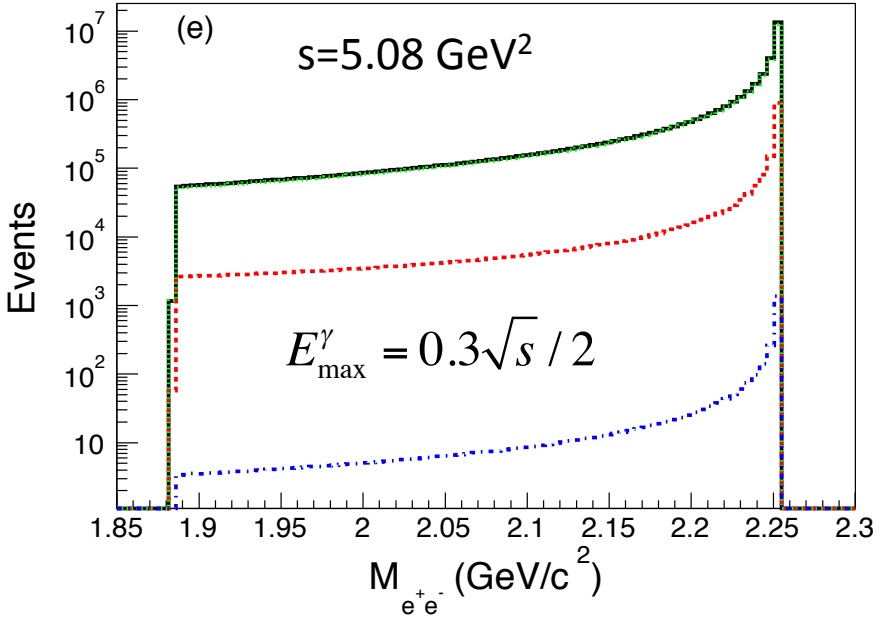


- Jacobian transformations of the two variables, the photon polar angle and the photon energy have been performed

Radiative corrections on $\bar{p}p \rightarrow e^+e^-$ at PANDA

Real photon emission- MC event generator





δ	$E^{\gamma}_{max} = 0.1\sqrt{s}/2$			$E^{\gamma}_{max} = 0.3\sqrt{s}/2$		
θ (degree)	Virtual	Real	Virtual+Real	Virtual	Real	Virtual+Real
30	-0.37606	0.31166	-0.06440	-0.37606	0.37066	-0.00540
90	-0.48275	0.39084	-0.09192	-0.48275	0.46010	-0.02265
150	-0.58893	0.28229	-0.11038	-0.58893	0.54895	-0.03998

Analyses of electromagnetic processes

Signal	Physics	Status
$\bar{p}p \to e^+e^-$	FFs	Completed and published (P3) publication in progress (P1, 2)
$\bar{p}p \to \mu^+\mu^-$	FFs	Completed, publications in progress
$\bar{p}p \to e^+e^-\pi^0$	FFs below threshold	Analysis ongoing
$\bar{p}p \to \gamma^*\pi^0$ $\bar{p}p \to J/\psi\pi^0$	TDAs	Completed and published (P3)
$\bar{p}p \to \gamma\gamma$ $\bar{p}p \to \pi^0\gamma$	GDAs	
$\bar{p}p \to \mu^+\mu^- X$ $\bar{p}p \to e^+e^- X$	TMD PDFs	Analysis ongoing