

# Electromagnetic and hard exclusive processes at PANDA

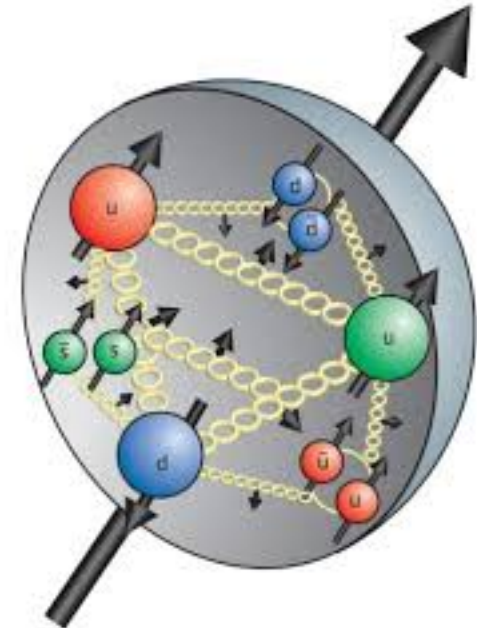
## Current activities

Alaa Dbeyssi (for the EMP working group)

*PANDA CM, 07.03.2017*

Helmholtz-Institut Mainz

Johannes Gutenberg University



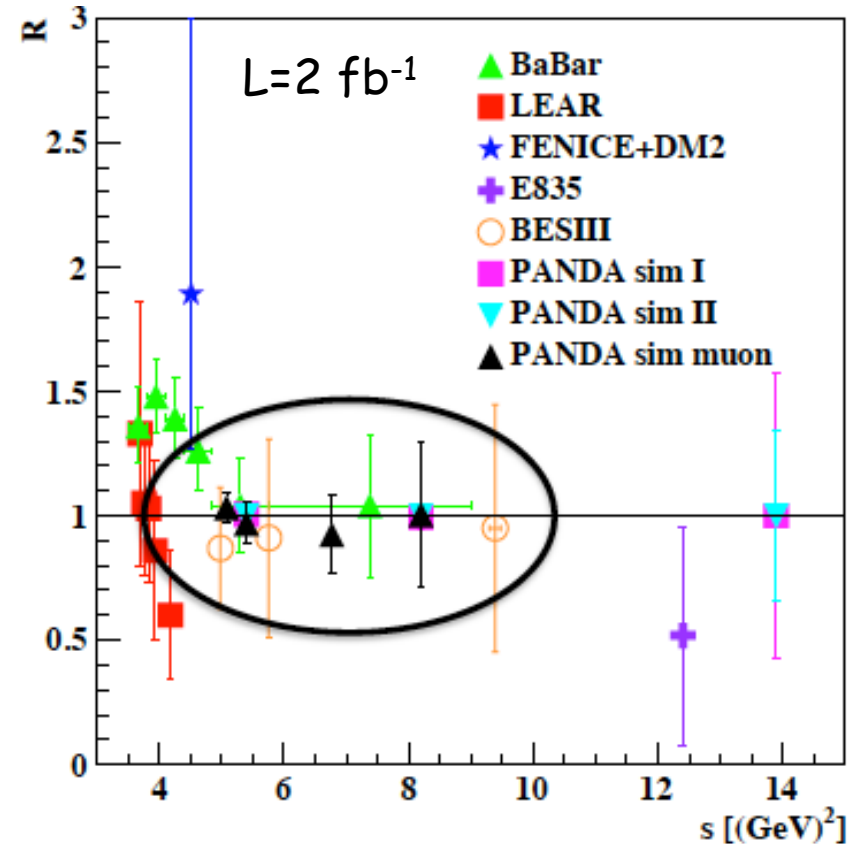
# EMP current activities

- PANDARoot simulations and analysis of the signal channels
- Development of Monte Carlo events generators for signal and background channels (to be implemented in PANDAROOT)
- Phenomenology studies and parameterization of cross sections (signal and/or background)
- Preparation for PANDA Phase 1

# Proton form factors with $\bar{p}p \rightarrow \mu^+ \mu^-$

Simulations with the **full luminosity** mode and **complete detector setup** @ 1.5, 1.7, 2.5 and 3.3 GeV/c

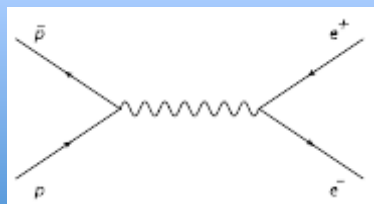
- ✓ Finalization of the analysis: optimization of selection cuts, determination of systematic errors, calculation of the total precision on the measurement of the effective FF, FF ratio,  $G_E$  and  $G_M$ , ...
- ✓ RN is updated and under review within the working group.
- Complete PANDA reviewing process for a **journal publication** will start soon



Total precision from 6.0 % to 29.3%

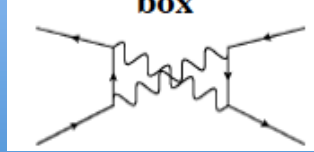
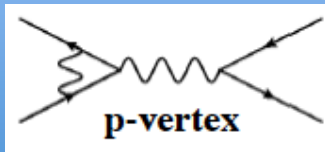
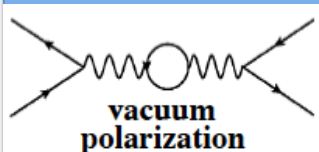
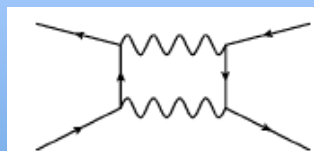
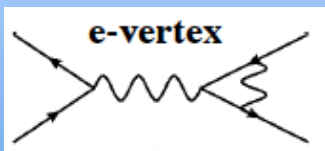
I. Zimmermann (HIM)

# The $\bar{p}p \rightarrow e^+e^-$ cross section : next to leading order

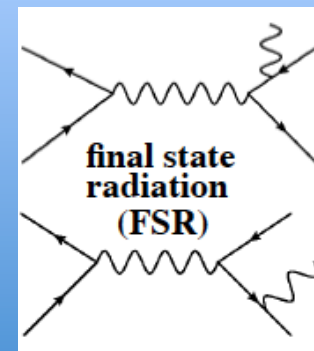
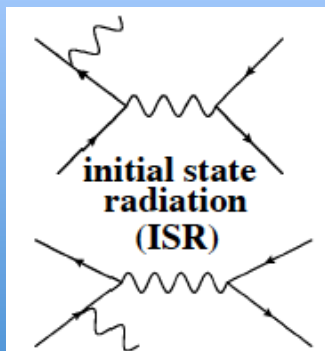


Born  $\rightarrow$  Form factors

Virtual corrections



Real corrections



Cross section calculator and (“stand alone”) event generator including Born amplitude, virtual corrections, and real corrections (soft photon only), **are finished and ready to use for physics analyses**

Ongoing work

- interfacing the generator to PandaRoot
- including hard photons

*M. Zambrana et al.*  
*In Collaboration with*  
Yu. M. Bystritskiy (JINR, Russia)  
and V.A. Zykunov (JINR, Russia)

# Preparations for PANDA “phase 1”

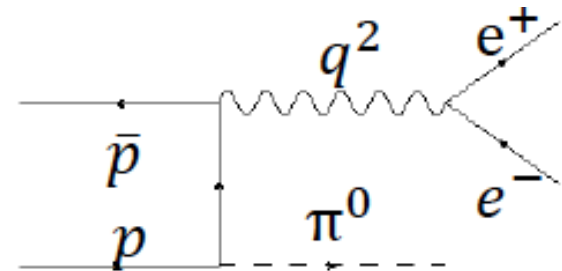
- **Low luminosity by a factor  $\sim 20$  compared to the HL mode**
- **Reduced detector setup**
- **New official release (Feb17) of PANDAROOT for Phase 1 simulations is now available**

➤ **Form factors with electron and muon pairs**  $\bar{p}p \rightarrow e^+e^-$   $\bar{p}p \rightarrow \mu^+\mu^-$

Tests with the new PANDARoot release: encountered problems are not yet solved

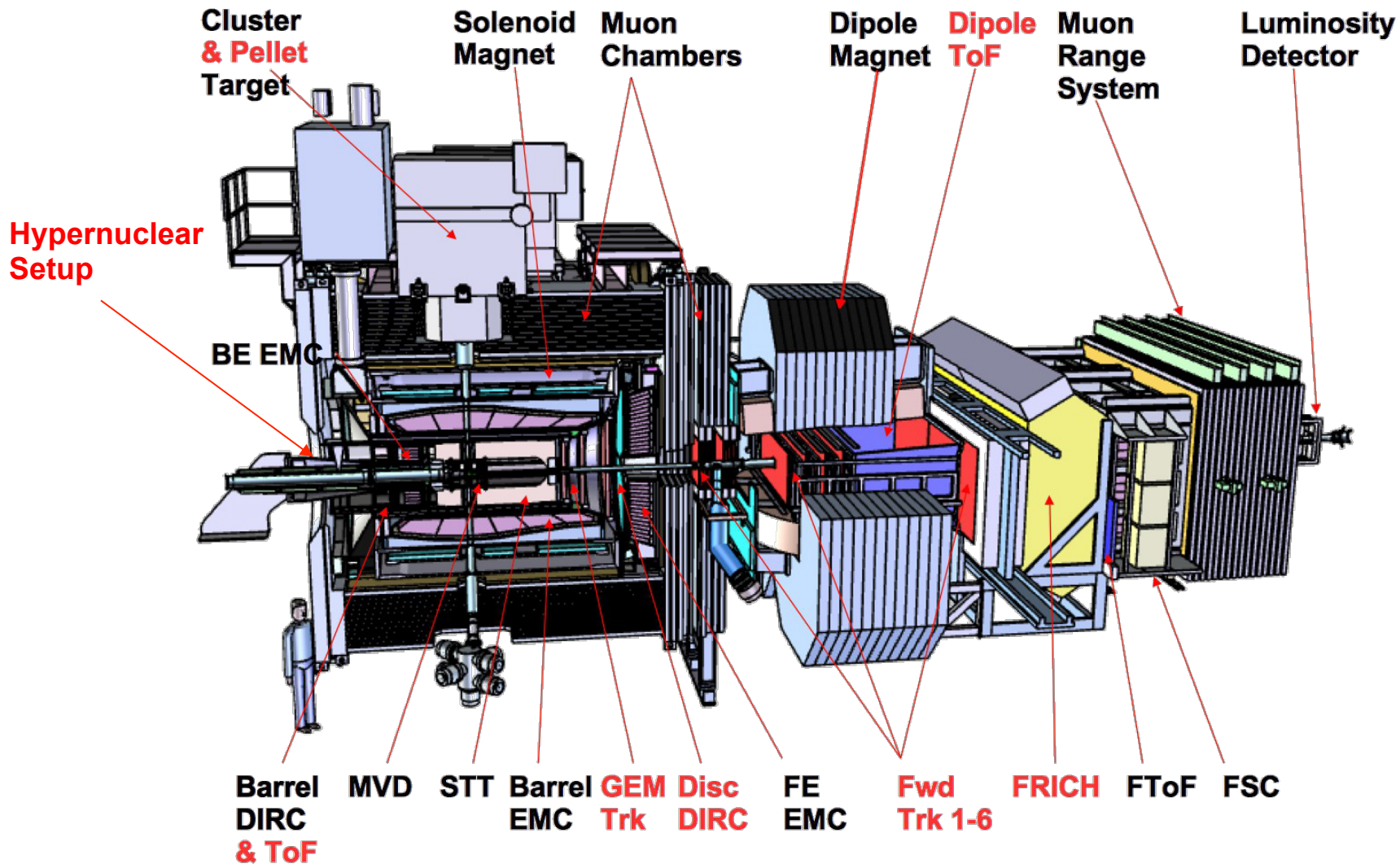
➤ **Form factors in the unphysical region**  $\bar{p}p \rightarrow e^+e^-\pi^0$

- PANDA: First measurement of proton form factors in the unphysical region (FF ratio, relative phase?)
- Feasibility studies were performed with BaBar framework
- **Feasibility studies with PANDAROOT for Day-1 will start soon (HIM Mainz)**



# PANDA Detector (Phase 1)

Reduced (Phase 1) and **full** setup



# PANDA EMP @ “phase one” (P1)

Signal	Physics	Comments on the process or the physics	Phase
$\bar{p}p \rightarrow e^+e^-$	FFs	High precision Large momentum range	1 (competition from BESIII)
$\bar{p}p \rightarrow \mu^+\mu^-$	FFs	The process is unique for PANDA	1 (Limited precision)
$\bar{p}p \rightarrow e^+e^-\pi^0$	FFs below threshold	Unique for PANDA	1
$\bar{p}p \rightarrow \gamma^* \pi^0$ $\bar{p}p \rightarrow J / \psi \pi^0$	TDAs	The processes are unique for PANDA	3
$\bar{p}p \rightarrow \gamma\gamma$ $\bar{p}p \rightarrow \pi^0\gamma$	GDAs	The process (with pi0 ) Is unique for PANDA	1 (Lack of person power)
$\bar{p}p \rightarrow \mu^+\mu^-X$	TMD PDFs		3

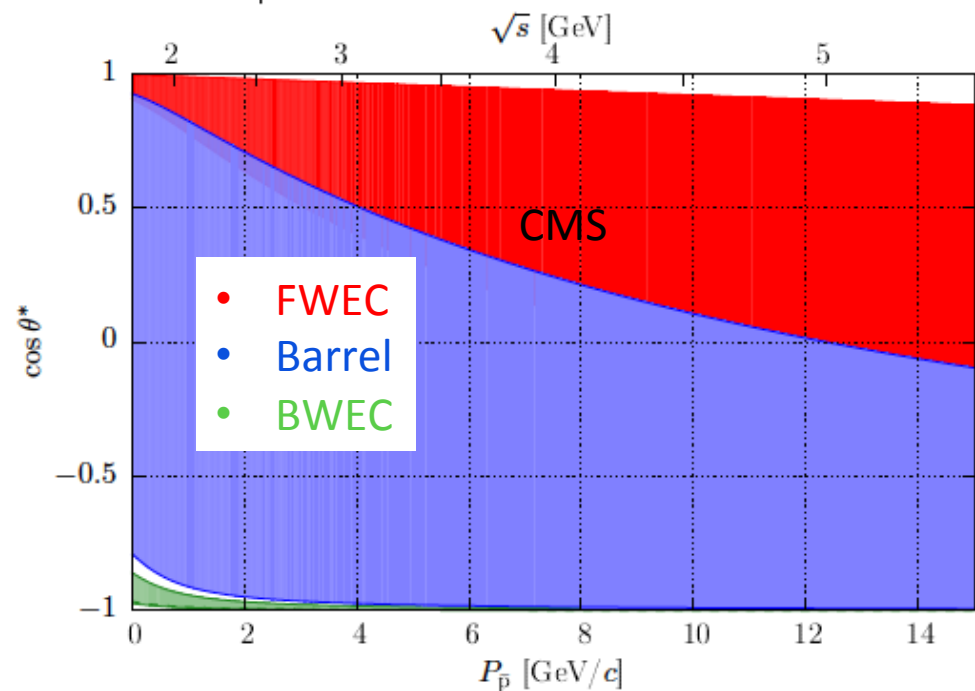
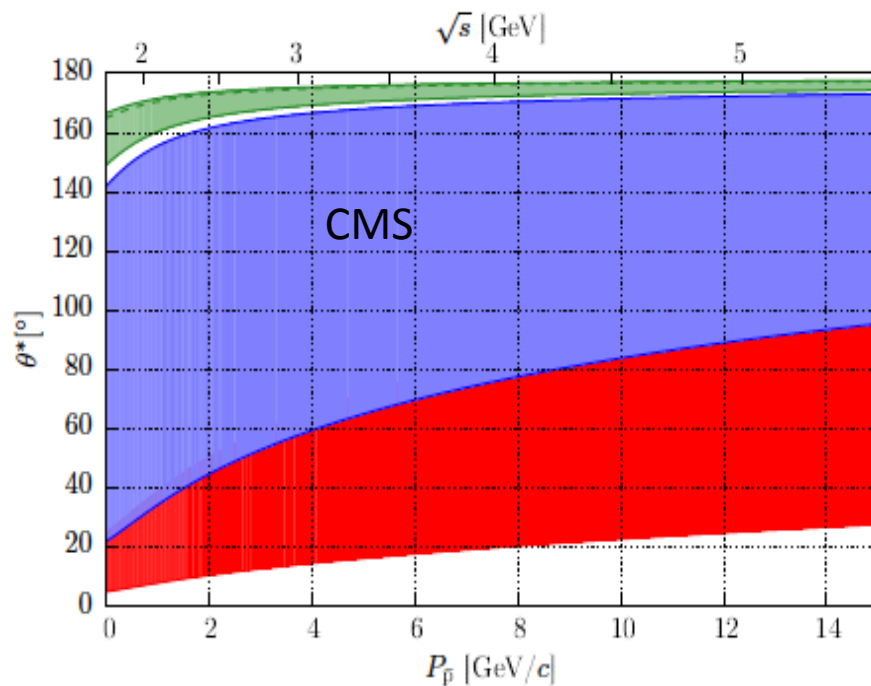
# Acceptance of the BWEMC

BWEM-MVD interference:

- Remove the inner layer of crystal from the BWEMC (?)
- Move the BWEMC by about 55 mm

Numerical values for the limits of  $\theta^*$  in the lab frame

	$\theta_{\min}$	$\theta_{\max}$	$\tilde{\theta}_{\max}$
FWEC	$5.0^\circ$	$25.0^\circ$	--
Barrel	$22.0^\circ$	$142.0^\circ$	--
BWEC	$149.1^\circ$	$166.6^\circ$	$165.0^\circ$

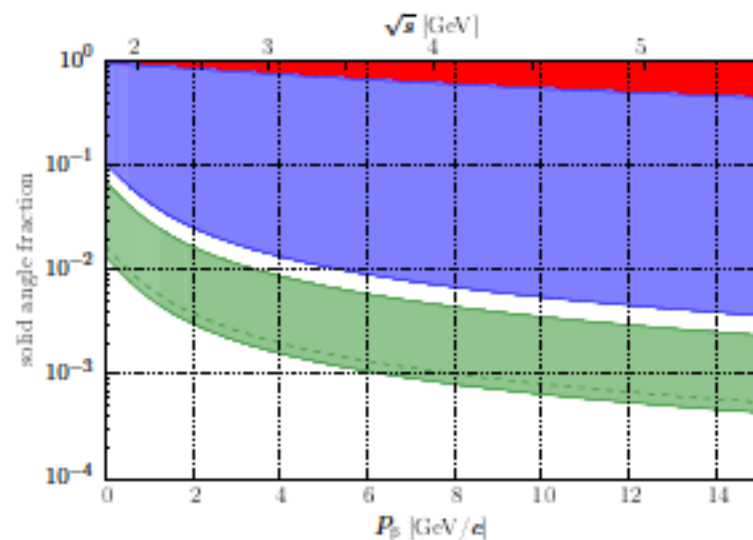
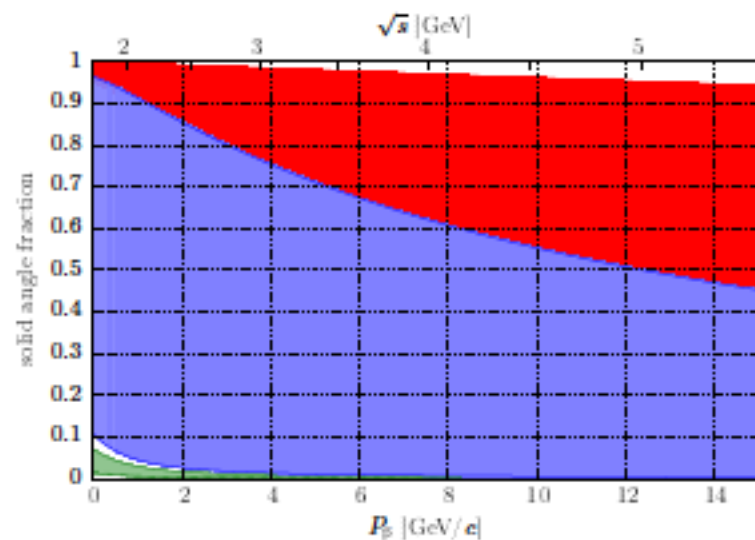
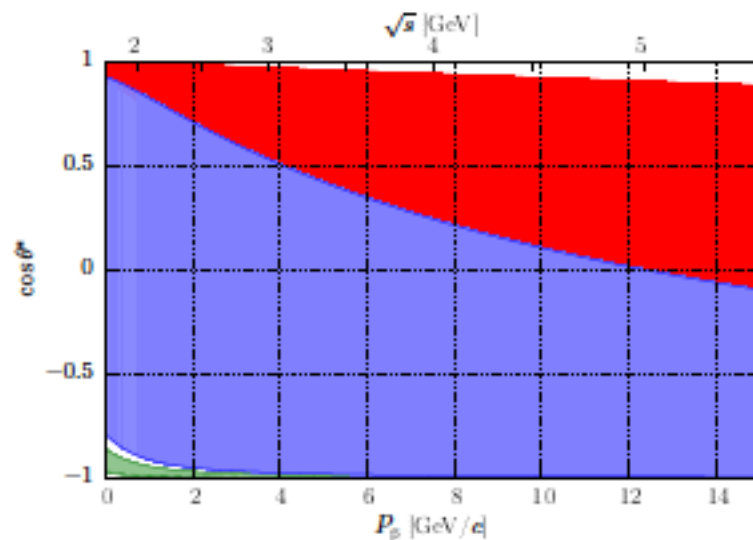
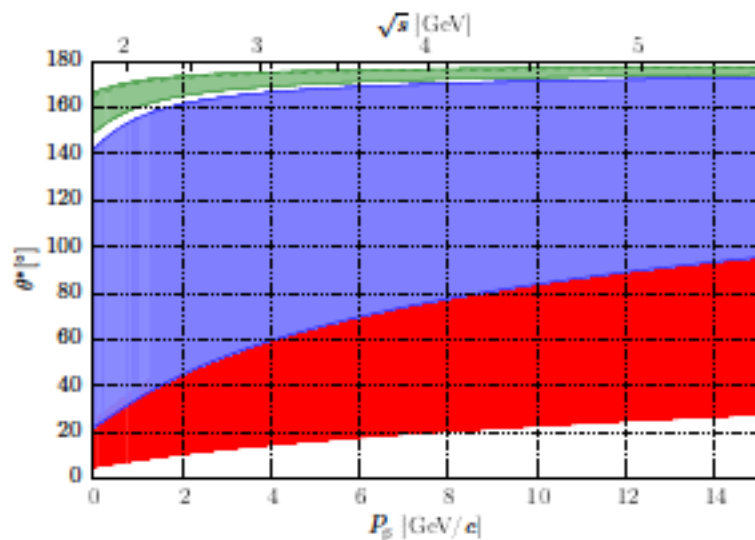


Luigi Cappozza, David Rodriguez



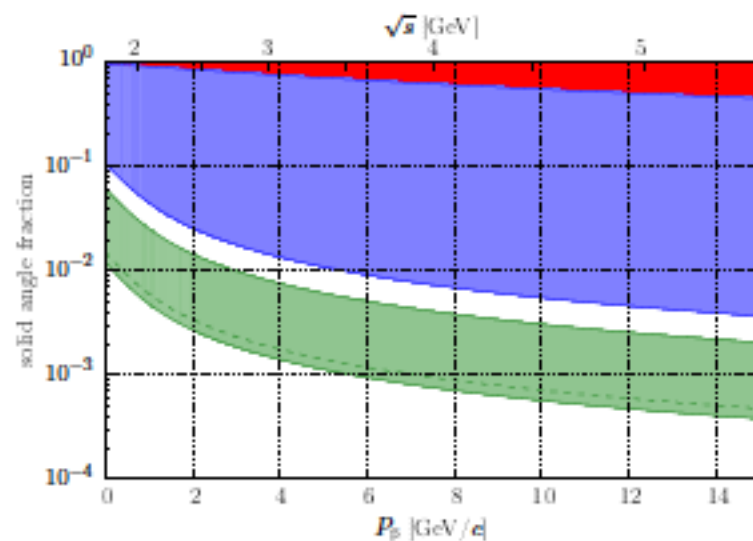
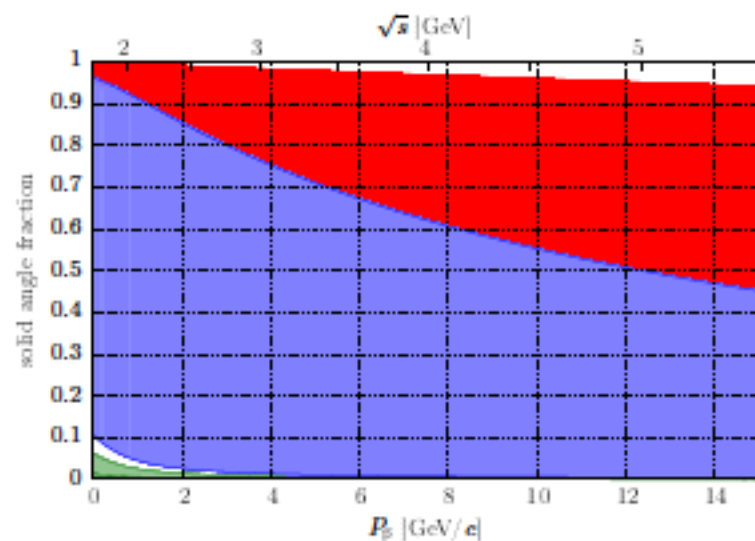
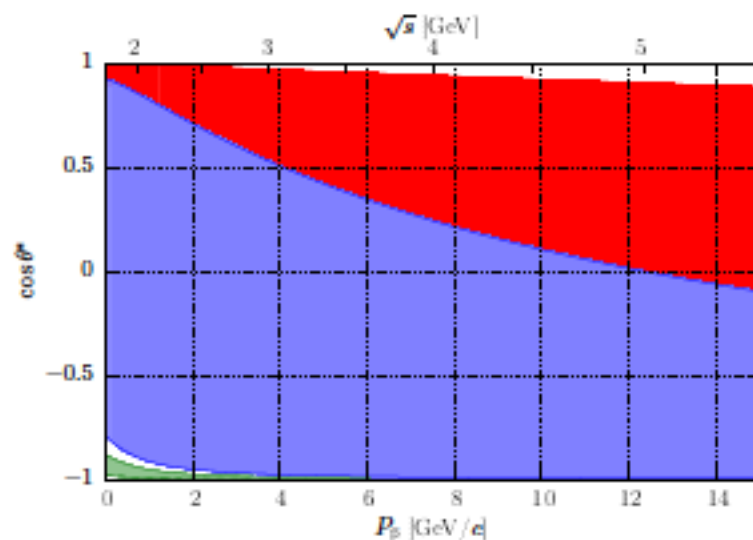
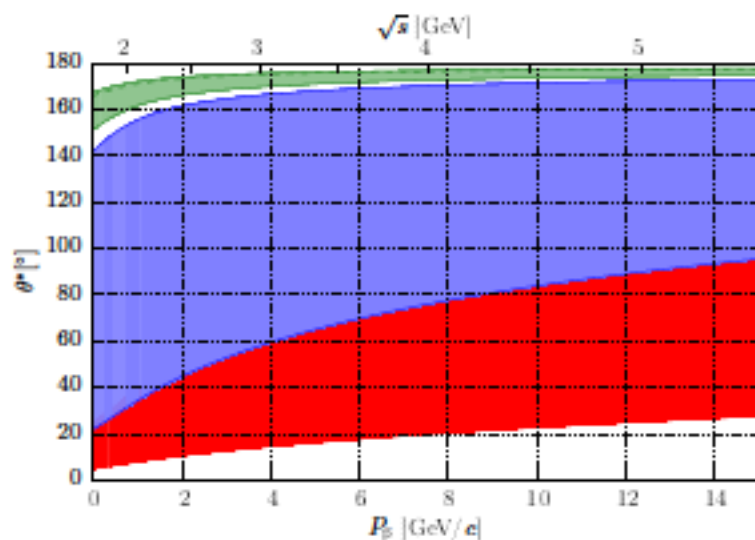
# Effect of moving the BWEC upstream

Original Z position:  $\theta_{\min} = 149.1^\circ$ ,  $\theta_{\max} = 166.6^\circ$ ,  $\tilde{\theta}_{\max} = 165.0^\circ$



## Effect of moving the BWEC upstream

Z position moved upstream by 55 mm:  $\theta_{\min} = 151.2^\circ$ ,  $\theta_{\max} = 167.4^\circ$ ,  $\tilde{\theta}_{\max} = 165.9^\circ$



# Electromagnetic processes @ PANDA

- Proton form factors in the unphysical region:  $\bar{p}p \rightarrow e^+e^-\pi^0$
- Transition Distribution Amplitudes (TDAs) with meson production in ppbar annihilation:

$$\bar{p}p \rightarrow \gamma^* \pi^0 \rightarrow e^+e^-\pi^0 \quad \bar{p}p \rightarrow J/\psi \pi^0 \rightarrow e^+e^-\pi^0$$

- Generalized Distribution Amplitudes with hard exclusive processes:

$$\bar{p}p \rightarrow \gamma\gamma \quad \bar{p}p \rightarrow \pi^0\gamma$$

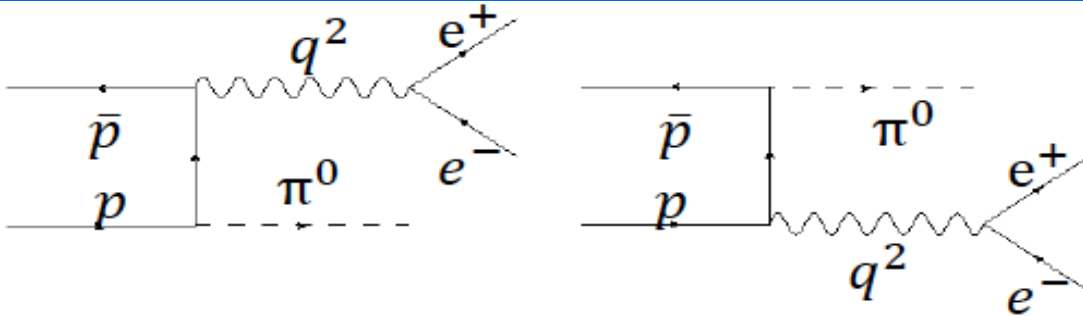
- Proton form factors with lepton pair (electrons and muons):

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

- Transverse Parton Distribution Functions in Drell-Yan Production

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

# Proton FFs in the unphysical region



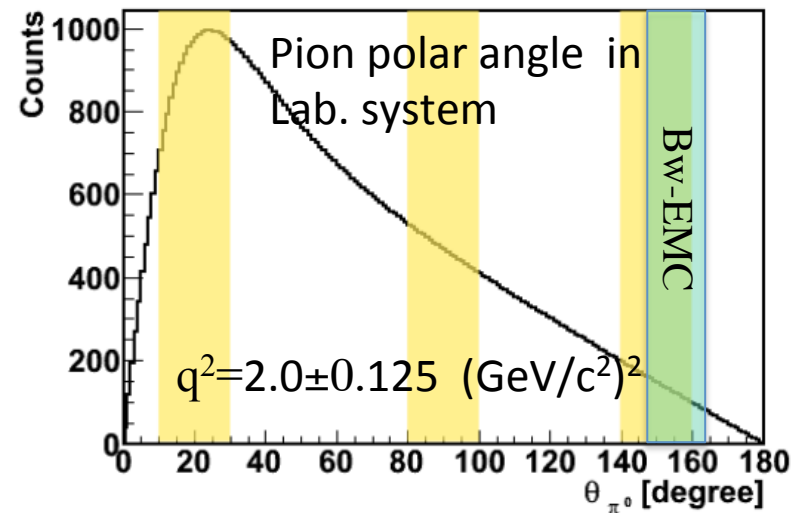
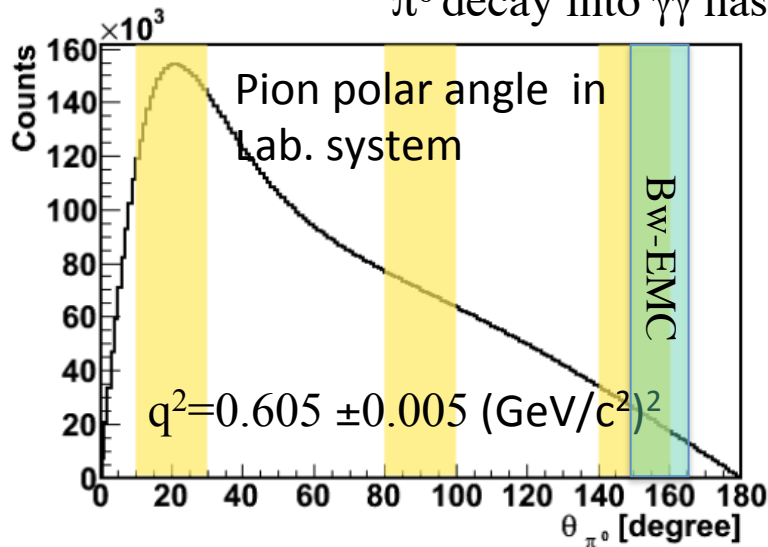
One nucleon exchange model

Feasibility studies were performed @  $p=1.7 \text{ GeV}/c$  with:

J. Boucher,  
PhD Thesis 2011, IPNO

- $q^2=0.605 \pm 0.005, 2.0 \pm 0.125 \text{ (GeV}/c^2)^2$ , at each  $q^2$ :
  - $10^\circ < \theta_{\pi^0} < 30^\circ, 80^\circ < \theta_{\pi^0} < 100^\circ$  and  $140^\circ < \theta_{\pi^0} < 160^\circ$  (Lab. System)

$\pi^0$  decay into  $\gamma\gamma$  has to be taken into account



# EMP@ PANDA: current activities

- Preparations for Phase-1 experiment (FF measurements) with:

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

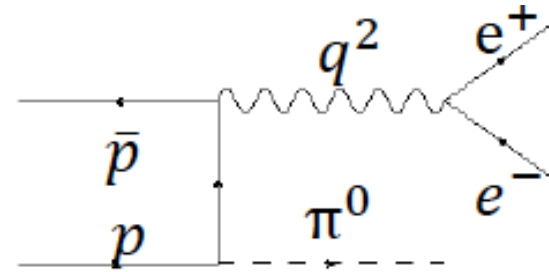
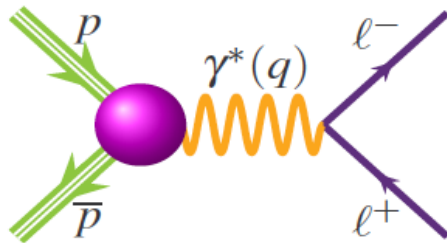
@ 1.5 up to  $\sim 4$  GeV/c

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

@  $\sim 1.5/1.7$  GeV/c

$$\bar{p}p \rightarrow e^+e^-\pi^0$$

@  $\sim 1.5/1.7$  GeV/c



- Proton FFs with electron pairs: Development of an **event generator** for the channel “ $p$ - $p$ bar  $\rightarrow e^+e^-$ ” including the Born amplitude, and **next-to leading order** virtual and real corrections (ongoing work)
- A PANDA related paper "Antiproton-proton annihilation into charged light meson pairs within effective meson theory" by Wang Ying, Yury M. Bystritskiy and Egle Tomasi-Gustafsson is under review.