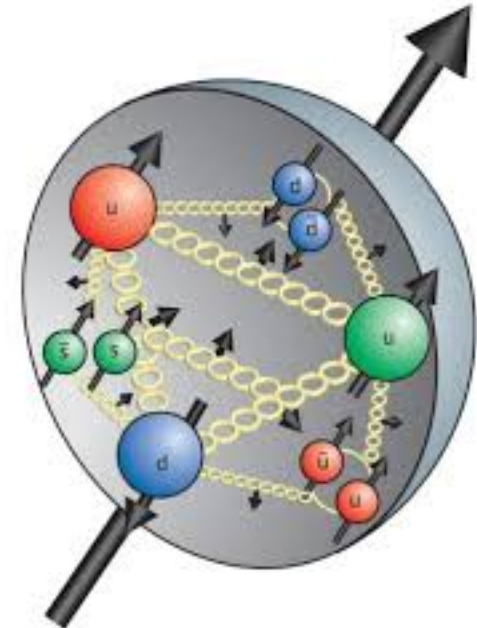# Electromagnetic and hard exclusive processes at PANDA Day-1 experiment

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PANDA LIX. CM, 05.12.2016 (Phys. Com. session)

Helmholtz-Institut Mainz
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Electromagnetic Processes at PANDA

- **Time-Like electromagnetic form factors (TL EM FFs) with lepton pair (electrons and muons)**

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

- **TL EM FFs in the unphysical region** $\bar{p}p \to e^+ e^- \pi^0$

- **Generalized Distribution Amplitudes with hard exclusive processes**

$$\bar{p}p \to \gamma\gamma \qquad \bar{p}p \to \pi^0 \gamma$$

- Transverse Parton Distribution Functions in Drell-Yan Production
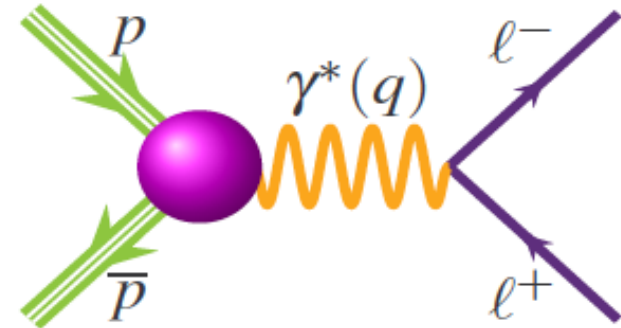
$$\bar{p}p \to \mu^+ \mu^- X$$

- Transition Distribution Amplitudes (TDAs) with meson production in ppbar annihilation

$$\bar{p}p \to J/\psi \pi^0 \qquad \bar{p}p \to \gamma^* \pi^0$$

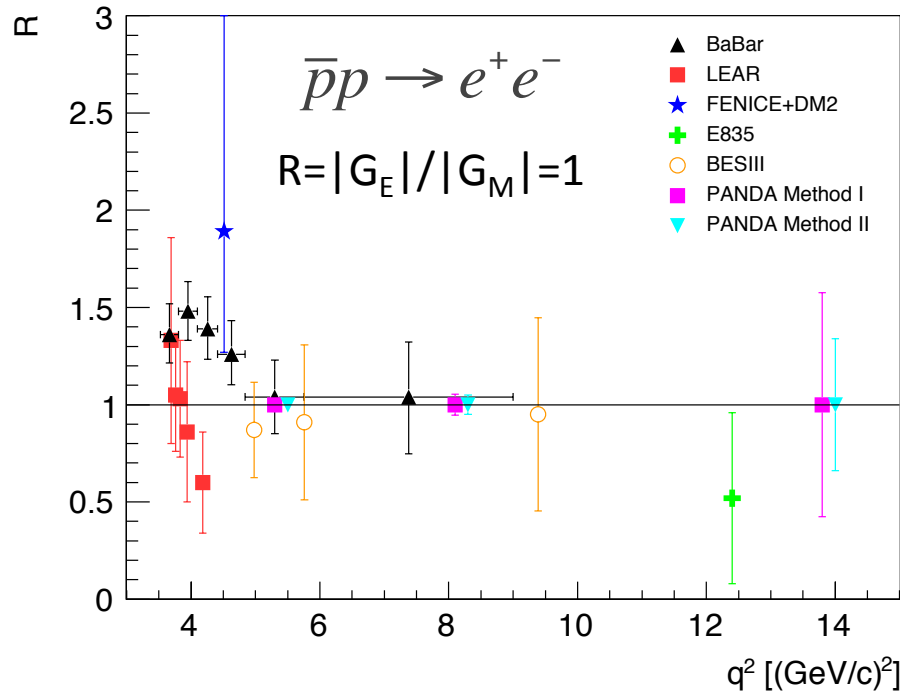- Results with the **full luminosity** mode and **full setup**:

$$L=2 \text{ fb}^{-1}$$
$$2.10^{32} \text{ cm}^{-1} \text{s}^{-1} \rightarrow 4 \text{ months data taking}$$

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

$$R=|G_E|/|G_M|=1$$

Legend:
- ▲ BaBar
- ■ LEAR
- ★ FENICE+DM2
- ＋ E835
- ○ BESIII
- ■ PANDA Method I
- ▼ PANDA Method II

Main PID sub-detectors:
$e^+ e^-$: **EMC + STT**
$mu^+ mu^-$: **Muon system**

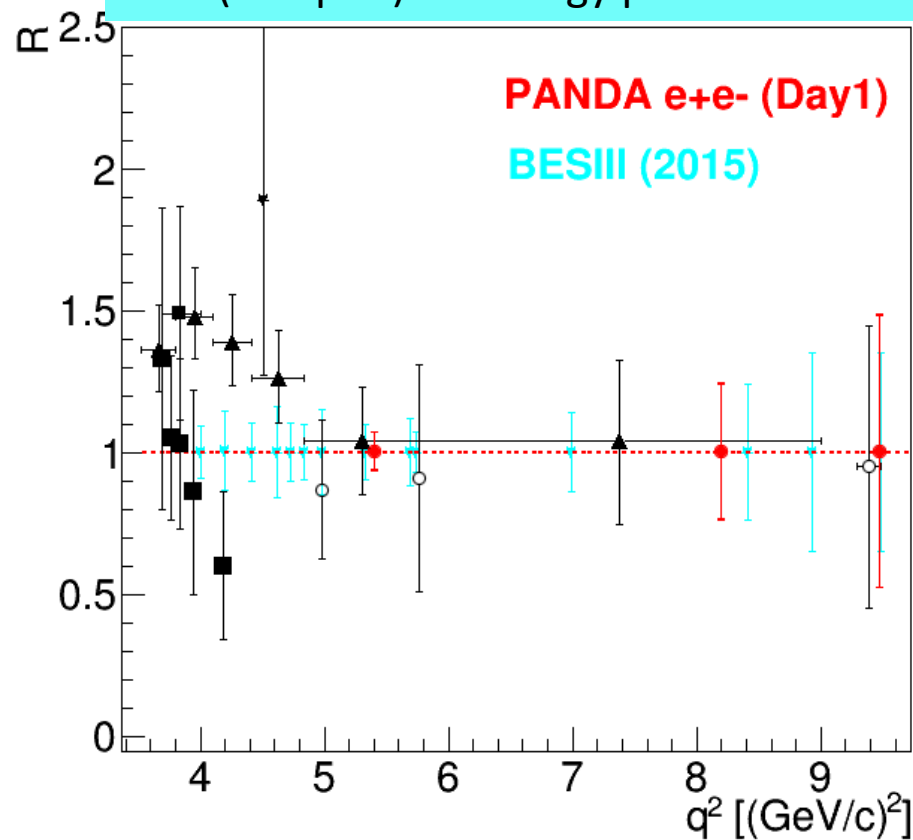| P [GeV/c]	ΔR/R (electrons)	ΔR/R (muons)
1.5-1.7	1.4 %	4.5 %
3.3	5.0 %	25 %
6.4	40.8 %	------

Statistical error on the proton FFs (Day1)

- The signal cross section is $\sigma \sim |G_E|^2$, $|G_M|^2$, R^2

- For the Day1 luminosity, the statistical error on the proton FFs will increase by a factor $= \sqrt{\dfrac{L_{HL}}{L_{Day1-L}}} \sim \sqrt{20}$

Estimations (R=1)

P [GeV/c]	ΔR/R (4 months-HL)	ΔR/R (4 months-Day1)
1.5-1.7	1.3 %	6.7 % (e) 28-36 % (μ)
3.3	5.3 %	24% (e)
4.0	11 %	48 % (e)

No significant effect from the reduced
Setup is expected for the PID performance

BESIII scan data 2015 between 2 and 3.08 GeV (552 pb^{-1}) 21 energy points
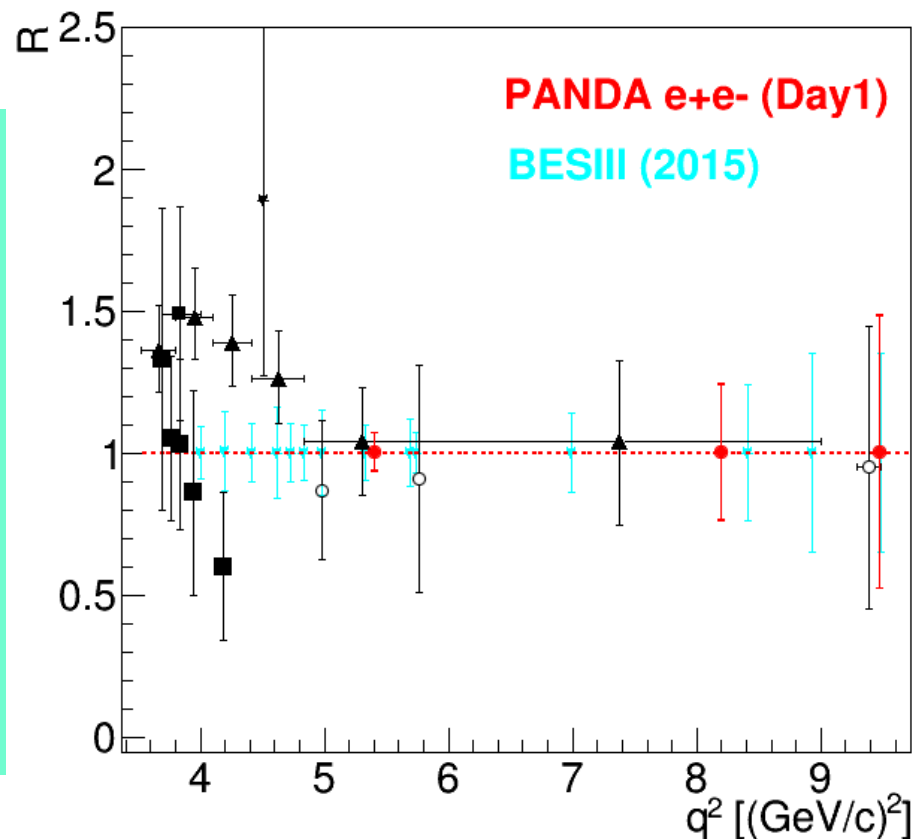

PANDA e+e- (Day1)
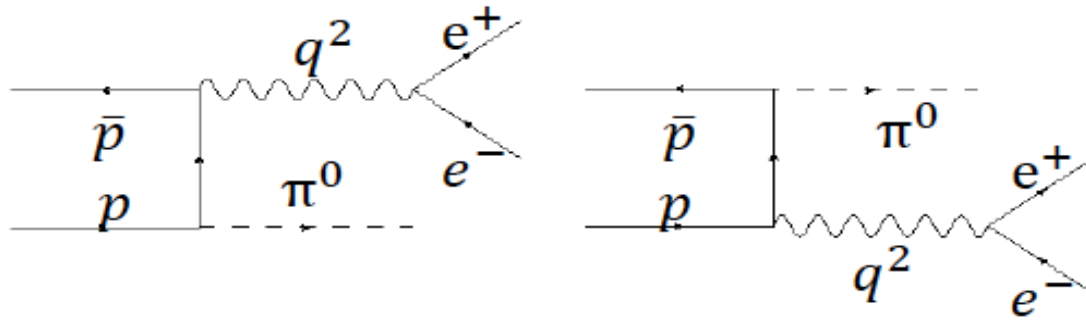BESIII (2015)

Statistical error on the proton FFs (Day1)

- The signal cross section is $\sigma \sim |G_E|^2, |G_M|^2, R^2$

- For the Day1 luminosity, the statistical error on the proton FFs will increase by a factor $= \sqrt{\dfrac{L_{HL}}{L_{Day1-L}}} \sim \sqrt{20}$

PANDA Day1

- **Competitive measurements** of $|G_E|$, $|G_M|$ and R with di-electron channel

- **First measurements** of $|G_E|$, $|G_M|$ and R with di-muon channel

- ✓ Monte Carlo simulations with reduced setup and reduced luminosity are ongoing (HIM-Mainz)
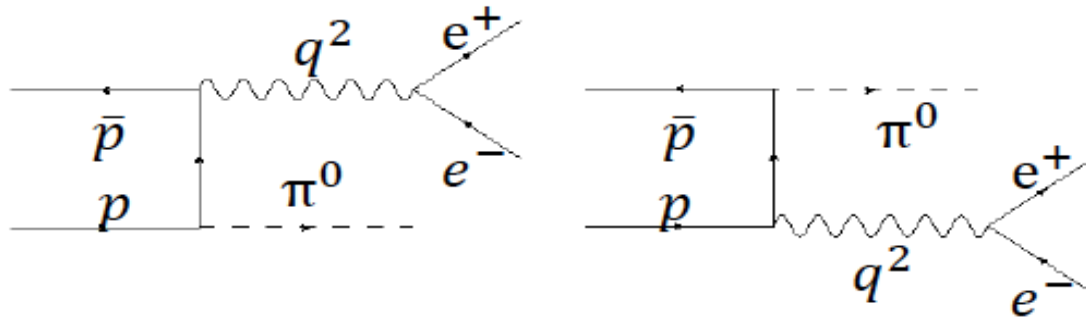
Proton FFs in the unphysical region

J. Boucher, PhD Thesis, IPNO

Complete feasibility studies were performed with:

- High **luminosity mode (2fb^{-1})** mode and **full setup, p=1.7 GeV/C**
- BaBar framework which contains the PANDA geometry (**no PANDARoot simulations**)
- ➢ PANDA: First measurement of proton FF ratio in the unphysical region
- ➢ PANDA: First time access, and in unpolarized experiment, to the relative phase G_E/G_M

$q^2 = 0.605 \pm 0.005\ (\text{GeV}/c^2)^2$		
$10° < \theta_{\pi°} < 30°$	$80° < \theta_{\pi°} < 100°$	$140° < \theta_{\pi°} < 160°$
$R = 1.0656$	$R = 1.0656$	$R = 1.0656$
1.0662 ± 0.0004	1.0628 ± 0.0004	1.0568 ± 0.0073
$\sigma = 0.0152 \pm 0.0003$	$\sigma = 0.0161 \pm 0.0003$	$\sigma = 0.2439 \pm 0.0069$

Proton FFs in the unphysical region

J. Boucher, PhD Thesis, IPNO

Estimations (R=1.07, $\theta_{\pi 0}$=[10°-30°])

P [GeV/c]	$\Delta R/R$ (**2fb^{-1}**)	$\Delta R/R$ (4 months-Day1)
1.7	1.4 %	~7%

PANDA Day1

- PANDA: First measurement of proton FF ratio in the unphysical region (relative phase?)
- No ongoing/planned MC simulations for the Day1 experiment.
- Only estimations based on the number of counting rate could be provided: based on the studies of "ppbar->e+e-", the analysis results from the BaBar framework can be well accepted.

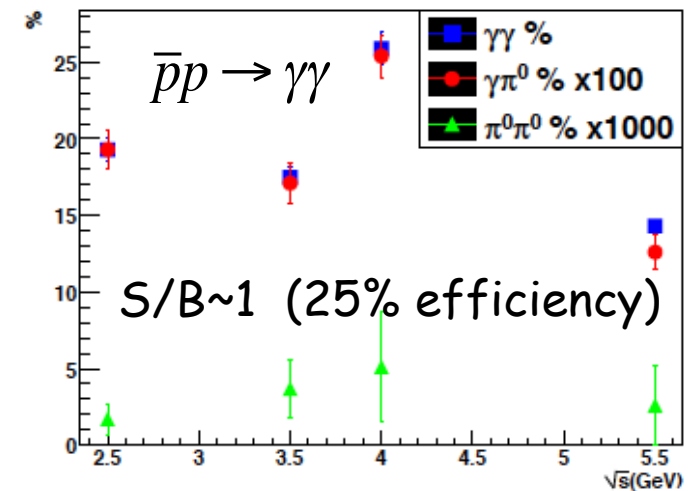# Feasibility studies for $\bar{p}p \rightarrow \gamma\gamma$ and $\bar{p}p \rightarrow \pi^0\gamma$ at PANDA

PANDARoot simulations:

- 4 different CM energies
- Main background channels:
  $\bar{p}p \rightarrow \pi^0\pi^0$ (for both signals)
  $\bar{p}p \rightarrow \pi^0\gamma$ (for signal1: $\bar{p}p \rightarrow \gamma\gamma$)
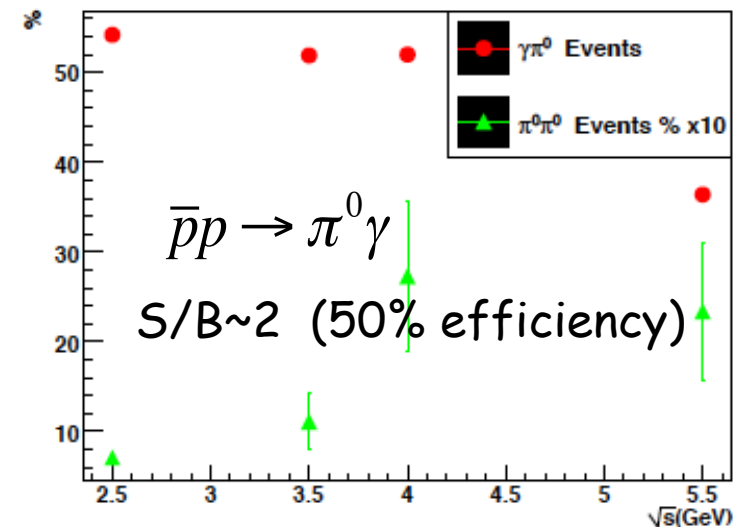
PANDA Physics Performance Report
arXiv:0903.3905

- The Monte Carlo simulations with the full detector setup and full Luminosity mode are not completed

Events left after Separation looking for γγ-events

Legend:
- γγ %
- γπ⁰ % x100
- π⁰π⁰ % x1000

$\bar{p}p \rightarrow \gamma\gamma$

S/B~1 (25% efficiency)

Events left after Separation looking for γπ⁰-events

Legend:
- γπ⁰ Events
- π⁰π⁰ Events % x10

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

S/B~2 (50% efficiency)

Fermilab (PRD **56** (1997) 5)

P. Kroll and A. Schafer, EPJA 26 , 89 (2005).

$\sqrt{s}$ (GeV)	$\int \mathcal{L}dt$ (nb^{-1})
2.911	53.1
2.950	197.5
2.975	423.9
2.979	165.3
2.981	392.6
2.985	200.2
2.990	513.0
2.994	308.9
3.005	171.0
3.050	53.6
3.097	384.4
3.524	4342.4
3.526	10466.7
3.527	1016.4
3.556	1377.4
3.591	923.8
3.595	826.8
3.613	1167.2
3.616	1048.0
3.619	575.0
3.621	1216.4
3.686	994.6
4.274	332.5

$\sigma(p\bar{p} \to \gamma \pi^0)$

E760

- PANDA Day1 luminosity for one month of data taking: 2.911 GeV $\to$ 2 . 10^4 nb^{-1}
  4.3 GeV $\to$ 3 . 10^4 nb^{-1}
- No ongoing/planned Monte Carlo simulations for the Day1 experiment.

Summary

Signal	Physics	Status	Beam time (Day1-experiment)
$\bar{p}p \rightarrow e^+ e^-$	FFs	Feasibile	4 months up to 4 GeV/c
$\bar{p}p \rightarrow \mu^+ \mu^-$	FFs		4 months @ 1.5 GeV/c
$\bar{p}p \rightarrow e^+ e^- \pi^0$	FFs below threshold	Feasibile	MC simulations (?? (parallel to x,y,z studies ??)
$\bar{p}p \rightarrow \gamma^* \pi^0$ $\bar{p}p \rightarrow J/\psi \pi^0$	TDAs	Feasibile	
$\bar{p}p \rightarrow \gamma\gamma$ $\bar{p}p \rightarrow \pi^0 \gamma$	GDAs	Feasibile	~1-2 months MC simulations (??)
$\bar{p}p \rightarrow \mu^+ \mu^- X$	TMD PDFs	Feasibile	

Back-up slides

Feasibility measurement of DYs at PANDA

Feasibility studies using Monte-Carlo simulation:

- Signal: $\bar{p}p \rightarrow \mu^+\mu^- X$ Unpolarized DY, Single-polarized DY

- Main background: $\bar{p}p \rightarrow n(\pi^+\pi^-)X$, required rejection factor $\sim 10^7$

- Simulations @ s=30 GeV² and $1.5 \leq M_{\gamma^*} \leq 2.5$ (non resonance region, large cross section)
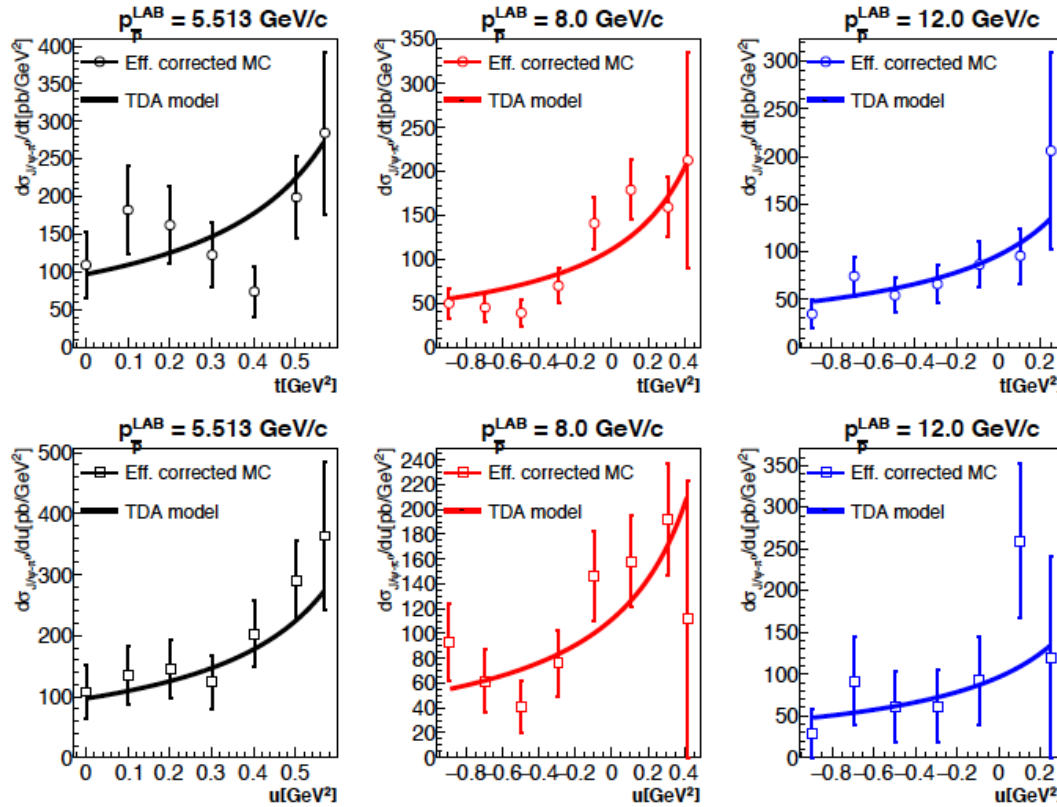
PANDA Physics Performance Report
arXiv:0903.3905

Acceptance, efficiency corrections, background rejection are still Under unvestigation: expectation: 130. 10^3 DY/month

One year data taking (full luminosity): azimuthal asymmetries with uncertainties of the order of the presented one

Day1 exepriment: luminosity is too low to extract information from DY

Nucleon to meson TDAs (MSV setup)

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

(same conclusion)

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

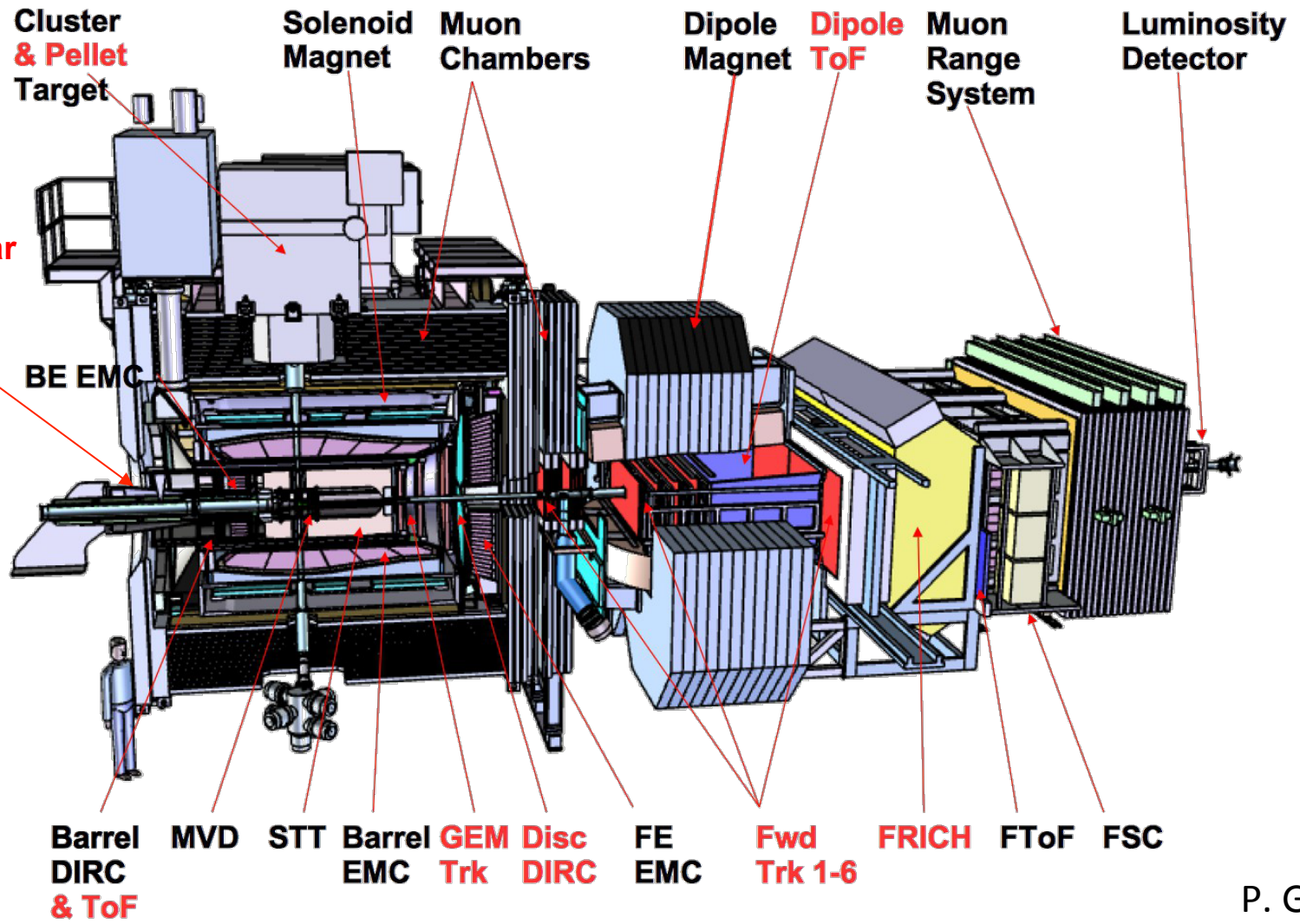- **MSV setup (4 months)**
  - Statistics will be too low even for single differential cross-section measurement
  - Useful for
    - Checking order of magnitude of cross-sections
    - Constraining pionic background sources with cross-sections in the mb range

$p_{\bar{p}}$ (GeV/c)	$\mathcal{L}(\text{nb}^{-1}/\text{day})$	$\mathcal{L}_{int}(4\text{mo})$ (pb^{-1})	$N_{evt}^{SIG}(valid)$, 4mo
5.513	796	95.5	1565
8.0	856	103	2582
12.0	902	108	2800

E. Atomsa, IPNO

PANDA Detector

Reduced and full setup

P. Gianotti

Luminosity for the Day-1 experiment

K. Götzen - Lumi @ PANDA

https://panda.gsi.de/system/files/user_uploads/k.goetzen/IN-IDE-2015-002.pdf

Target: $n_t = 4 \cdot 10^{15}$ cm^{-2}

- HESR= accumulation in HESR with
  - *beam dump after cycle*;
  - rate R=$1 \cdot 10^7$/s;
  - $N_{max}=10^{10}$ antiprotons;

	R [s^{-1}]	L/(nb·d)			
		2 · 10^7		1 · 10^7	
p [GeV/c]	E$_{cm}$ [GeV]	HL	HR	HESR	HESRr
1.5	2.25	6732	1073	627	788
2.5	2.60	9555	1170	737	917
3.5	2.93	11493	1230	809	997
4.5	3.22	13123	1322	895	1095
5.5	3.50	13475	1348	933	1133
6.5	3.75	13631	1363	961	1160
7.5	3.99	13722	1372	982	1179
8.5	4.22	13771	1377	998	1192
9.5	4.44	13790	1379	1010	1202
10.5	4.64	13791	1379	1020	1208
11.5	4.84	13778	1378	1028	1213
12.5	5.03	13757	1376	1034	1216
13.5	5.21	13730	1373	1039	1218
14.5	5.39	13698	1370	1043	1219
15.5	5.56	13663	1366	1047	1220