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Electromagnetic and hard exclusive processes at PANDA Day-1 experiment

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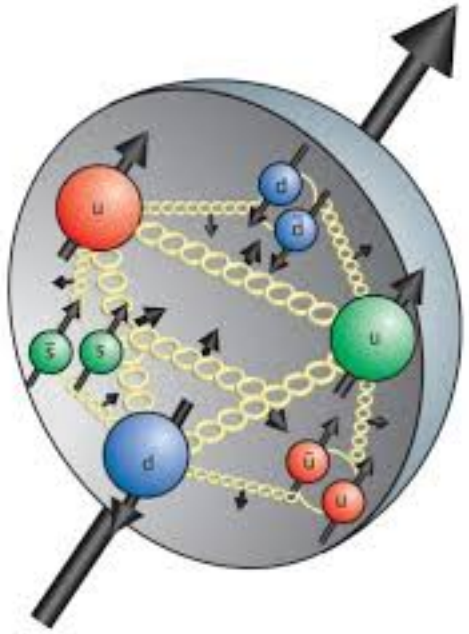
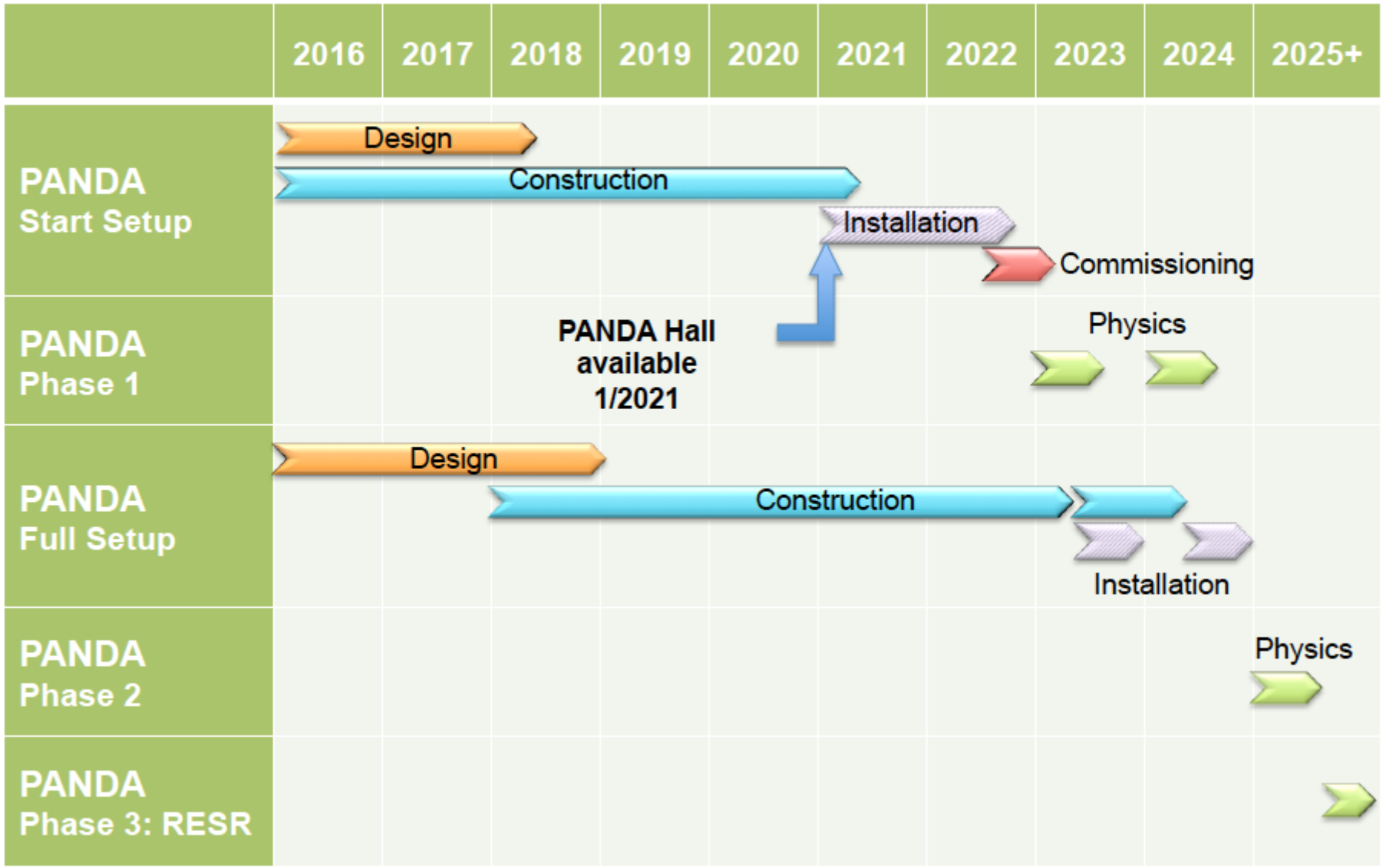
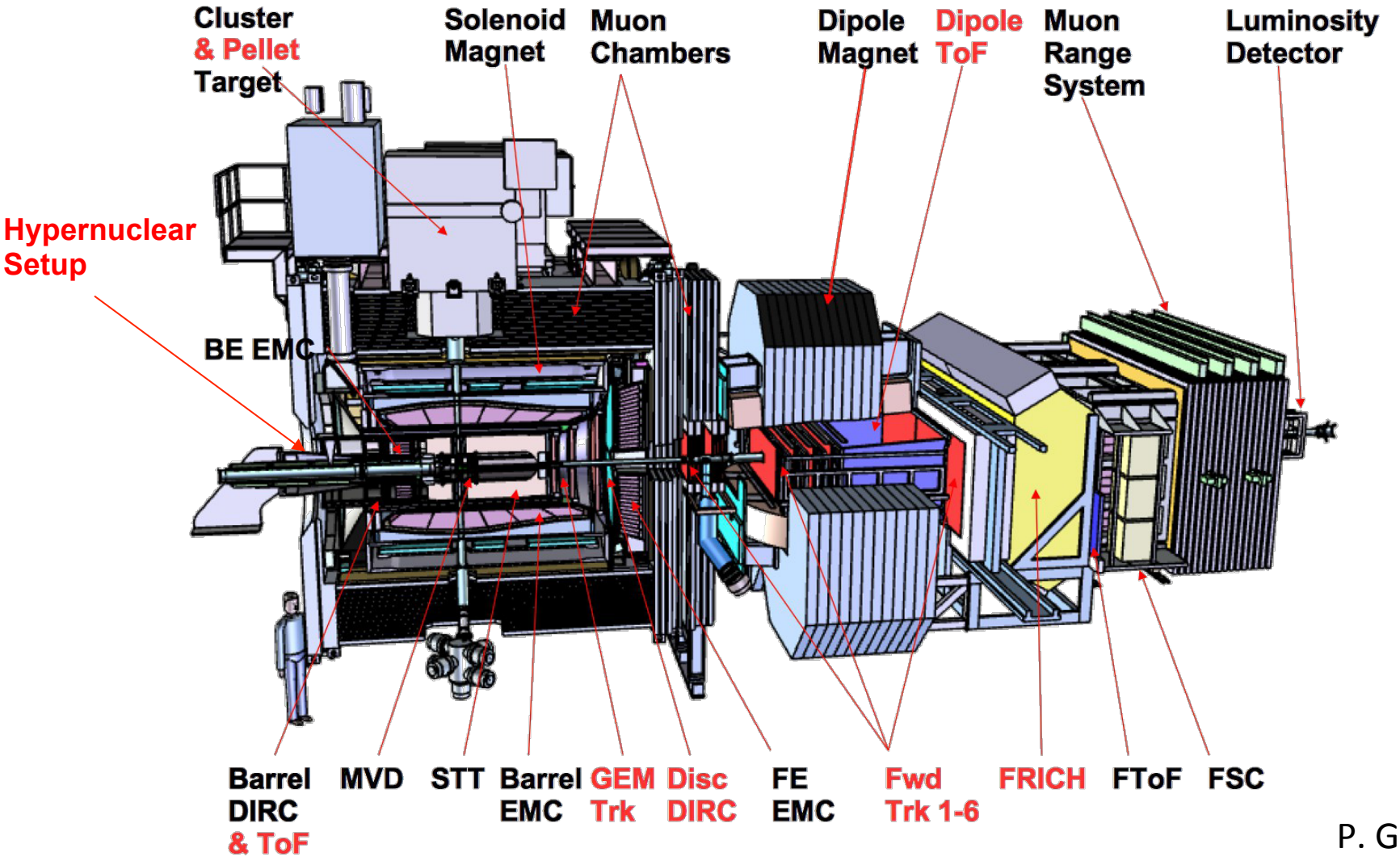


PANDA Phases



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;

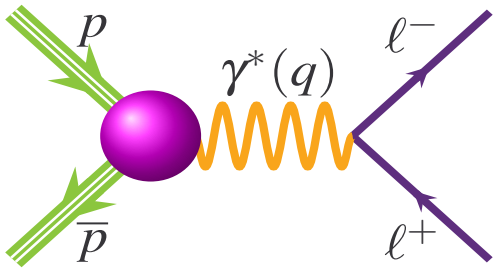
		L/(nb·d)			
	R [s^{-1}]	$2 \cdot 10^7$		$1 \cdot 10^7$	
p [GeV/c]	E_{cm} [GeV]	HL	HR	HESR	HESRr
1.5	2.25	6732	1073	627	788
2.5	2.60	9555	1170	737	917
3.5	2.93	11493	1230	809	997
4.5	3.22	13123	1322	895	1095
5.5	3.50	13475	1348	933	1133
6.5	3.75	13631	1363	961	1160
7.5	3.99	13722	1372	982	1179
8.5	4.22	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

Electromagnetic Processes at PANDA

- Preparation of a journal paper describing in detail the PANDA Physics Program. Dead line beginning of 2017:
  - Low luminosity
  - Reduced detector setup

- Time-Like electromagnetic form factors (TL EM FFs) with lepton pair (electrons and muons)
- TL EM FFs in the unphysical region
- Transition Distribution Amplitudes (TDAs) with meson production in ppbar annihilation
- Generalized Distribution Amplitudes with hard exclusive processes
- Transverse Parton Distribution Functions in Drell-Yan Production

Time-Like electromagnetic form factors



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

Statistical error on the proton FFs

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

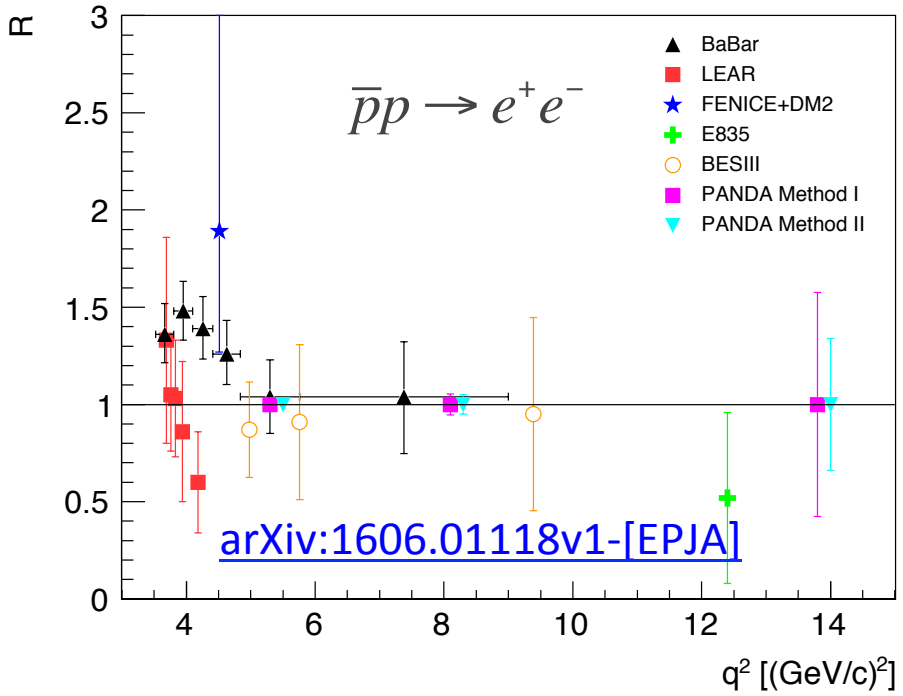
L=2 fb^{-1}

2.10^{32} cm^{-1} s^{-1}-> 4 months data taking

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

P [GeV/c]	Input R	ΔR
1.7	1	1.3%
3.3	1	5.3%
6.4	1	56%

p_{lab}	[GeV/c]	1.70	3.30	6.40
PID$_c$	[%]	>99	>99	>99.5
PID$_s$	[%]	>10	>10	>10
dE/dx_{STT}	[a.u.]	>6.5	>5.8	0 or >6.5
E_{EMC}/p_{reco}	[GeV/(GeV/c)]	>0.8	>0.8	>0.8
EMC LM	-	<0.66	<0.75	<0.66
EMC E1	[GeV]	>0.35	>0.35	>0.35
$\lvert\theta+\theta'-180\rvert$	[degree]		<5	
$\lvert\phi-\phi'-180\rvert$	[degree]		<5	
M_{inv}	[GeV/c^2]	-	>2.2	>2.7



PID: **EMC + STT** + MVD + DIRC

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

Statistical error on the proton FFs

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

L=2 fb^{-1}

2.10^{32} cm^{-1} s^{-1}-> 4 months data taking

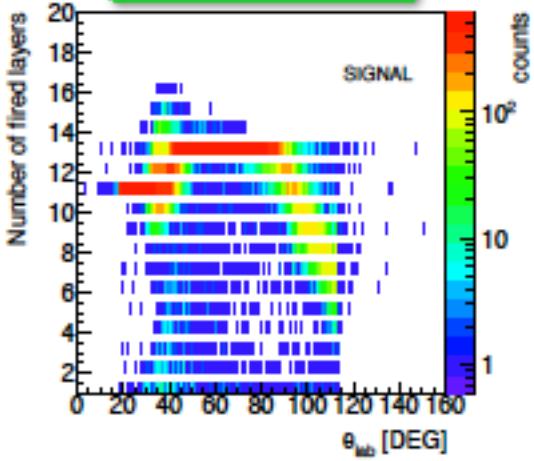
$\bar{p}p \rightarrow \mu^+\mu^-$

P [GeV/c]	Input R	ΔR/R
1.5	1	4.5 %
1.7	1	6.9 %
3.3	1	25 %

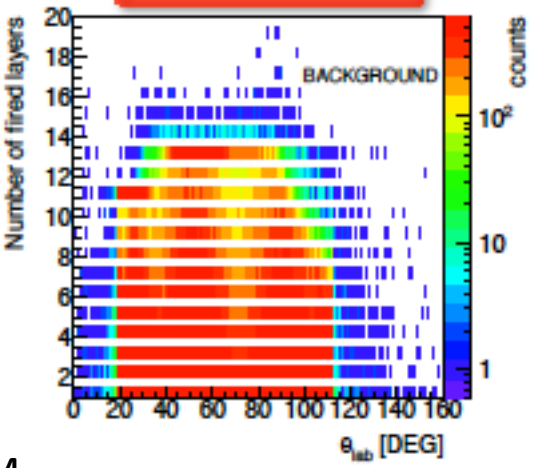
- Kinematical cuts
- Detector observables from Muon System, EMC and STT

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

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



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



I. Zimmermann, HIM

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 $\approx \sqrt{\frac{L_{HL}}{L_{Day1-L}}}$

Estimations

P [GeV/c]	Input R	ΔR/R HL mode	ΔR/R (1 months-Day1)	ΔR/R (2 months-Day1)	ΔR/R (3 months-Day1)	ΔR/R (4 months-Day1)
1.5-1.7	1	1.3 %	14 % 56 % (μ)	9.5 % 40-50 % (μ)	8 % 32-42 % (μ)	6.7 % 28-36 % (μ)
3.3	1	5.3 %	48%	34 %	28 %	24%
4.0	1	11 %			56 %	48 %

ΔR/R ~ 10 % limit for a competetive measurement

ΔR/R ~ 50-60 % limit for a meaningful measurement

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 $\approx \sqrt{\frac{L_{HL}}{L_{Day1-L}}}$

Estimations

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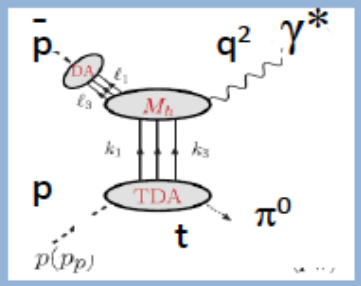
3.3	1	5.3 %	48%	34 %	28 %	24%
4.0	1	11 %			56 %	48 %

Realistic Monte Carlo simulations are ongoing

Transition Distribution Amplitudes

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

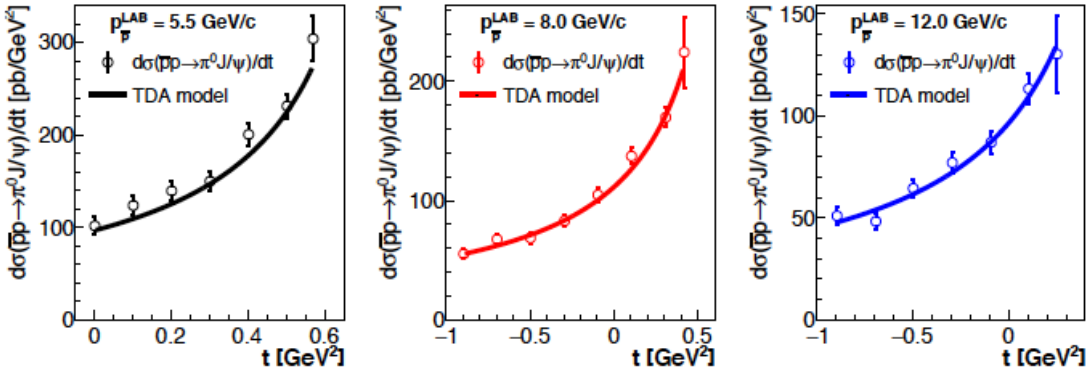
$\bar{p}p \to e^+ e^- \pi^0$ Fwd/bwd

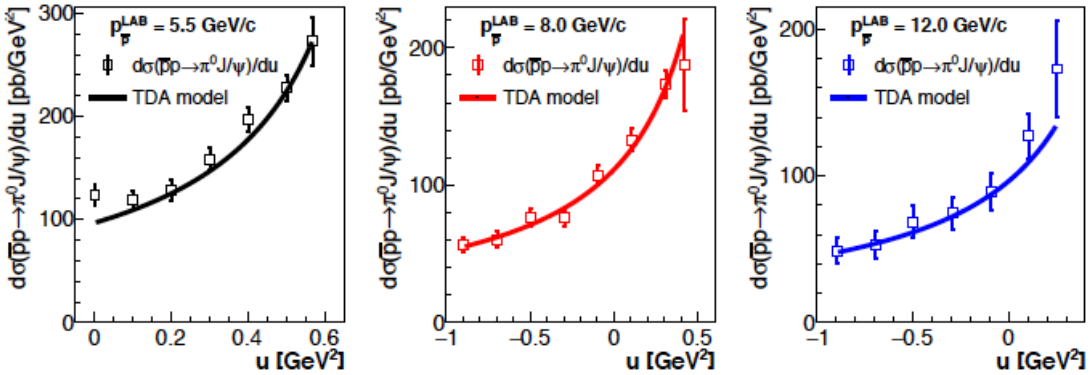


Large q^2 small t or u

Transition Distrib. Amplitudes

Nucleon to meson TDAs (Full setup, 2fb^{-1})





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

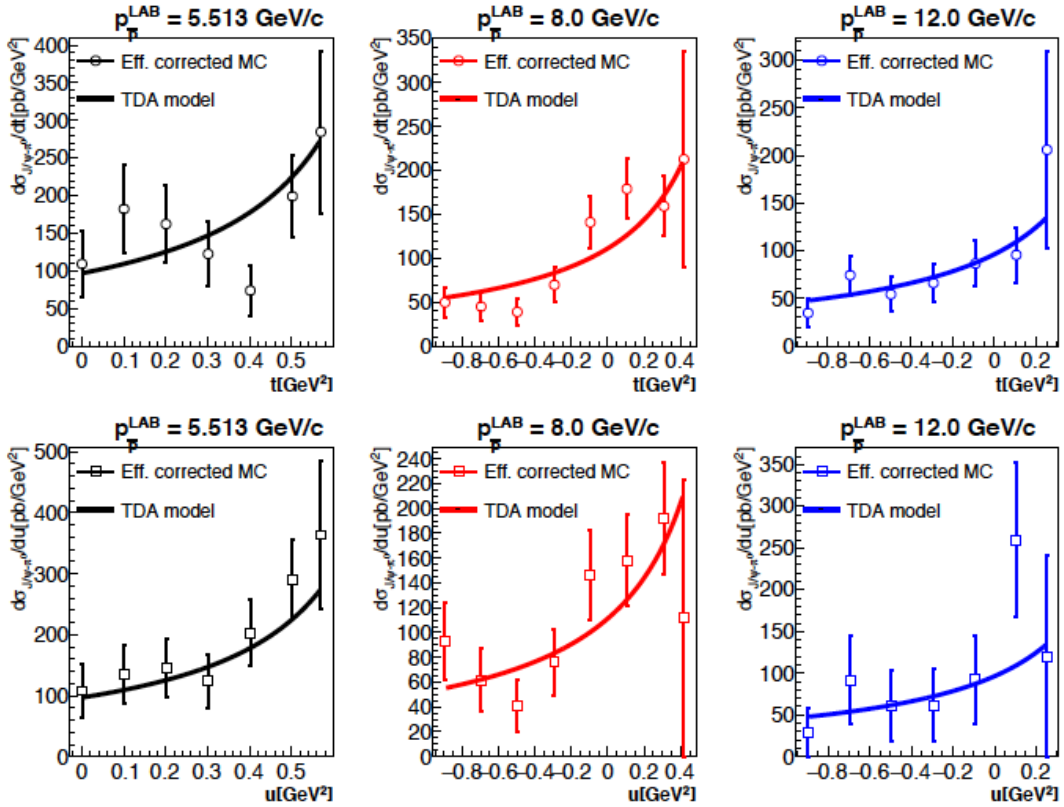
Intagrated cross section (for both near-forward and nearbackward), and production yields for signal and background:

$p_{\bar{p}}$ (GeV/c)	$\Delta\sigma_{valid}^{J/\psi\pi^0}$ (pb)	$N_{valid}^{e^+e^-\pi^0}$ (2 fb^{-1})	$\Delta\sigma_{valid+m\_cut}^{\pi^+\pi^-\pi^0}$ (mb)
5.5	207	24.6k	8.2×10^{-3}
8.0	281	33.3k	1.6×10^{-3}
12.0	200	23.7k	3.28×10^{-4}

- Full FAIR setup (2fb^{-1})
  - 4-5 months of data taking at each energy
  - Sufficient statistics to have meaningful constraints on TDA models

E. Atomsa, IPNO

Nucleon to meson TDAs (MSV setup)



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

(same conclusion)

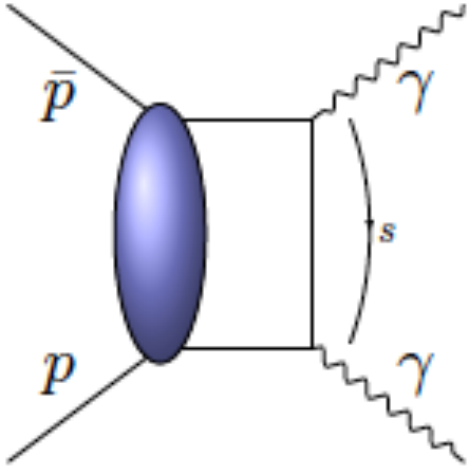
$$\bar{p}p \rightarrow \gamma^*\pi^0 -> e^+e^-\pi^0$$

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

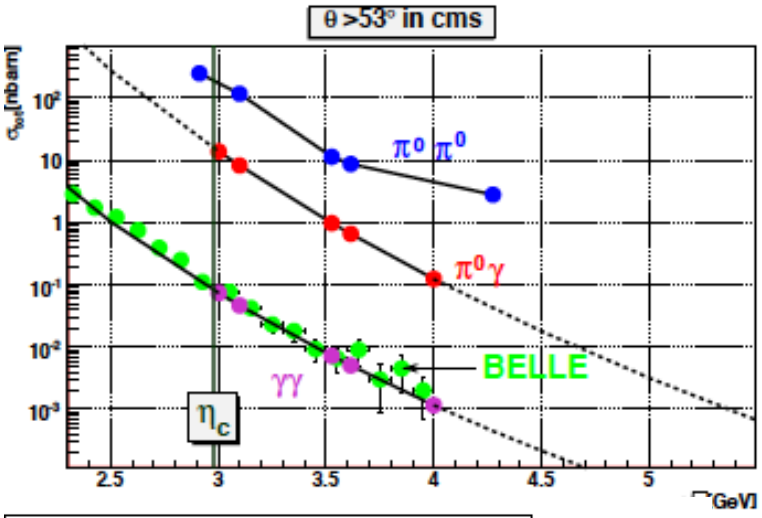
E. Atomsa, IPNO

Generalized Distribution Amplitudes



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

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



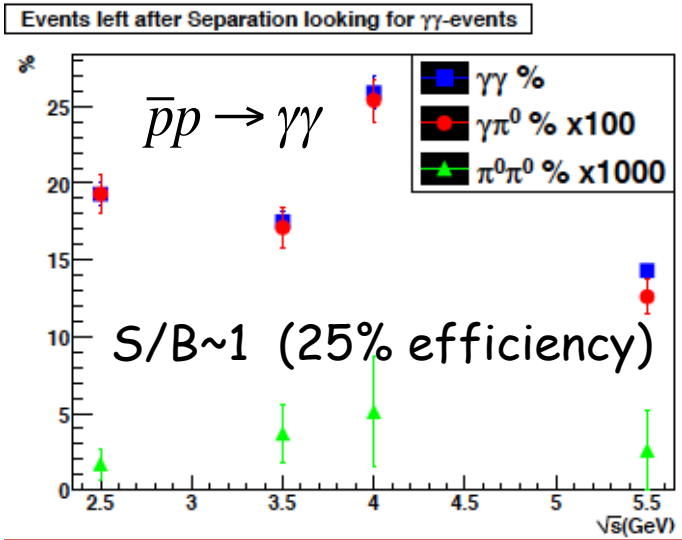
PANDARoot simulations:

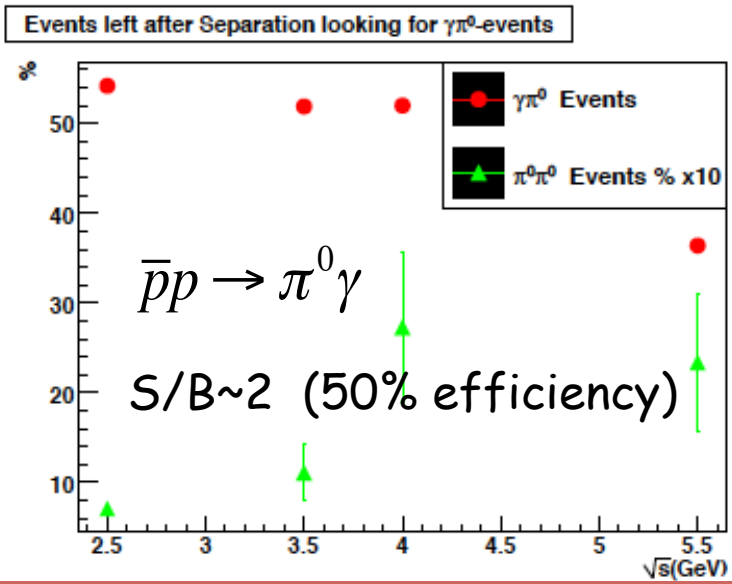
- 4 different CM energies
- Main background channels:

  $\bar{p}p \to \pi^0\pi^0$ (for both signals)

  $\bar{p}p \to \pi^0\gamma$ (for signal1: $\bar{p}p \to \gamma\gamma$)

PANDA Physics Performance Report
arXiv:0903.3905





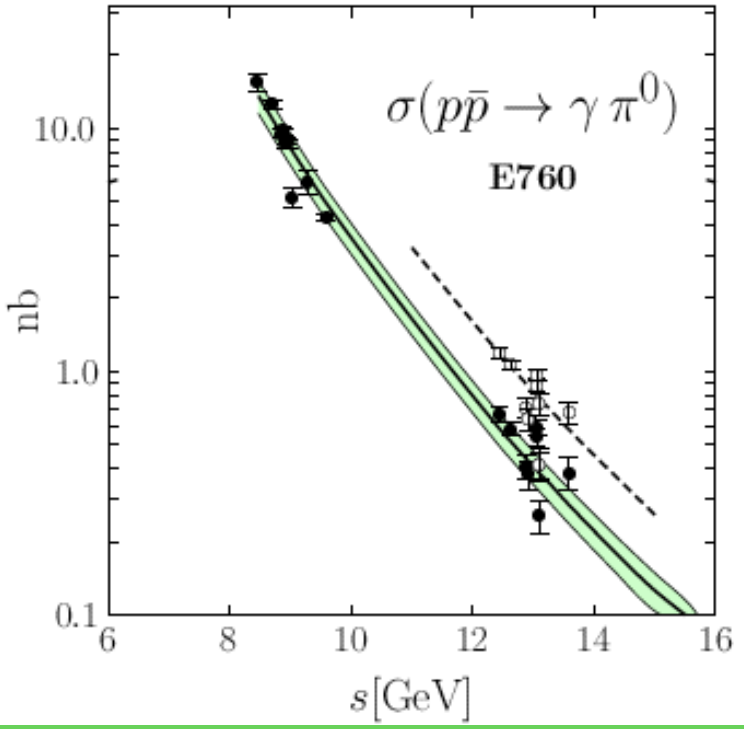
Monte Carlo simulations with the full detector setup and full Luminosity mode is needed need to be updated

Estimations for Day1 experiment : $\bar{p}p \to \gamma\gamma$ and $\bar{p}p \to \pi^0\gamma$

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

$\sqrt{s}$ (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

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



PANDA Day1 luminosity for one month of data taking

2.911 GeV → $2 \cdot 10^4$ nb^{-1}

4.3 GeV → $3 \cdot 10^4$ nb^{-1}

Estimations for Day1 experiment : $\bar{p}p \to \gamma\gamma$ and $\bar{p}p \to \pi^0\gamma$

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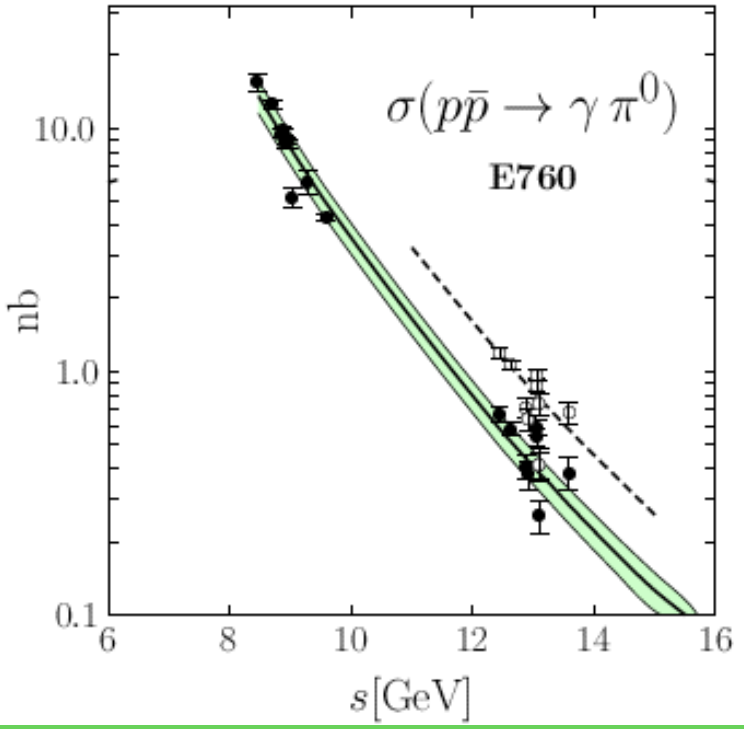
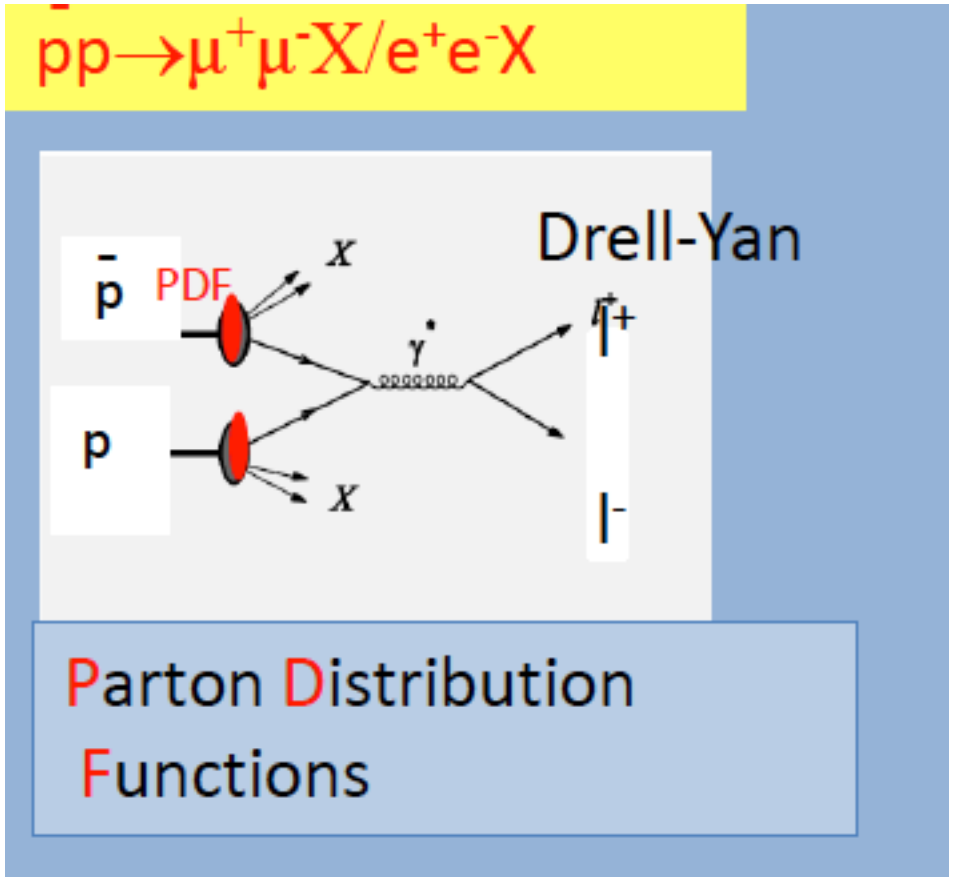


PANDA Day1 luminosity for one month of data taking

2.911 GeV → 2 ... 10^4 nb^{-1}

Monte Carlo simulations need to be performed for these two channels

Transverse Parton Distribution Functions



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 ~10^7
- Simulations @ s=30 GeV^2 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

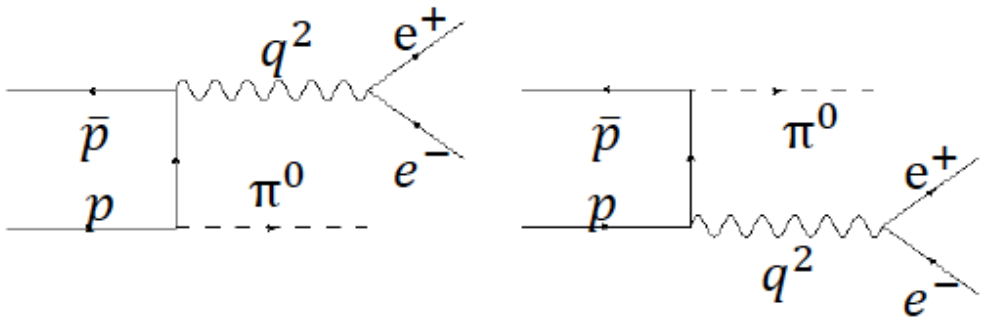
Summary

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

Proton FFs in the unphysical region

J. Boucher, PhD Thesis, IPNO

Integrated luminosity 2fb^{-1}



$q^2 = 0.605 \pm 0.005\ (\mathrm{GeV/c^2})^2$		
$10° < \theta_{\pi^\circ} < 30°$	$80° < \theta_{\pi^\circ} < 100°$	$140° < \theta_{\pi^\circ} < 160°$
$R = 1.0656$	$R = 1.0656$	$R = 1.0656$
1.0657 ± 0.0002 $\sigma = 0.0077 \pm 0.0001$	1.0632 ± 0.0002 $\sigma = 0.0072 \pm 0.0001$	1.0667 ± 0.0023 $\sigma = 0.0742 \pm 0.0016$
1.0655 ± 0.0003 $\sigma = 0.0137 \pm 0.0003$	1.0626 ± 0.0003 $\sigma = 0.0143 \pm 0.0003$	1.0564 ± 0.0062 $\sigma = 0.2010 \pm 0.0057$
1.0662 ± 0.0004 $\sigma = 0.0152 \pm 0.0003$	1.0628 ± 0.0004 $\sigma = 0.0161 \pm 0.0003$	1.0568 ± 0.0073 $\sigma = 0.2439 \pm 0.0069$

1.4%

Summary

- Measurements of 5 electromagnetic channels are expected to be feasible for the Day1 experiment:
  - Monte Carlo simulations are ongoing (HIM group) for:

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

  - Monte Carlo simulations for $\bar{p}p \rightarrow \pi^0\gamma, \gamma\gamma, e^+e^-\pi^0$ are needed (working group ??)

- Update of the Monte Carlo simulations for hard exclusive processes and Drell-Yann for the full setup and full luminosity mode is also needed

- Your suggestions and contributions are welcome

Estimations for Day1 experiment : $\bar{p}p \to \gamma\gamma$ and $\bar{p}p \to \pi^0\gamma$

- No significant effect from the reduced setup is expected on the signal efficiency (main identification detector is the EMC)

- Comparison with feasible electromagnetic channel:

$\bar{p}p \to \pi^0\gamma \quad (\bar{p}p \to \gamma\gamma)$	$\bar{p}p \to \mu^+\mu^-$
σ~10 nb (0.1 nb)	σ~ 0.4 nb
ε= 50% (25%)	ε= 12%
Signal/Background ~2/1 (1/1)	Signal/Background ~1/4

Monte Carlo simulations need to be performed for these two channels