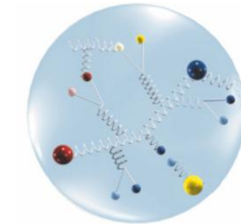
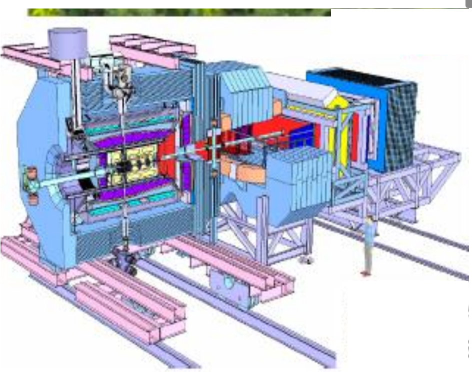
Future prospects for proton structure studies using electromagnetic processes at PANDA

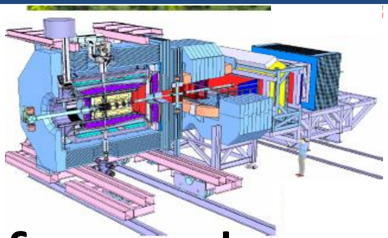


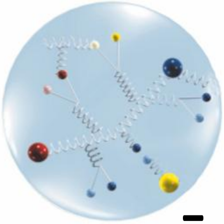
B. Ramstein, IPN Orsay, France



Annual Meeting of the GDR PH-QCD November 26th

Outline

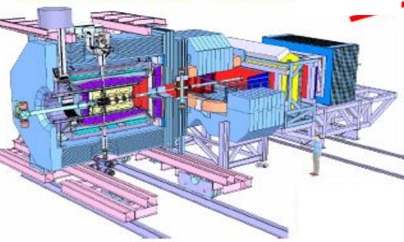




- Global motivations for nucleon structure studies in $\bar{p}p$ annihilation reactions

  Complementarity with electron or photon scattering experiments

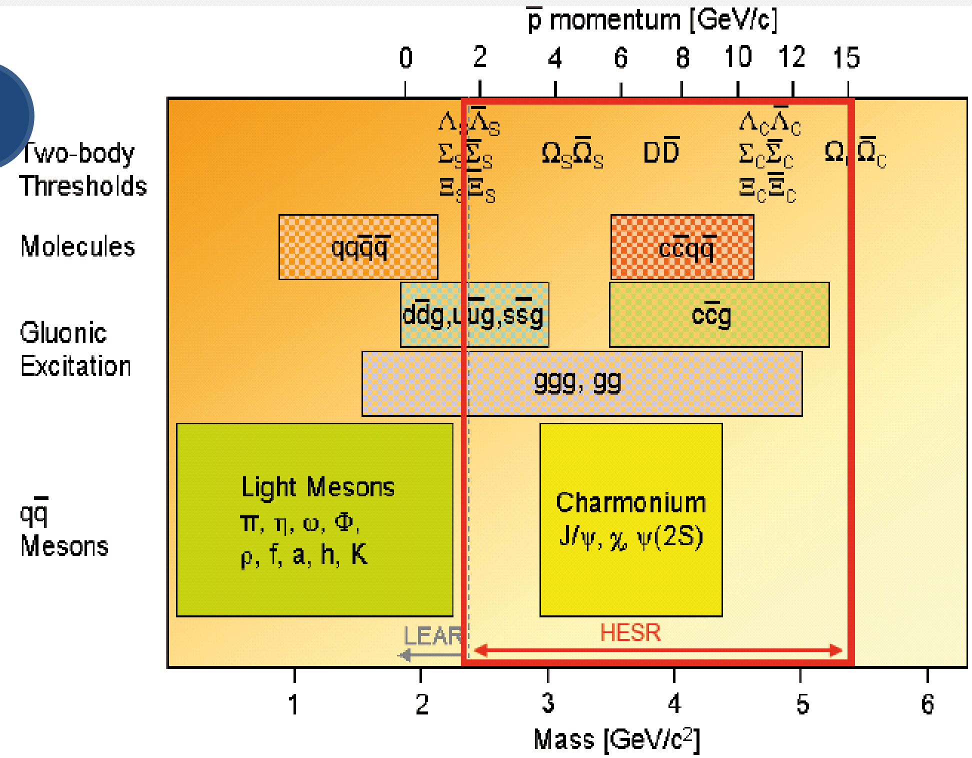
- Technical issues related to electromagnetic process measurements
- Status of feasibility studies
- Conclusion and perspectives

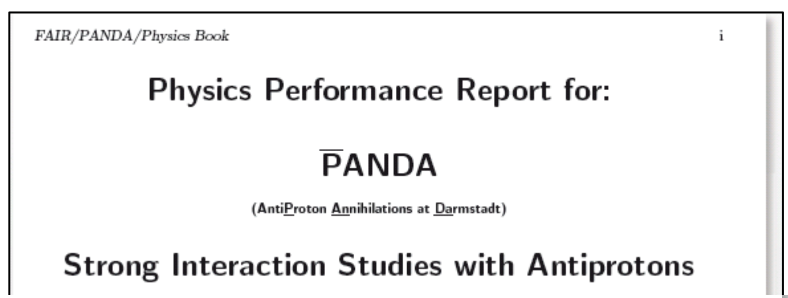


P̄ANDA physics program

AntiP̄roton ANnihilation at DArmstadt

- ✓ Meson spectroscopy
  - D mesons
  - Charmonium
  - Glueballs, hybrids, tetraquarks, molecules,…
- ✓ Charmed and multi-strange baryon spectroscopy
- ✓ Single and double hypernuclei
- ✓ Hadrons in nuclear matter
- ✓ Proton structure





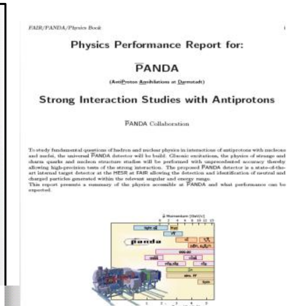
FAIR/PANDA/Physics Book i

Physics Performance Report for:

P̄ANDA

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons



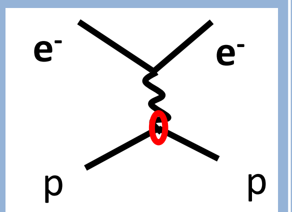
arXiv:0903.3905v1

Hadron and lepton probes for nucleon structure

Crossing symmetry $\rightarrow$ same matrix elements in crossed channels
$\rightarrow$ counterpart observables

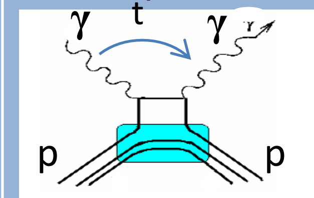
$e^-p \rightarrow e^-p$

$q^2<0$



Space Like electro magnetic Form factors

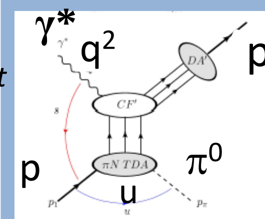
$\gamma p \rightarrow \gamma p$ Wide Angle Compton Scattering



Large p_t

Generalized Parton Distributions

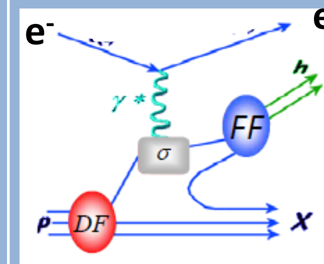
$e^-p \rightarrow e^-p\pi^0$ Bwd electroproduction



Large q^2 *small u*

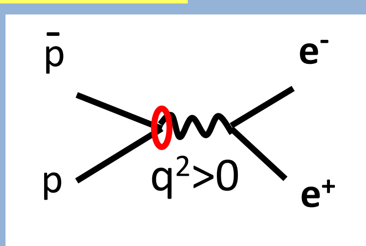
Transition Distrib. Amplitudes

$e^-p \rightarrow e^-hX$ SIDIS



Parton Distrib. Functions

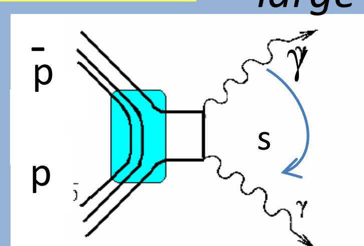
$\bar{p}p \rightarrow e^+e^-$



Time Like electro magnetic Form factors

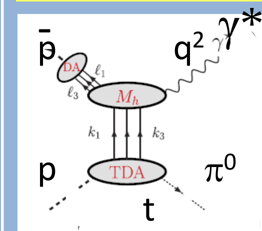
$\bar{p}p \rightarrow \gamma\gamma$

large p_t



Generalized Distrib. Amplitudes

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

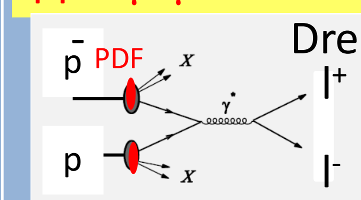


Large q^2 *small t or u*

Transition Distrib. Amplitudes

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

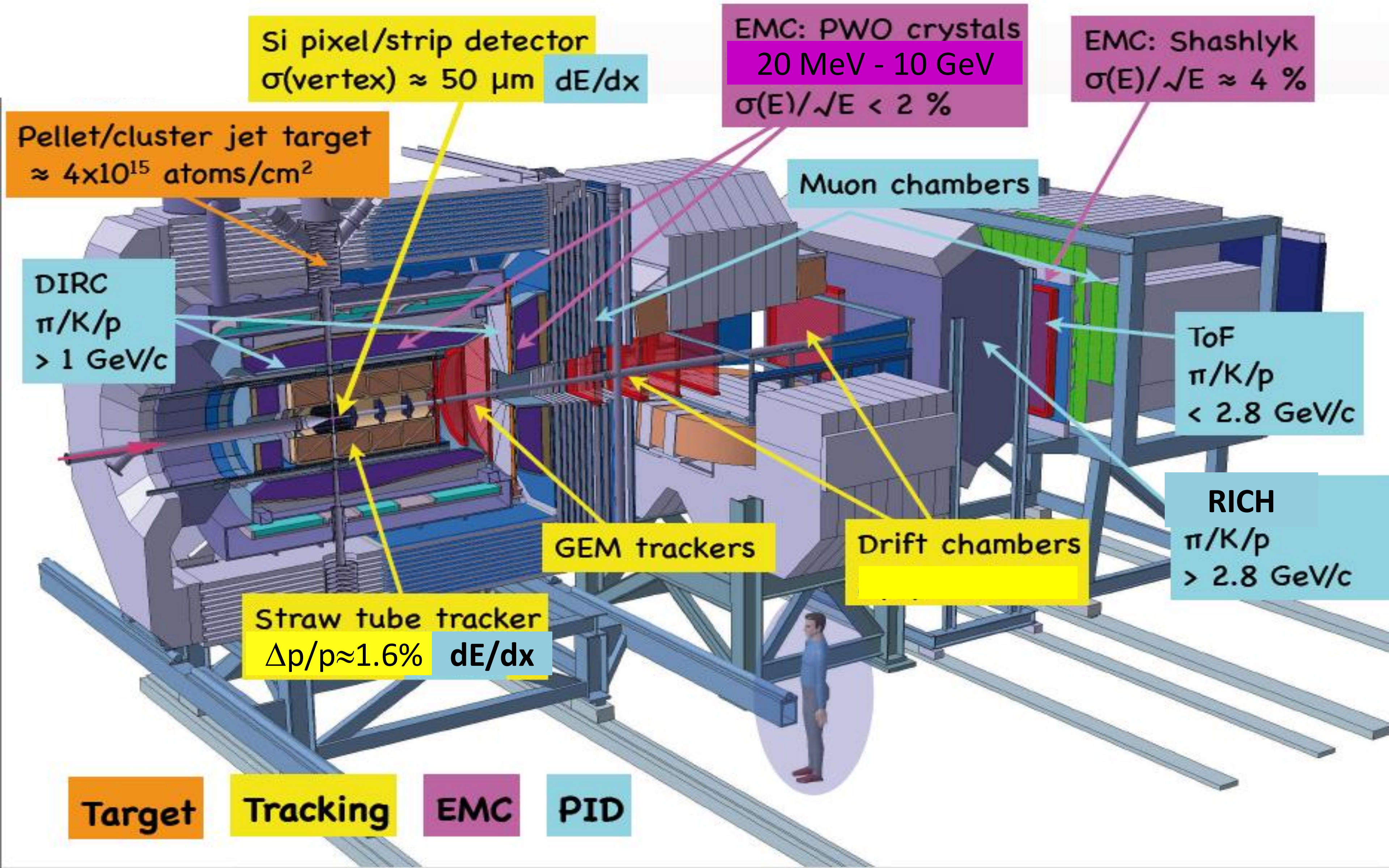
Drell-Yan



Parton Distrib. Functions

Challenge of l^+l^- exit channels: much higher background

The PANDA experimental set-up



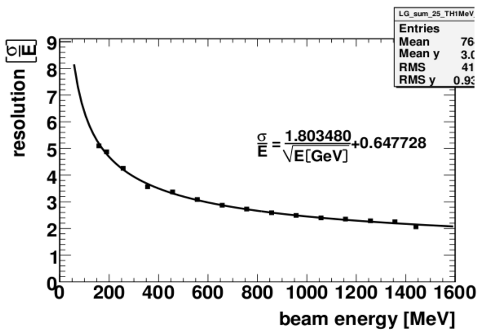
Detectors for electromagnetic channels

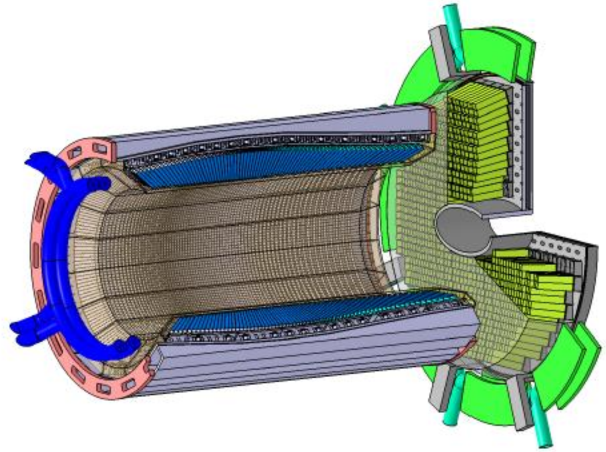
- Barrel calorimeter: 11000 PbWO4 crystals

cooled to -25°

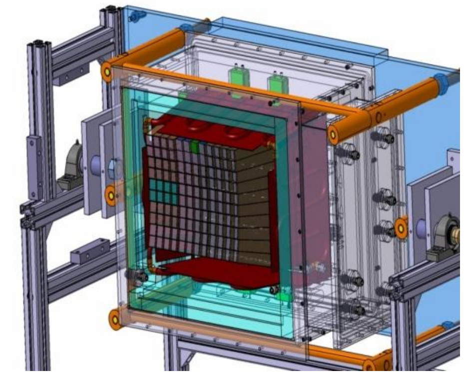
In 16 slices =

720 crystals





PROTO 120

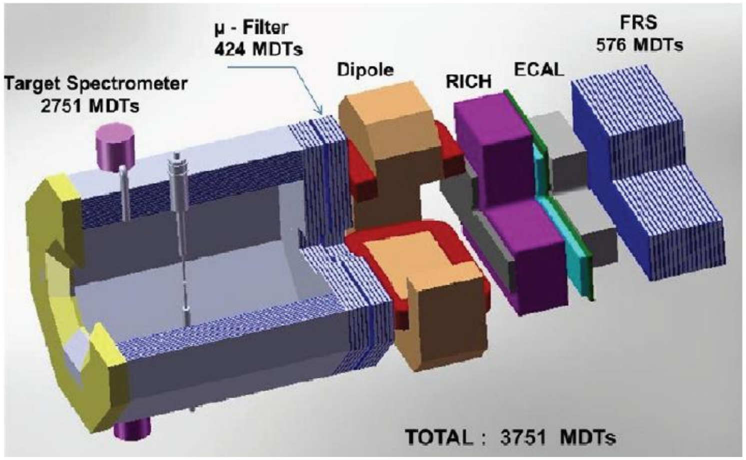


120 crystals = 1/6 sector

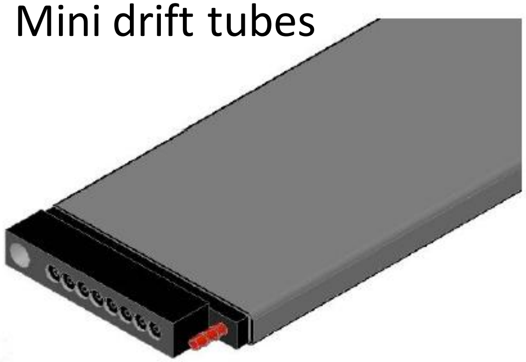
$\sigma_E/E = 1.8\% / \sqrt{E} + 0.65\%$

Validation of simulations by prototype measurements (Groningen, Juelich, Varsovie)

Range system for muons

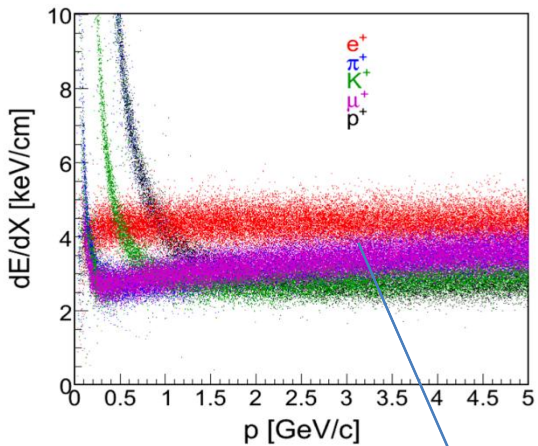


Mini drift tubes

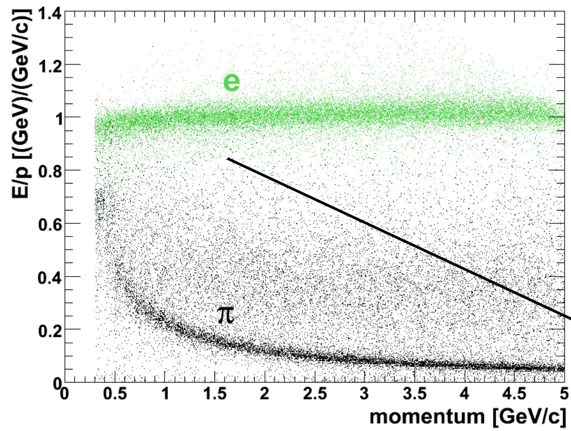


Rejection of pionic background

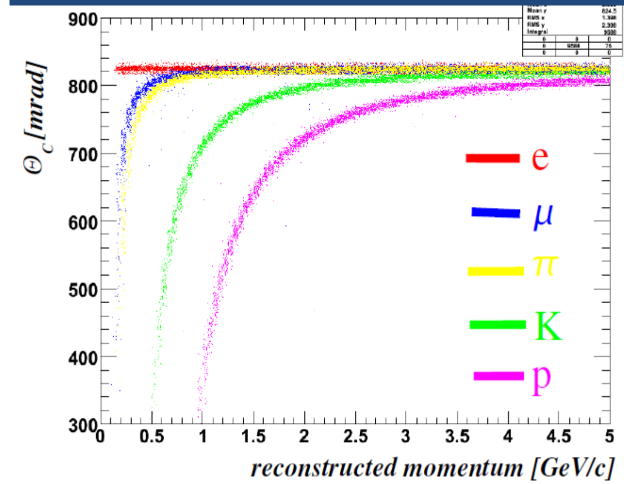
Straw Tube Tracker



ElectroMagneticCalorimeter



DIRC(Cerenkov)

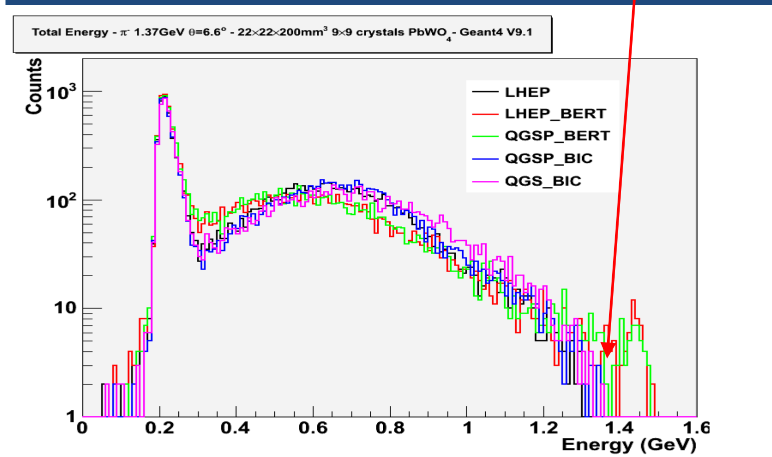


(π^-, π°), $\pi^\circ \rightarrow 2\gamma$

$E_{dep}/p \sim 1$

Non-gaussian tails of truncated dE/dx distribution

EMC response to π^- p=1.5 GeV/c



1) Use complementarity of e/π discrimination capability of the different detectors

2) Use the different kinematical constraints of $\bar{p}p \rightarrow e^+e^- X$ and $\bar{p}p \rightarrow \pi^+\pi^- X$ reactions

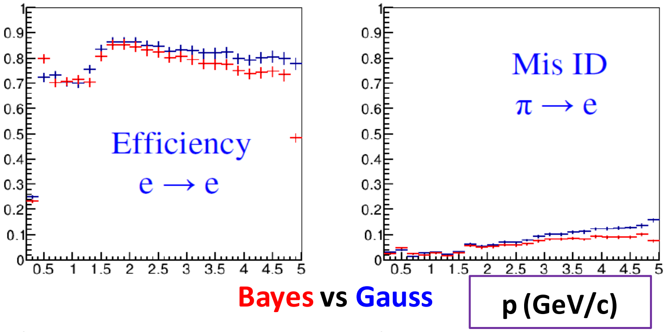
More difficult for muons !

T.Zerguerras, IPN Orsay

Very recent update by E. Atomssa (IPN Orsay)

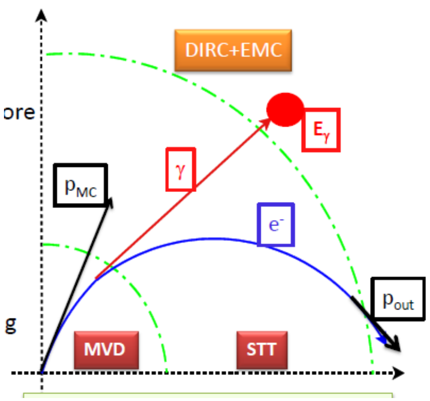
Analysis tool developments

Particle Identification using Straw Tubes (dE/dx)
Comparison bayesian/gaussian

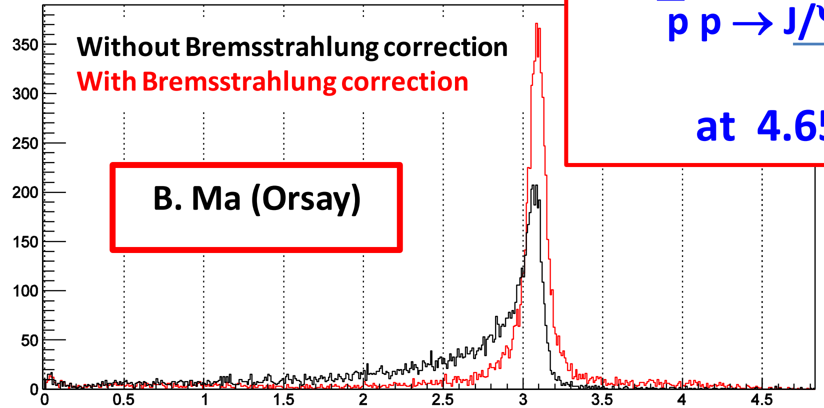


R. Kunne (Orsay)/ M. Gumberidze (Darmstadt)

Bremsstrahlung correction using photon detection in EMC



Effect on J/ψ reconstruction



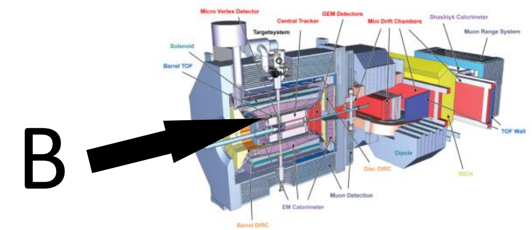
$\bar{p}\,p \rightarrow J/\Psi\,\pi^0$, $J/\Psi \rightarrow e^+e^-$
at 4.65 GeV

B. Ma (Orsay)

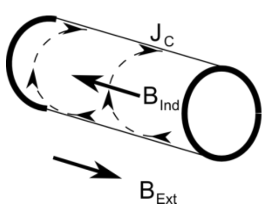
Polarized target developments
HIM Mainz

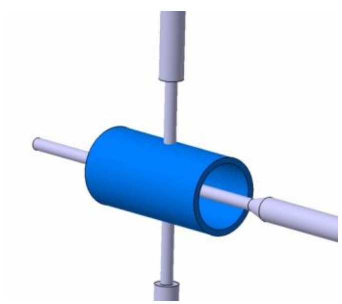
- Goal : transversely polarized target for PANDA
  - $\bar{p}p \rightarrow e^+e^-$: access to $Im(G_E G^*_M)$
  - Drell-Yan: access to Sivers function $f_{1T}(x,k_T)$ and transversity $h_{1T}(x)$
- Main problem:

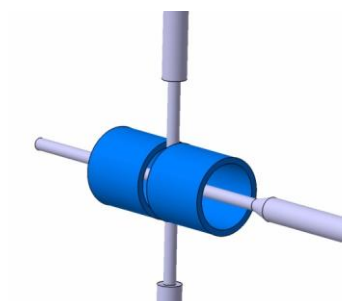
  PANDA barrel solenoid field B=1-2T



- Principle: superconducting shield







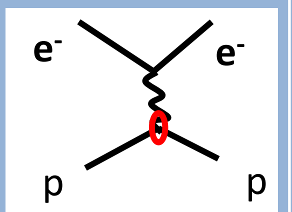
On-going studies: Residual field in target region for different geometries
Material budget
B. Froehlich (Feher), HIM Mainz

Hadron and lepton probes for nucleon structure

Crossing symmetry $\rightarrow$ same matrix elements in crossed channels
$\rightarrow$ counterpart observables

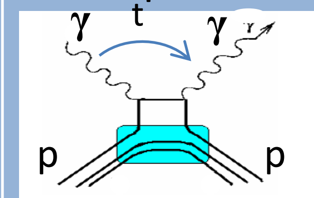
$e^- p \rightarrow e^- p$

$q^2<0$



Space Like electro magnetic Form factors

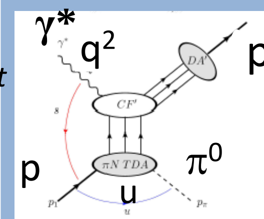
$\gamma p \rightarrow \gamma p$ Wide Angle Compton Scattering



Large p_t

Generalized Parton Distributions

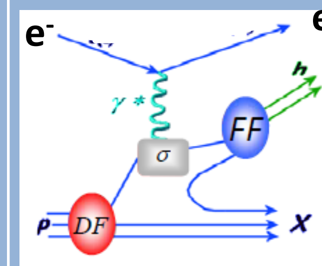
$e^- p \rightarrow e^- p \pi^0$ Bwd electroproduction



Large q^2
small u

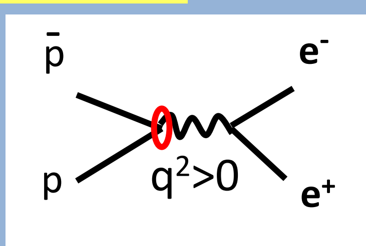
Transition Distrib. Amplitudes

$e^- p \rightarrow e^- hX$ SIDIS



Parton Distrib. Functions

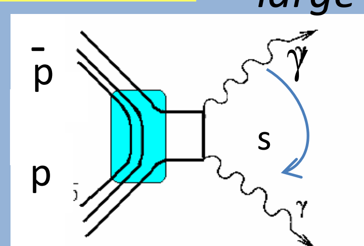
$\bar{p}p \rightarrow e^+e^-$



Time Like electro magnetic Form factors

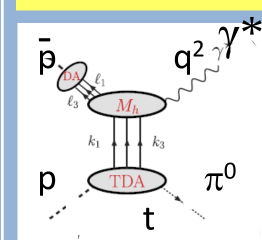
$\bar{p}p \rightarrow \gamma\gamma$

large p_t



Generalized Distrib. Amplitudes

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

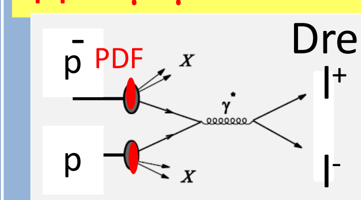


Large q^2
small t or u

Transition Distrib. Amplitudes

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

Drell-Yan



Parton Distrib. Functions

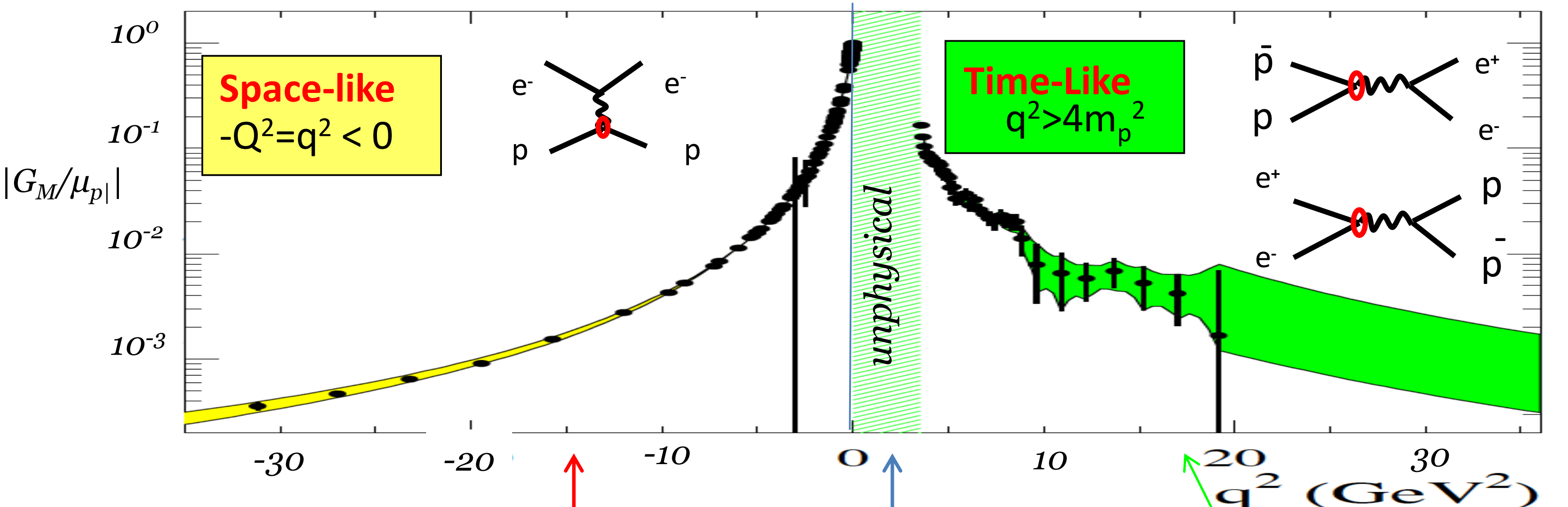
Challenge of l^+l^- exit channels: much higher background

Time-Like and Space-Like electromagnetic form factors : an unified picture

two electromagnetic form factors for the proton $G_E(q^2), G_M(q^2)$

complex analytical functions (*real for $q^2 < 4m_\pi^2$*)

From S. Pacetti, arXiv:1012.1232v1



Dispersion relations:

$q^2 < 0$

$$G(q^2) = \frac{1}{\pi}\left[\int_{4m_\pi^2}^{4m_p^2} \frac{\mathrm{Im}\ G(s)\,ds}{s-q^2} + \int_{4m_p^2}^{\infty} \frac{\mathrm{Im}\ G(s)\,ds}{s-q^2}\right]$$

Feasibility studies for form factor in the unphysical region ($q^2<4m_p^2$) with PANDA

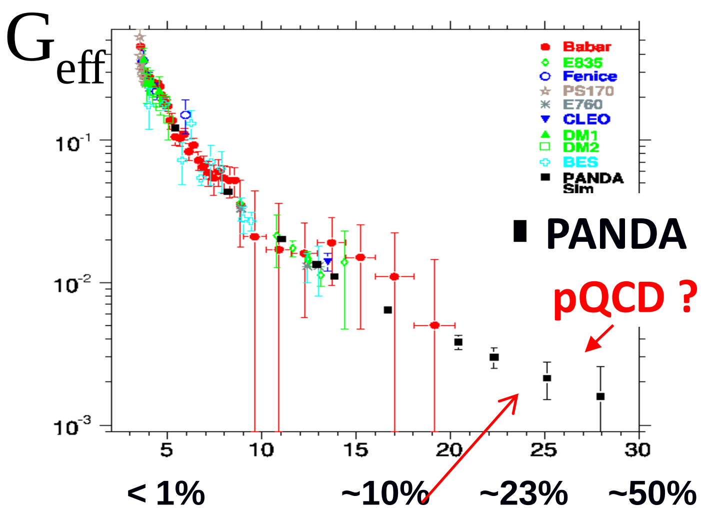
- ✓in $\bar{p}p \rightarrow e^+e^-\pi^0$ (J. Boucher, Orsay, PhD 2011)
- ✓In $\bar{p}d \rightarrow ne^+e^-$ (H. Fonvieille and V.A. Karmanov EPJA42 (2009) 287-298)

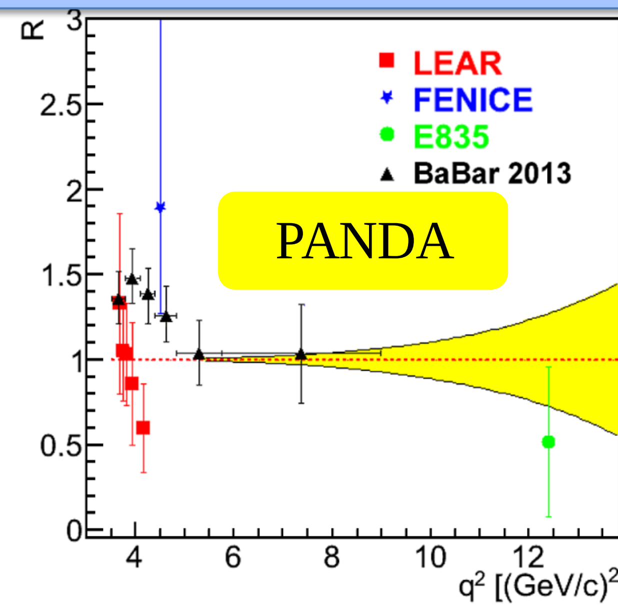
Time-Like Form Factor measurement with PANDA :

Projections for PANDA L=2 fb^{-1} (120 days at full luminosity)

- Background suppression factor >10^9 (per bin) taking into account PID & kinematic fit
- $\rightarrow$ contamination << 1% per bin
- Signal efficiency ~ 40-15%

Orsay/Mainz M. Sudol et al. EPJA 44 (2010) 373





Phragmèn-Lindelöf theorem

$$\lim_{q^2 \rightarrow -\infty} G^{SL}(q^2) = \lim_{q^2 \rightarrow +\infty} G^{TL}(q^2)$$

$\rightarrow$ PANDA is unique for Time-Like form factor measurements at large q^2 (q^2>9 $(GeV/c)^2$)

New simulations with PANDARoot software :

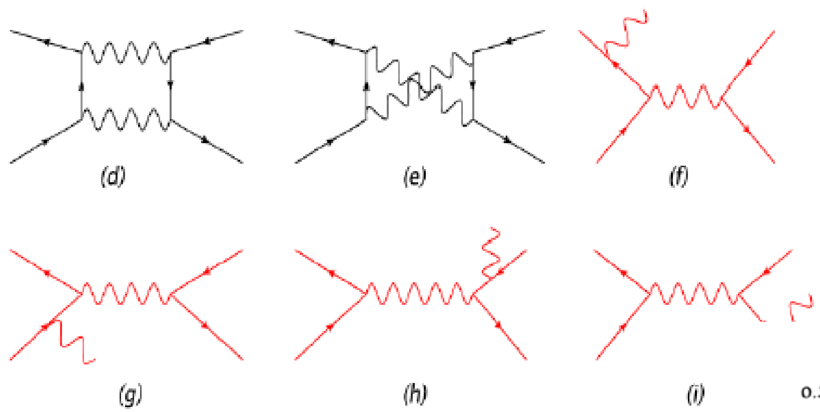
A. Dbeyssi (PHD Sept2013 Orsay) , Dmitry Khaneft (HIM Mainz)

interest of polarization: relative phase between G_E and G_M

see A. Dbeyssi's talk

Radiative corrections for $\bar{p}p \rightarrow e^+e^-$: electron and proton radiation

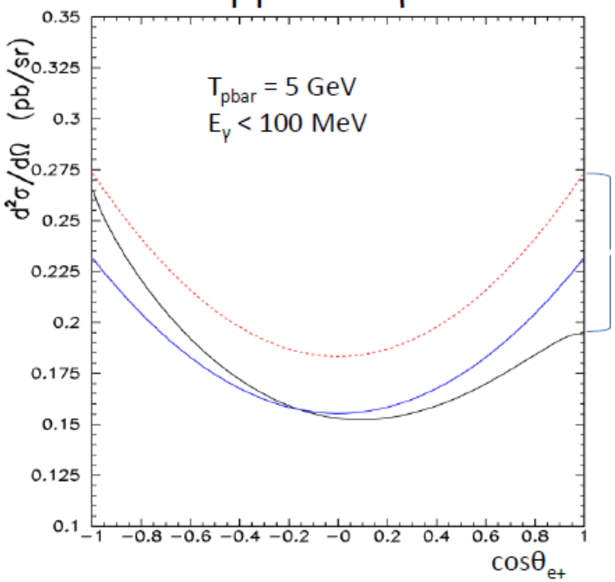
Photon emission from both leptons and hadrons



A.I.Ahmadov et al Phys.Rev.D82 094016(2010)
J.Van de Wiele et S Ong, Eur.Phys.J. A49 (2013) 18

N.B. PHOTOS event generator: has no radiation from the proton

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



40% but depends on the cut

Born cross section
No radiation from hadrons
With radiation from both leptons and hadrons

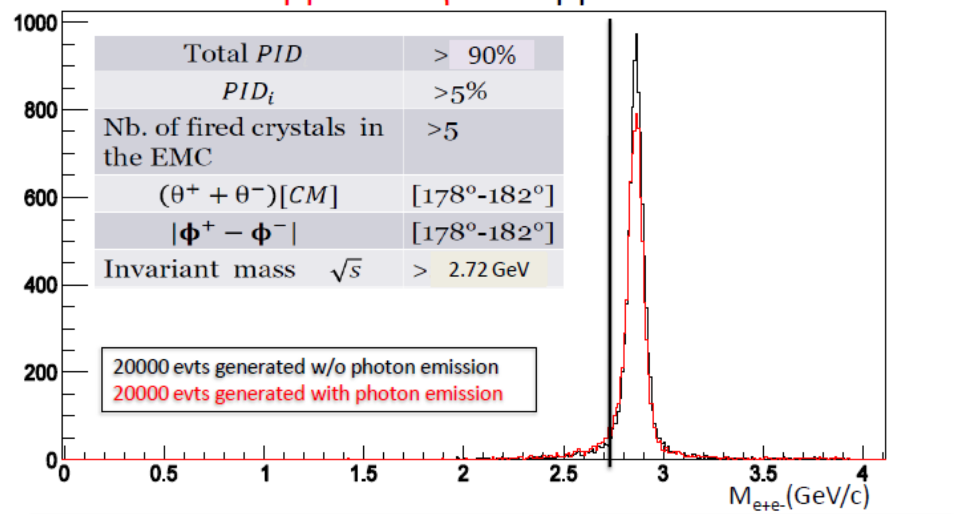
Radiative corrections for $\bar{p}p \rightarrow e^+e^-$ in practice

Effect of radiation
$\rightarrow$ reduction of the selection efficiency
by 17% without Bremsstrahlung correction
by 10 % with Bremsstrahlung correction

p_p=3.3 GeV/c
q^2=8.21(GeV/c)^2

B. Ma (IPN Orsay)
GDR working group on annihilation and scattering electromagnetic processes
Orsay Oct. 7-8 th

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



strategy for radiative corrections
- ✓ Implement photon emission (both from electron and protons) in the event generator
- ✓ Global correction: efficiency + radiative correction

Time-Like electromagnetic form factors in $\bar{p}p \to \mu^+\mu^-$

Mass effect negligible

$$\frac{d\sigma}{d\cos\theta_{CM}}(s,\theta) = \frac{\alpha^2\pi}{2\cdot s}\cdot\frac{p_l}{\overline{p}}\cdot|G_M|^2\left[\frac{4M_p^2}{s}\left(1-\beta^2\cos^2\theta_{CM}\right)\cdot R^2 + \left(1+\frac{4m_l^2}{s}+\beta^2\cos^2\theta_{CM}\right)\right]$$

- Extract $|G_E|$ and $|G_M|$

$$R = \frac{|G_E|}{|G_M|}$$

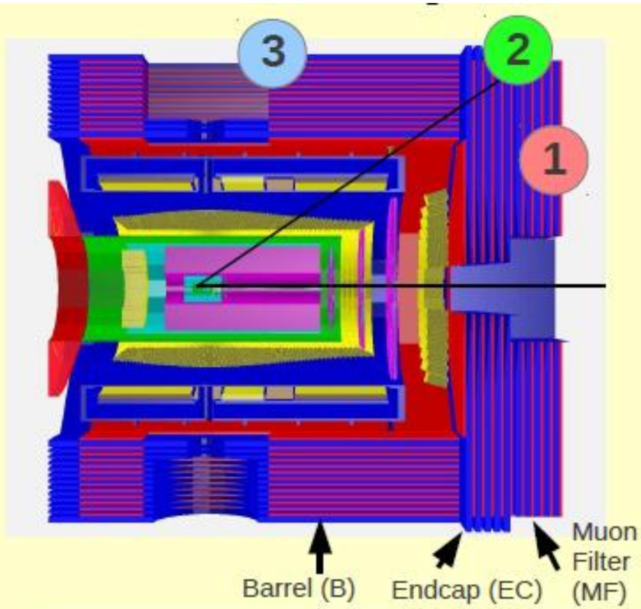
- G_E and G_M can be extracted in the same way as for $\bar{p}p \to e^+e^-$

$\to$Additionnal measurement with

- ✓ different systematic errors
- ✓ no radiation correction needed

On-going feasibility study (I. Zimmermann, HIM Mainz)

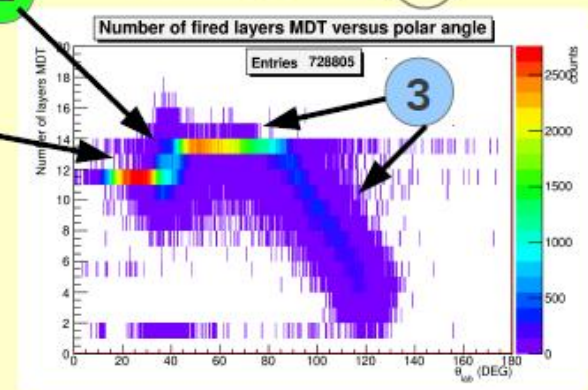
First studies for $\bar{p}p \rightarrow \mu^+\mu^-$



1. EC & MF: 11 detection layers of Mdt´s
2. ~40° polar production angle: overlap region B& EC: "Hybrid tracking"
3. B: 13 detection layers
4. Forward Range System (FRS) (not shown): 16 detection layers

1.5 GeV/c beam momentum

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

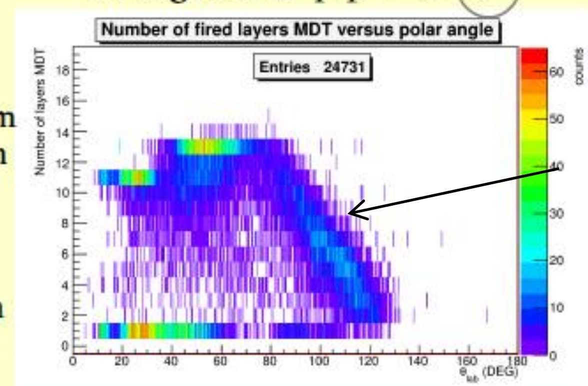


PID:
- MDT
- MVD
- STT
- EMC
- DIRC
- DISC

No 4-momentum conservation checked

PID criterium "very tight"

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



Pion decays

eff*acc after PID and kinematical cuts:

for $\mu^+\mu^-$ = 50%

for $\pi^+\pi^-$ = 0.02% (10^{-8} needed !)

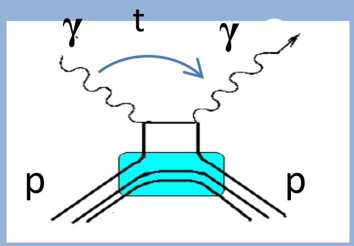
Tracking software (S. Spataro Torino)
Simulations: I. Zimmerman (HIM Mainz)

Muon tracking will significantly improve the result, but $\pi^+\pi^-$ subtraction probably necessary

Hadron and lepton probes for nucleon structure

Crossing symmetry $\rightarrow$ same matrix elements in crossed channels
$\rightarrow$ counterpart observables

$\gamma p \rightarrow \gamma p$ Wide Angle Compton Scattering

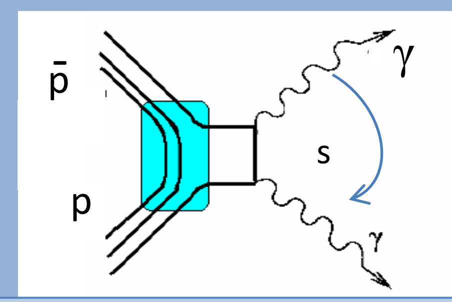


Large p_t

Generalized **P**arton **D**istributions

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

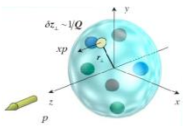
Large p_t



Generalized **D**istrib. **A**mplitudes

Hard exclusive processes at large P_t: GDA

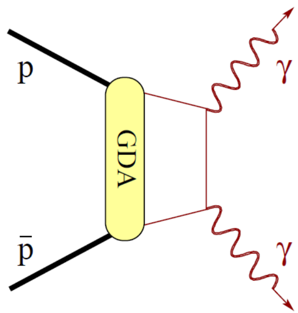
Generalized Distribution Amplitudes (cf GPD)



Quark momentum correlations

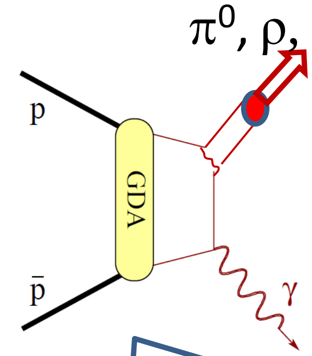
P. Kroll and A. Schäfer, EPJ. A26,89 (2005).

$\bar{p}p \to \gamma\gamma$



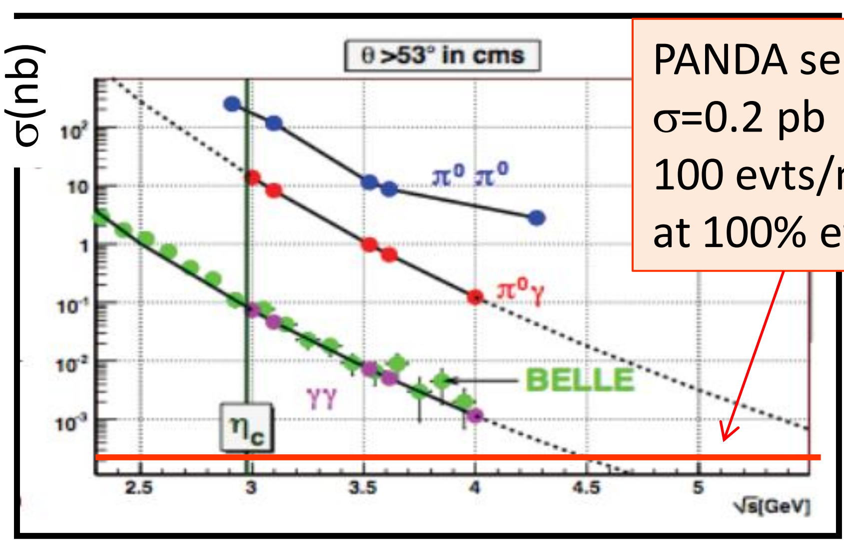
$\bar{p}p \to \gamma\pi^0, \gamma\rho . \gamma\phi, \ldots$

easier !



$\gamma\gamma \to \bar{p}p$ from BELLE up to $\sqrt{s}$=4 GeV
C.-C. Kuo et al., Phys. Lett. B621, 41 (2005)

$\bar{p}p \to \gamma\pi^0$ Fermilab data E760 up to $\sqrt{s}$=3.7 GeV
T. A. Armstrong et al, Phys. Rev. D 56, 2509 (1997).



PANDA sensitivity
σ=0.2 pb
100 evts/month
at 100% efficiency

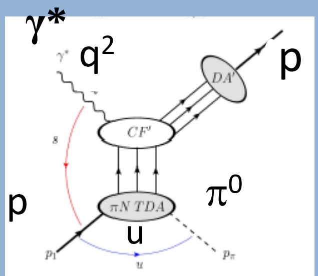
First estimates:
S/B ~ 1 for γγ (25% signal efficiency)
S/B ~ 2 for $\pi^0\gamma$ (50% signal efficiency)

PANDA group from Giessen university

Hadron and lepton probes for nucleon structure

Crossing symmetry $\rightarrow$ same matrix elements in crossed channels
$\rightarrow$ counterpart observables

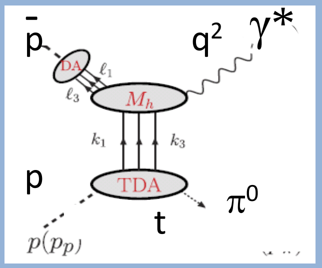
$e^- p \rightarrow e^- p \pi^0$ Bwd electroproduction



Large q^2
small u

Transition Distrib. Amplitudes

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

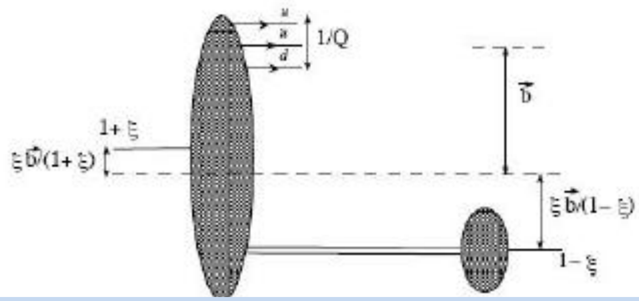


Large q^2
small t or u

Transition Distrib. Amplitudes

On going analysis in π^0 electroproduction at backward angles (JLAB) $\rightarrow$ access to same TDA

Explores pionic components
in the nucleon wave function
Transverse picture of pion cloud



Hard exclusive processes at forward or backward angles : TDA

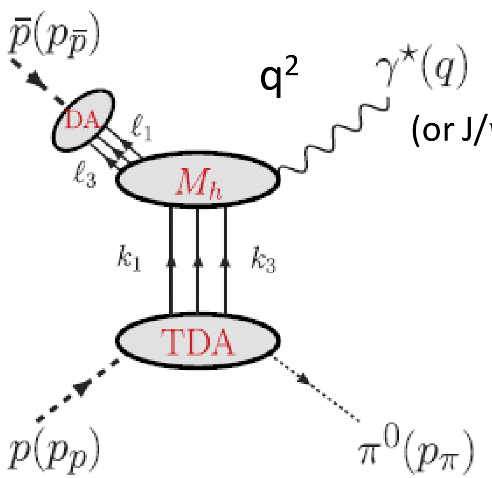
Access to Transition Distribution Amplitudes

Signatures: angular distribution of the e^+/e^- in the γ^* frame
$d\sigma/d\Omega \sim (1+\cos^2\theta)$
$\sigma \sim 1/q^8$

$\bar{p}p \rightarrow e^+e^-\pi^0, e^+e^-\rho^0, e^+e^-\eta, \ldots$

Kinematical conditions:
- large q^2
- small t or u ($\theta_\pi = 0^o$ or $\theta_\pi = 180^o$)

Factorization



or ρ, η, ϕ,

$$\xi = -\frac{(p_\pi - p_N)\cdot n}{(p_\pi + p_N)\cdot n}$$ skewness

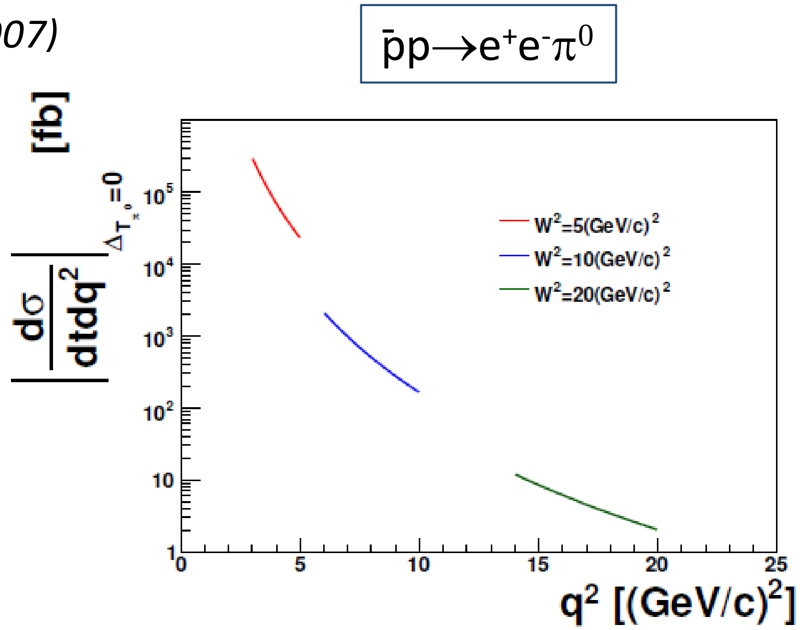
$$\Delta_T = f(t, \xi)$$ transverse transfer

TDA universal objects: depend only on ξ and Δ_t

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

First cross section predictions:
J.P. Lansberg et al, PRC76,111502(2007)

π^0 emitted at 0^0 or 180^0



- Feasibility studies for s=5 and 10 GeV^2
  M.C. Mora-Espi, PhD Mainz, 2013
- for L= 2fb^{-1}, 4000 counts for q^2=5 GeV/c^2 250 counts for q^2=10 GeV/c^2
- Background = mostly $\pi^+\pi^-\pi^0$ rejected by factor > 10^8
- Signal efficiency =20-50%

- Counting rates highly model dependent *J.P. Lansberg et al. Phys.Rev. D86 (2012) 114033*

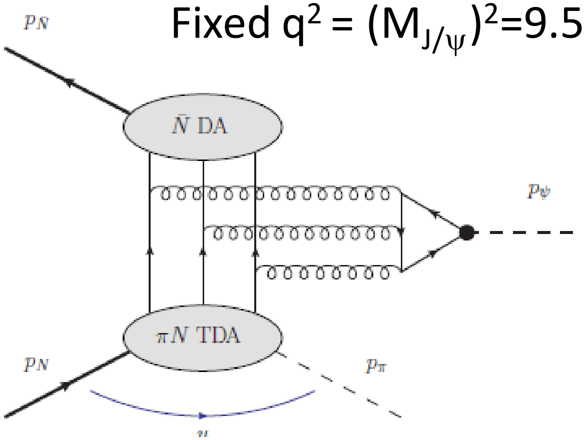
TDA in $\bar{p}p \to J/\psi\ \pi^0$

- Advantage with respect to $\bar{p}p \to e^+e^-\pi^0$
  - Higher counting rate
  - This process is a background for the charmonium study

$\bar{p}p \to h_c \to J/\psi\ \pi^0$ M_{hc}=3.525 GeV/c^2

See talk by K. Semenov tomorrow

Fixed $q^2 = (M_{J/\psi})^2$=9.59 GeV/c^2



$$\bar{p} + p \to J/\Psi + \pi^0$$
$$J/\Psi \to e^+ + e^-$$
$$\pi^0 \to 2\gamma$$

Validity of the factorization |t| or |u|<<$q^2 = (M_{J/\psi})^2$=9.59 GeV/c^2

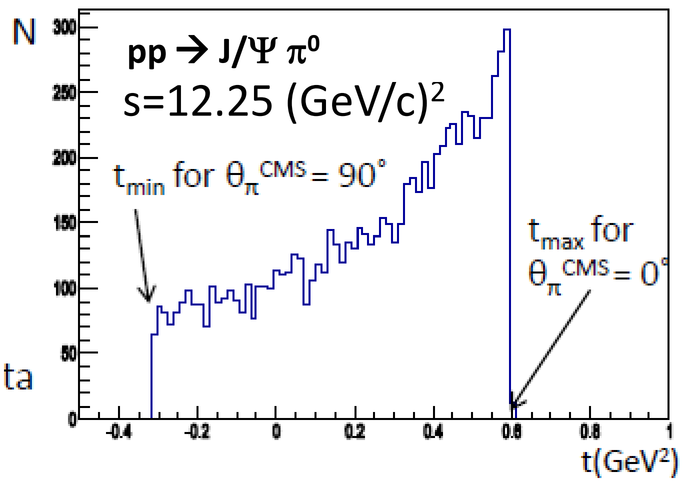
Predictions for PANDA $\bar{p}p \rightarrow J/\psi\, \pi^0$

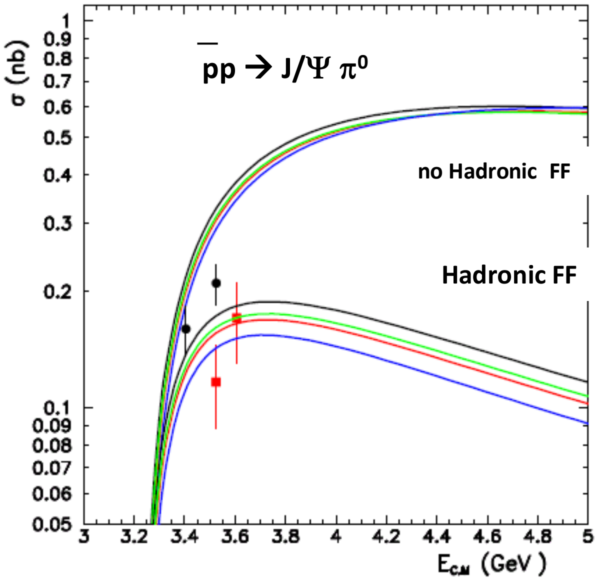
New event generator based on TDA model
B. Pire et al., Phys.Lett. B724 (2013) 99-107

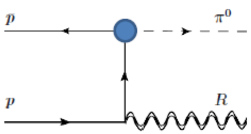
B. Ma (IPN Orsay) in collaboration with
K. Semenov (university of Liege)

σ=102 pb at s = 12.25 GeV/c^2
✓Consistent with data (141 evts in total from FERMILAB E760,E835)
✓ alternative approach: Lagrangian models

J. Van de Wiele and S. Ong, submitted to EPJA







13000 evts (2fb^{-1}) for forward π^0 emission
J/ψ can be easily reconstructed (see slide 8)

✓Total and differential cross section can be measured with PANDA
✓Background study needed ($e^+e^-\pi^0$, $\pi^+\pi^-\pi^0$)

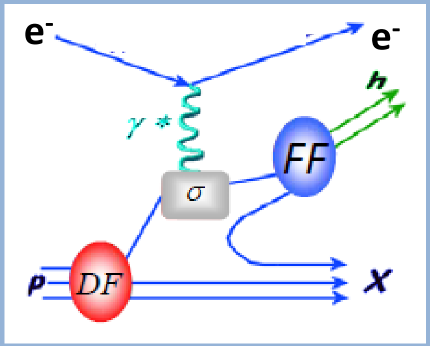
Hadron and lepton probes for nucleon structure

Crossing symmetry $\rightarrow$ same matrix elements in crossed channels

$\rightarrow$ counterpart observables

$e^- p \rightarrow e^- hX$

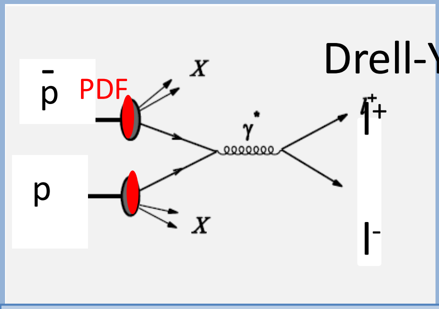
SIDIS



Parton Distribution Functions

A. Bianconi's talk on monday

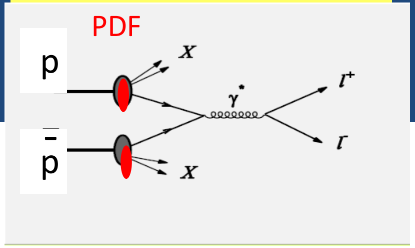
$\bar{p}p \rightarrow \mu^+\mu^- X / e^+e^- X$



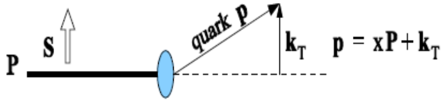
Parton Distribution Functions

Drell-Yan processes

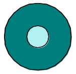
$p\bar{p} \rightarrow \mu^+\mu^- X / e^+e^- X$



- access to Parton Distribution Functions



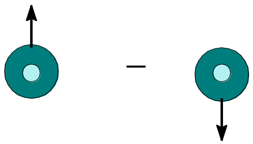
- Unpolarized cross section:

$f_1(x)$ 

$h_1(x,k_T)$ 

Boer-Mulders term in Cos 2ϕ

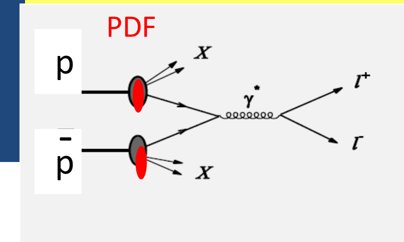
- Further perspectives with transversely polarized target (***on going R&D in Mainz***)
  → access to Sivers function $f_{1T}(x,k_T)$ and transversity $h_{1T}(x)$

$f^{\perp}_{1T} =$ 

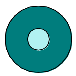
$h^{\perp}_{1T} =$ 

Drell-Yan processes: projections for PANDA

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



- Unpolarized cross section:

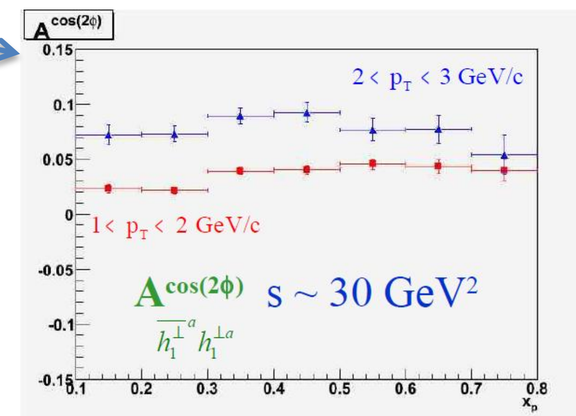
$f_1(x)$ 

$h_1(x,k_T)$ 

Boer-Mulders term in Cos 2ϕ

Projections for PANDA: ϕ asymetries

$1.5\ GeV/c^2 < M_{\mu\mu} < 2.5\ GeV/c^2$

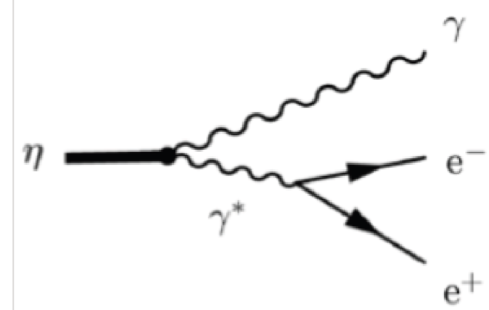


x_p

Simulations for PANDA

- Dubna and Torino/Brescia groups
  - A. Skachkova hep-ph/0506139 (Dubna)
  - A. Bianconi, M. Radici, Phys. Rev. D71, 074014 (2005)
- $\sigma \sim 0.8$ nb @ s = 30 GeV^2 (p=15GeV/c)
  130 kevts/month for $1.5\ GeV/c^2 < M_{\mu\mu} < 2.5\ GeV/c^2$
- Kinematical criteria to reject $\mu^+\mu^-$ pairs of non Drell-Yan origin.
- Detailed study of contamination of charged pions neceesary

Perspectives for other studies



Meson transition Form Factors: (J. Meschendorp, KVI)

$\eta \to \gamma e^+e^-$, $\eta' \to \gamma e^+e^-$, $\omega \to \pi^0 e^+e^-$, $J/\psi \to e^+e^- \eta_{c}$,.....

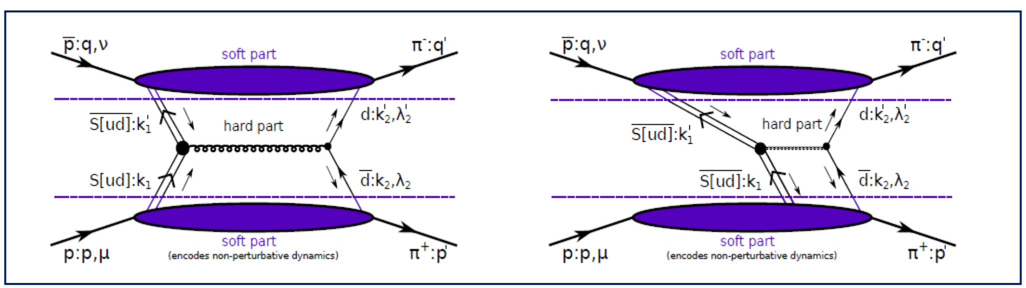
$\bar{p}p \to \pi^+\pi^-$, $\bar{p}p \to K^+K^-$

Need to be measured to control the background for electromagnetic channels

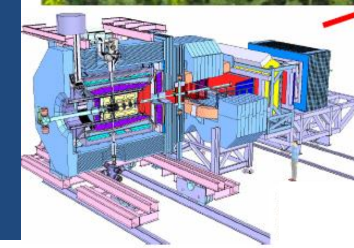
Intrinsic interest : reaction mechanism , transition towards perturbative QCD regime

Double-handbag mechanism: TDA in $\bar{p}p \to \pi^+\pi^-$

A.T. Goritschnig et al., arXiv:1311.1908[hep-ph]



Summary



- *Fair and PANDA are on track*

→ *Unique opportunity for hadron physics in Europe*

→ *Exciting perspectives for nucleon structure studies using electromagnetic channels in pp*

- *Experimental challenges for electromagnetic channels : PID, tracking, electron Bremsstrahlung , muon detection*

- *further perspectives with polarization*

PANDA Collaboration

More than 520 physicists from 67 institutions in 17 countries

Aligarh Muslim University
U Basel
IHEP Beijing
U Bochum
Magadh U, Bodh Gaya
BARC Mumbai
IIT Bombay
U Bonn
IFIN-HH Bucharest
U & INFN Brescia
U & INFN Catania
NIT, Chandigarh
AGH UST Cracow
JU Cracow
U Cracow
IFJ PAN Cracow
GSI Darmstadt

Karnatak U, Dharwad
TU Dresden
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
FIAS Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Glasgow
U Gießen
Birla IT&S, Goa
KVI Groningen
Sadar Patel U, Gujart
Gauhati U, Guwahati
IIT Guwahati

IIT Indore
Jülich CHP
Saha INP, Kolkata
U Katowice
IMP Lanzhou
INFN Legnaro
U Lund
U Mainz
U Minsk
ITEP Moscow
MPEI Moscow
TU München
U Münster
BINP Novosibirsk
IPN Orsay
U & INFN Pavia
IHEP Protvino

PNPI Gatchina
U of Silesia
U Stockholm
KTH Stockholm
Suranree University
South Gujarat U, Surat
U & INFN Torino
Politechnico di Torino
U & INFN Trieste
U Tübingen
TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw

http://www-panda.gsi.de

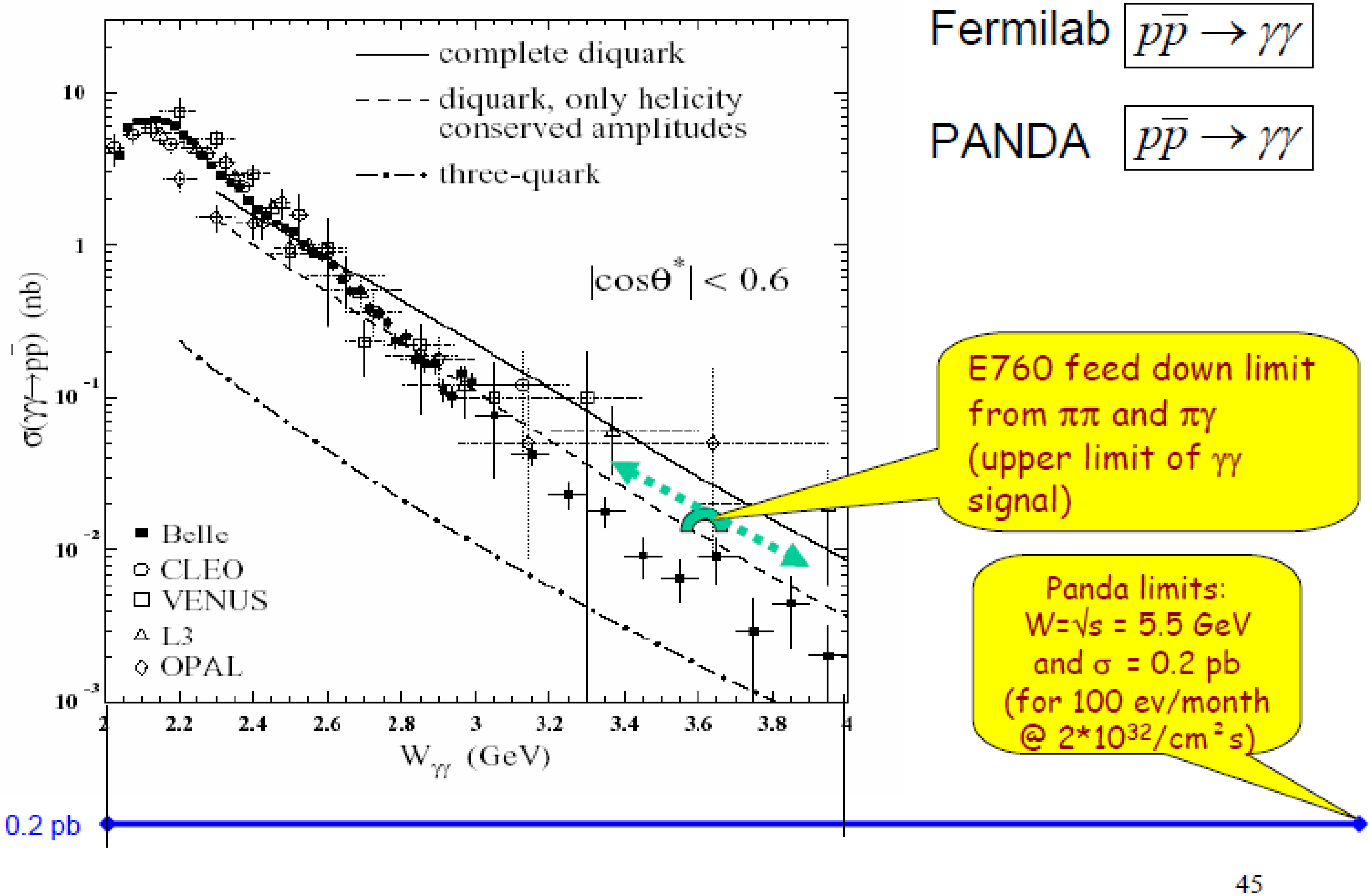
Thank you for your attention

FAIR

BACK-UP

Cross section comparison

Belle	$\gamma\gamma \to p\bar{p}$
Fermilab	$p\bar{p} \to \gamma\gamma$
PANDA	$p\bar{p} \to \gamma\gamma$

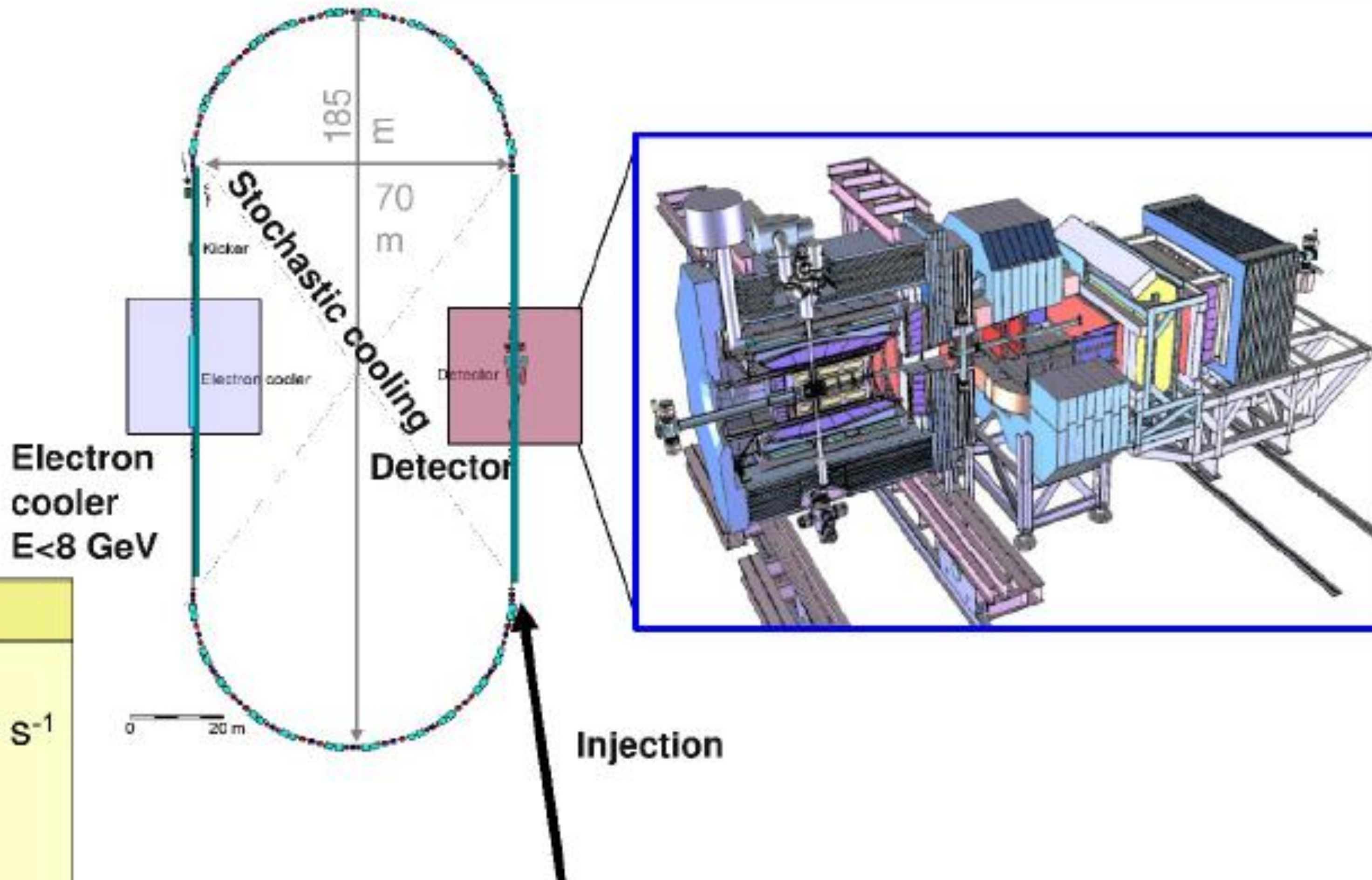


HESR

Cooling: electron/stochastic

High resol. mode: $\mathcal{L} = 10^{31}\ cm^{-2}\ s^{-1}$ $\delta p/p \sim 10^{-5}$

High lum. mode: $\mathcal{L} = 2 \cdot 10^{32}\ cm^{-2}\ s^{-1}$ $\delta p/p < 10^{-4}$



Characteristics

P_{max} = 15 GeV/c

$\mathcal{L}_{max} = 2 \cdot 10^{32}\ cm^{-2}\ s^{-1}$

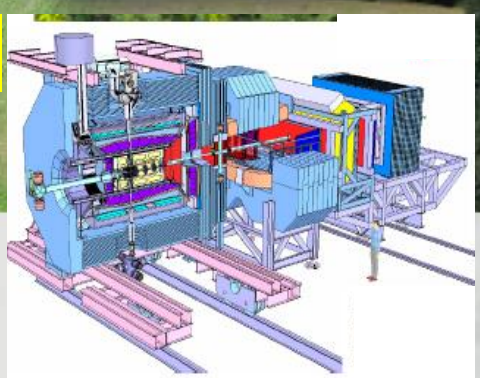
Ø < 100 μm

$\delta p/p < 10^{-5}$

internal target

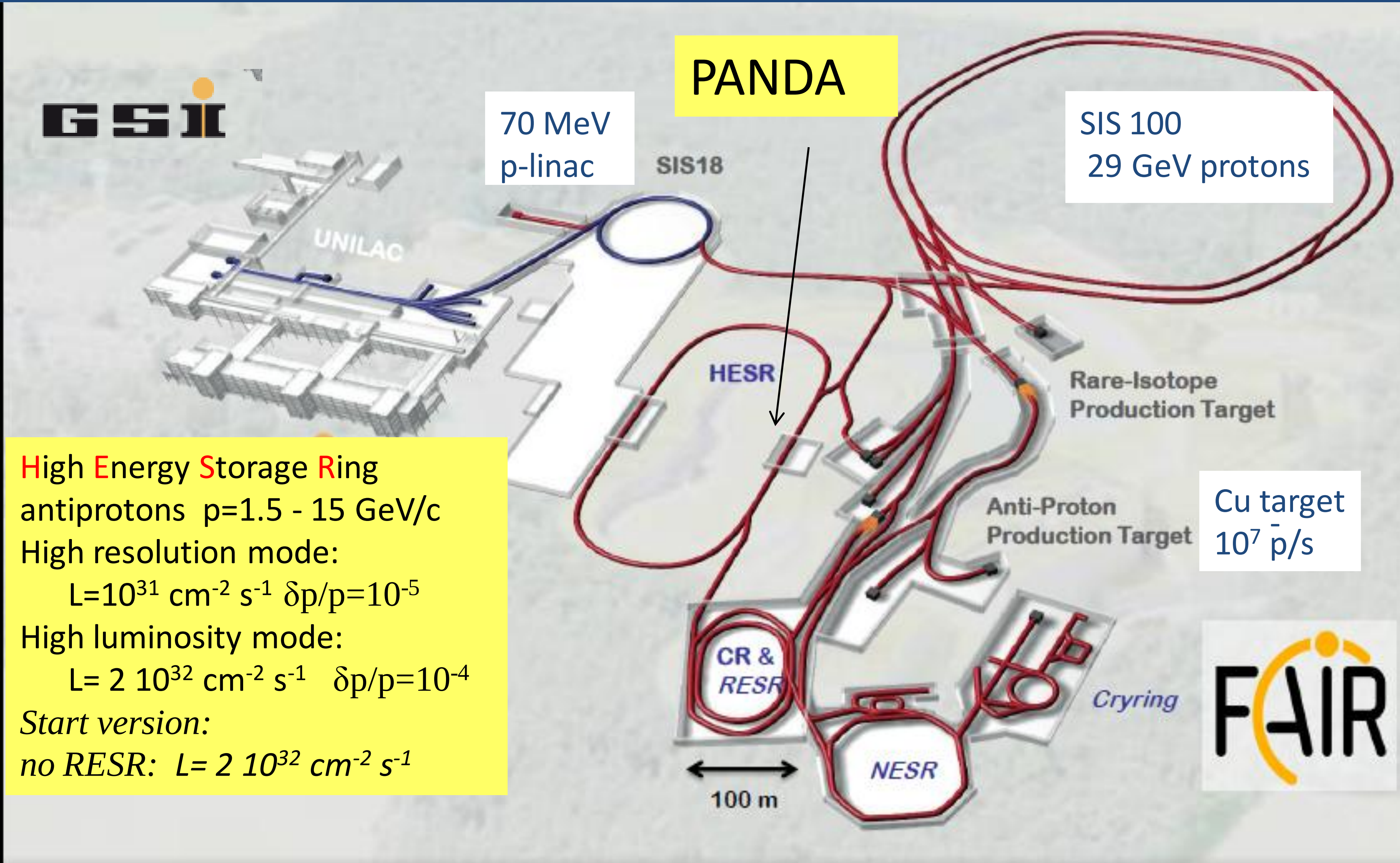
Facility for Antiproton and Ion Research

PANDA



Civil construction started,
accelerator components ordered
First beams 2018-data taking 2019

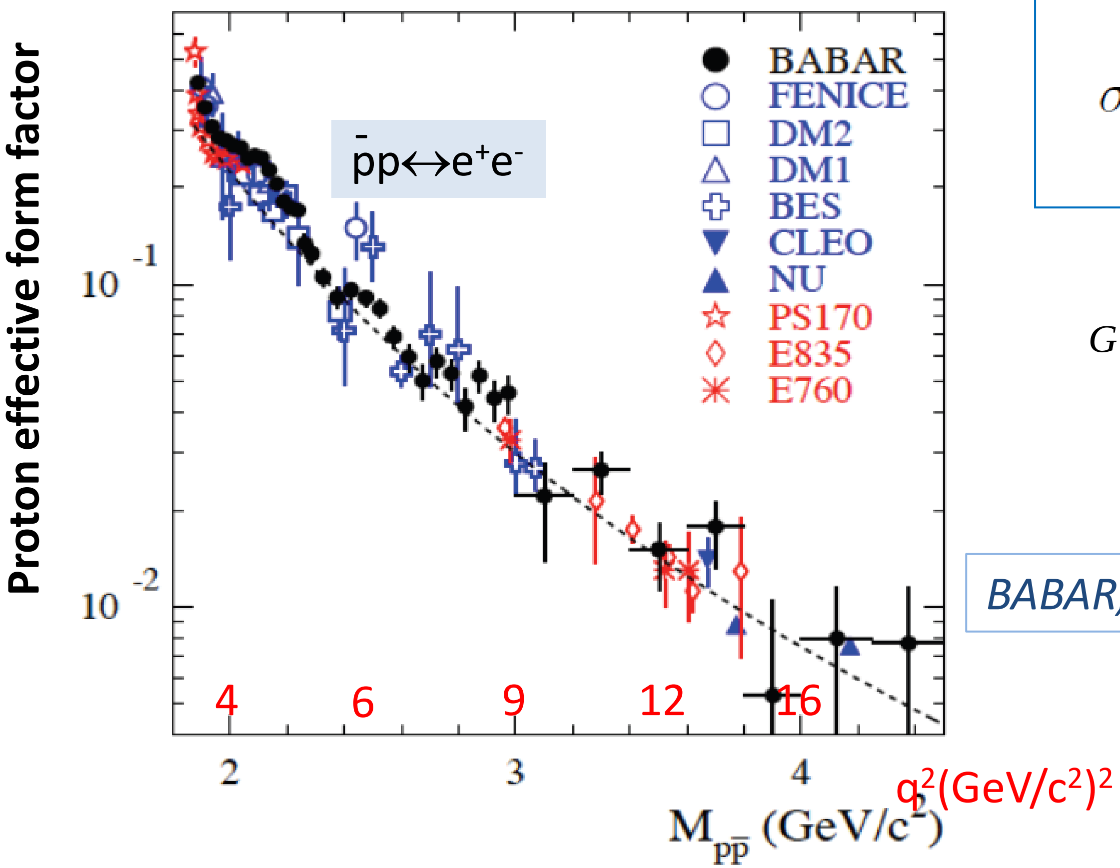
Antiproton beams at FAIR



High Energy Storage Ring
antiprotons p=1.5 - 15 GeV/c
High resolution mode:
L=10^{31} cm^{-2} s^{-1} $\delta p/p=10^{-5}$
High luminosity mode:
L= 2 10^{32} cm^{-2} s^{-1} $\delta p/p=10^{-4}$
Start version:
no RESR: L= 2 10^{32} cm^{-2} s^{-1}

Experimental situation in Time-Like region: G_{eff}

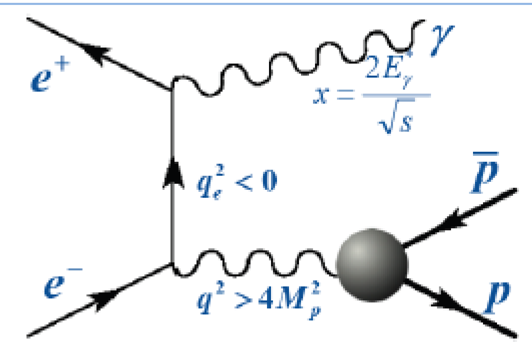
Recent review A. Denig and M. Salme arXiv:1210.4689[hep-ex]



$$\sigma_{tot} = \frac{\pi(\alpha\hbar c)^2}{6m_p^2}\frac{(2\tau+1)\,|G_{eff}|^2}{\tau\sqrt{\tau(\tau-1)}}.$$

$$G_{eff}^{\ 2} = \frac{2\tau|G_M|^2 + |G_E|^2}{2\tau+1} \qquad \tau = \frac{q^2}{4M_p^2}$$

BABAR, BESIII Initial State Radiation technique



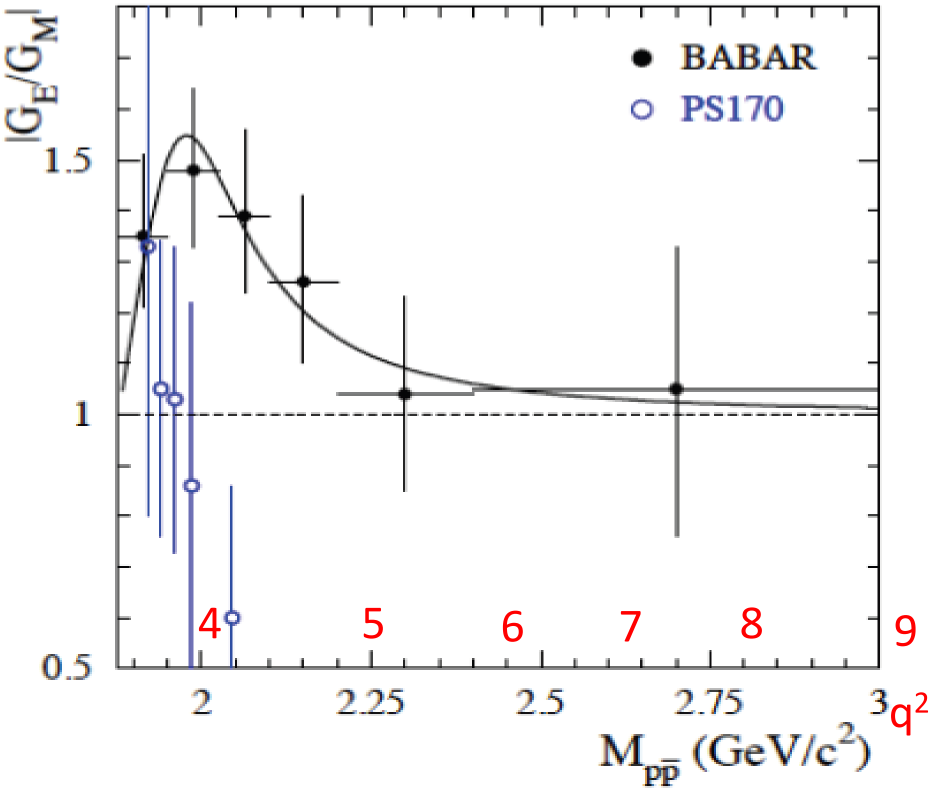
BABAR √s=10.57 GeV/c
BES √s=3.773 GeV/c

- **most recent results from BABAR Phys.Rev. D87 (2013) 0920**
- **on-going analysis at BESIII : better precision than BABAR expected for $q^2 < 9$ (GeV/c)^2**

Experimental situation in Time-Like region : $|G_E/G_M|$

angular distributions: $\bar{p}p \rightarrow e^+e^-$

$$\frac{d\sigma}{d(\cos\theta_{CM})} = \frac{\pi\alpha^2}{8M_p^2\tau\sqrt{\tau(\tau-1)}}\left[\tau\left|G_M^{TL}\right|^2(1+\cos^2\theta_{CM}) + \left|G_E^{TL}\right|^2\sin^2\theta_{CM}\right]$$



BABAR Phys.Rev. D87 (2013) 092005
PS170: Bardin et al.,NPB 411,3, (1994)

✓BABAR results incompatible with old PS170/LEAR measurements
✓Improvements expected from BES at $q^2 < 9$ $(GeV/c)^2$
✓Need for precise measurements at large q^2