A Fixed-Target ExpeRiment (AFTER) using the LHC beams

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Les Houches, January 17th 2014

- Physics opportunities with a fixed target experiments using the LHC proton and ion beams
- Expected luminosities
- Quarkonium case: yields and first studies

Physics opportunities of A Fixed-Target ExpeRiment (AFTER) @LHC

- **Idea: use LHC beams on fixed target**
  - 7 TeV proton beam ($\sqrt{s}$ ~115 GeV)
    - p+H, p+A
  - 2.76 TeV Pb beam ($\sqrt{s_{NN}}$ ~72 GeV)
    - Pb+A, Pb+H

- **High boost and luminosity give access to the QCD at large *x* = [0.3-1]**
  - Nucleon partonic structure
  - Spin physics
  - Nuclear shadowing
  - Quark Gluon Plasma
  - W/Z production near threshold
  - Other ?

- **Multi-purpose experiment**

Physics Opportunities of a Fixed-Target Experiment using the LHC Beams

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Abstract

We outline the many physics opportunities offered by a multi-purpose fixed-target experiment using the proton and lead-ion beams of the LHC extracted by a bent crystal. In a proton run with the LHC 7-TeV beam, one can analyze *pp*, *pd* and *pA* collisions at center-of-mass energy $\sqrt{s_{NN}} \simeq 115$ GeV and even higher using the Fermi motion of the nucleons in a nuclear target. In a lead run with a 2.76 TeV-per-nucleon beam, $\sqrt{s_{NN}}$ is as high as 72 GeV. Bent crystals can be used to extract about 5×10^8 protons/sec; the integrated luminosity over a year reaches 0.5 fb^{-1} on a typical 1 cm-long target without nuclear species limitation. We emphasize that such an extraction mode does not alter the performance of the collider experiments at the LHC. By instrumenting the target-rapidity region, gluon and heavy-quark distributions of the proton and the neutron can be accessed at large x and even at x larger than unity in the nuclear case. Single diffractive physics and, for the first time, the large negative-x_F domain can be accessed. The nuclear target-species versatility provides a unique opportunity to study nuclear matter versus the features of the hot and dense matter formed in heavy-ion collisions, including the formation of the quark-gluon plasma, which can be studied in *PbA* collisions over the full range of target-rapidity domain with a large variety of nuclei. The polarization of hydrogen and nuclear targets allows an ambitious spin program, including measurements of the QCD lensing effects which underlie the Sivers single-spin asymmetry, the study of transversity distributions and possibly of polarized parton distributions. We also emphasize the potential offered by *pA* ultra-peripheral collisions where the nucleus target *A* is used as a coherent photon source, mimicking photoproduction processes in *ep* collisions. Finally, we note that *W* and *Z* bosons can be produced and detected in a fixed-target experiment and in their threshold domain for the first time, providing new ways to probe the partonic content of the proton and the nucleus.

Keywords: LHC beam, fixed-target experiment

Contents

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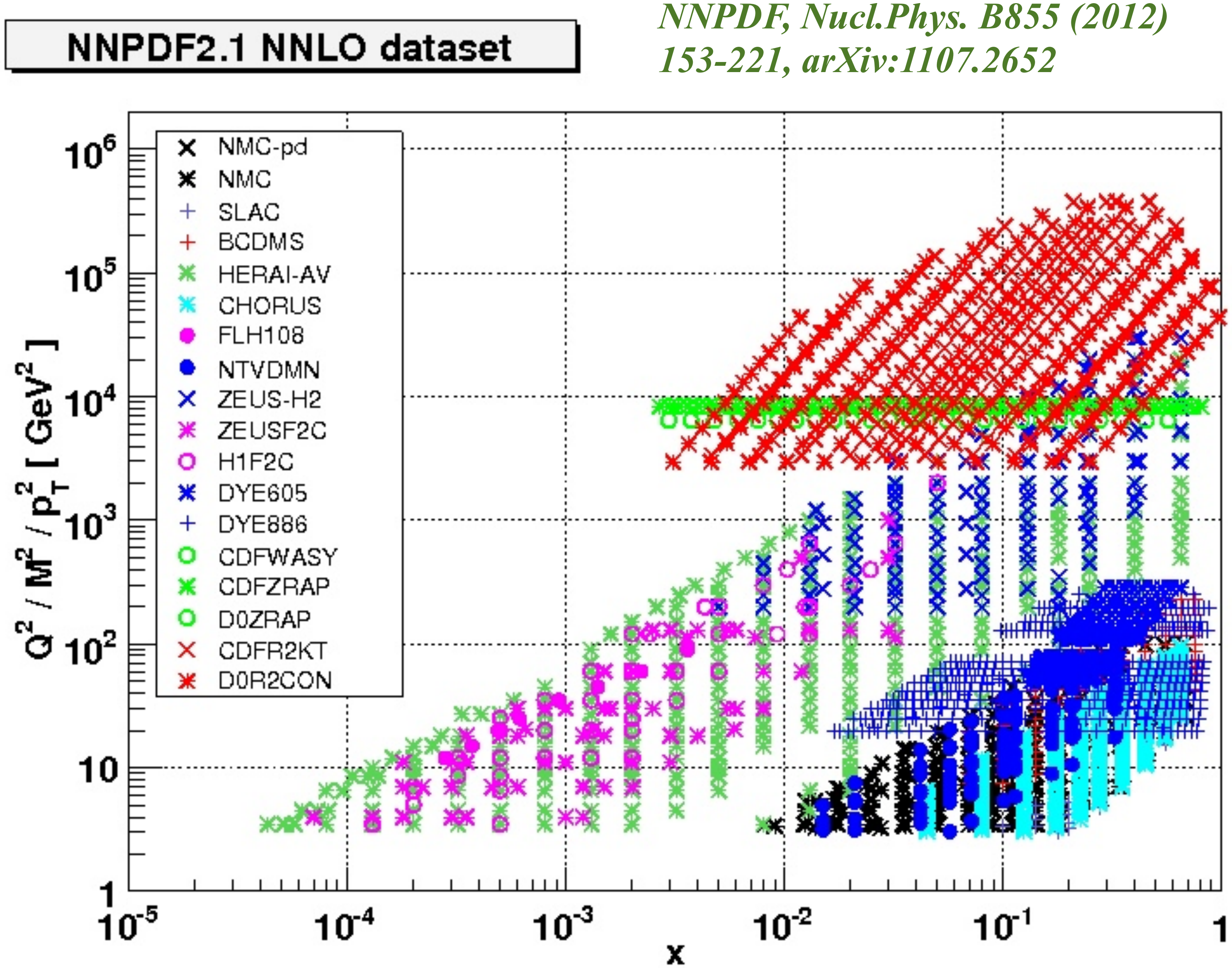
Proton structure: our current knowledge

Deep inelastic scattering (ep), Drell-Yan/Jet/Isolated photon/W/Z in hadronic collisions (pp): fixed-target or collider

High-x pdfs: few data available (DIS) and mostly sensitive to valence-quarks

Sea and gluon pdfs at large x extracted from DGLAP evolution equation → large uncertainty also for large scale

NNPDF, Nucl.Phys. B855 (2012) 153-221, arXiv:1107.2652



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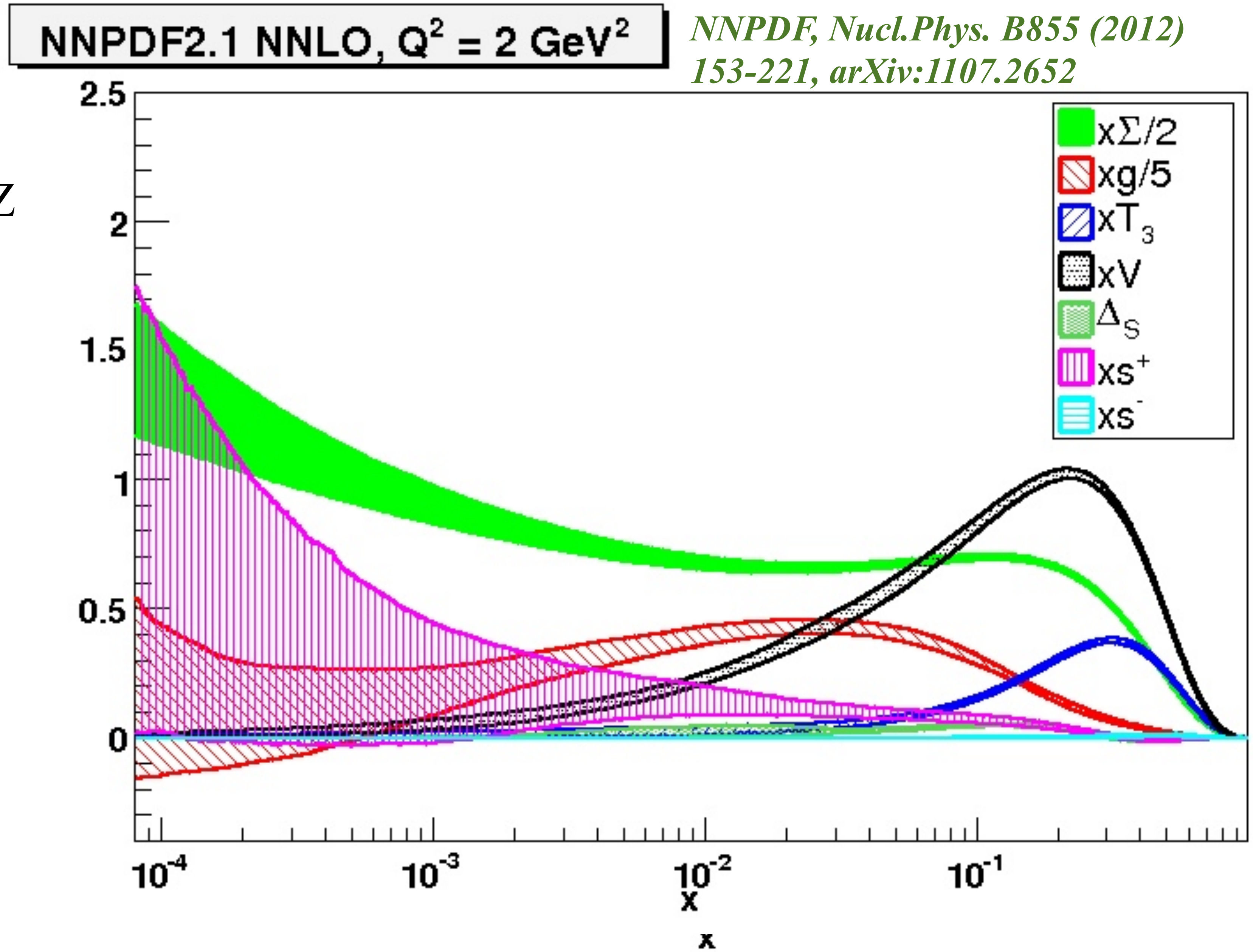
What about $x = 0.3 - 1$ in proton, neutron and nuclear matter?



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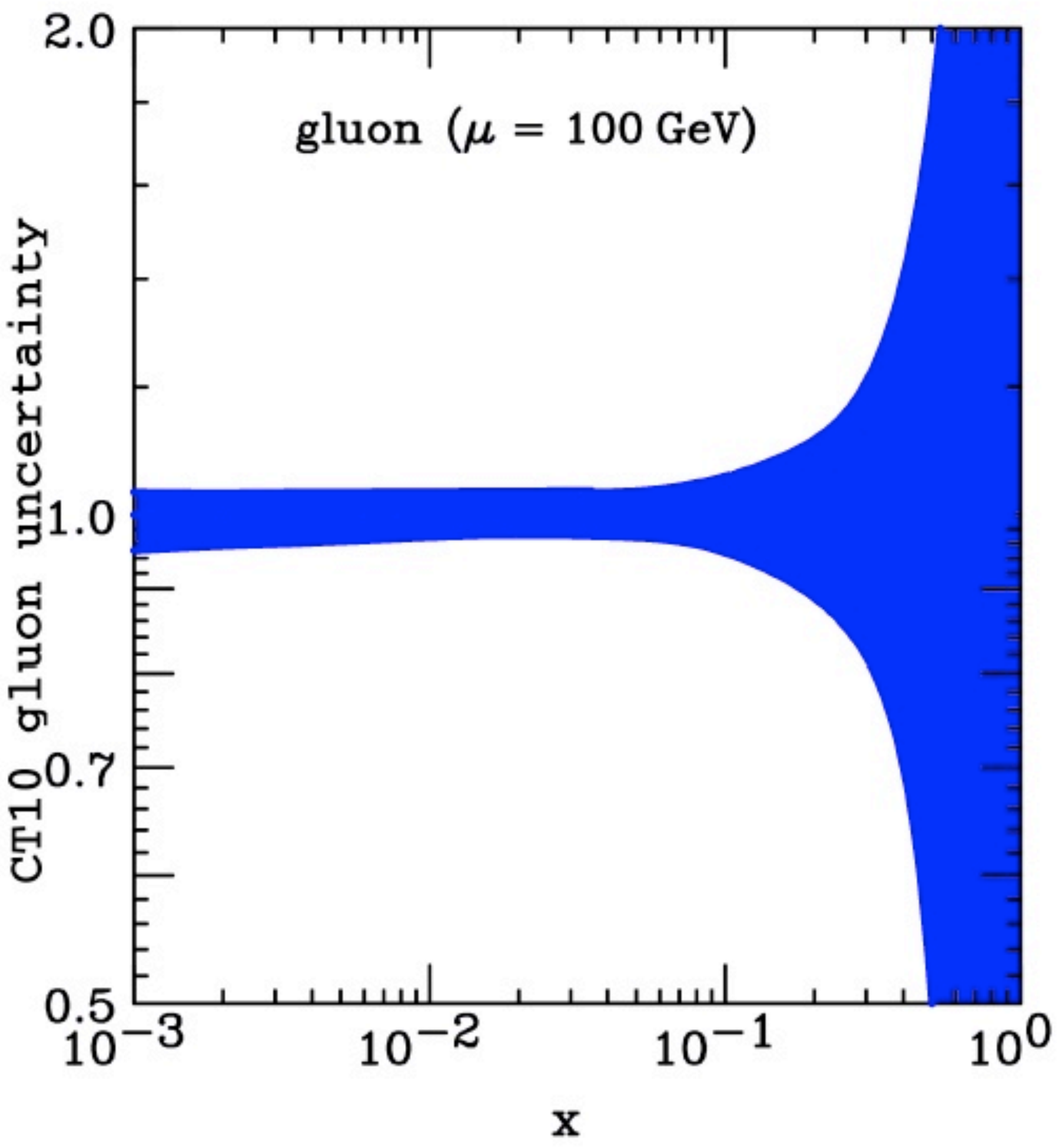
Gluon distribution in the nucleon at large x

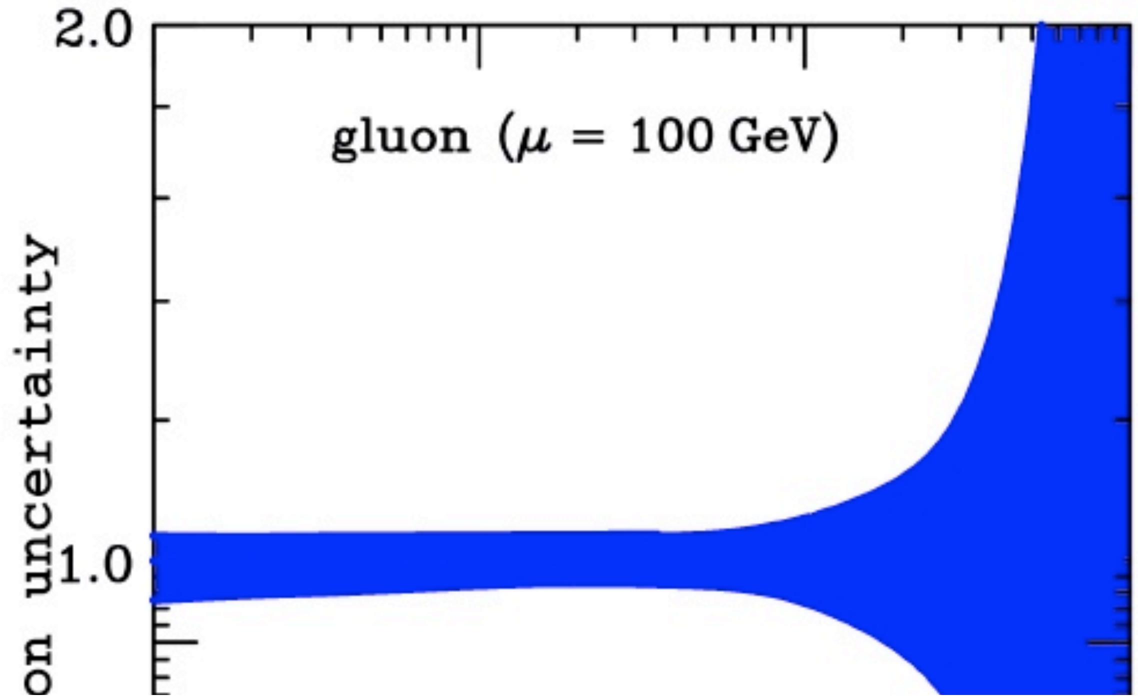
Gluon distribution function in the proton: very large uncertainty at large x also at large Q



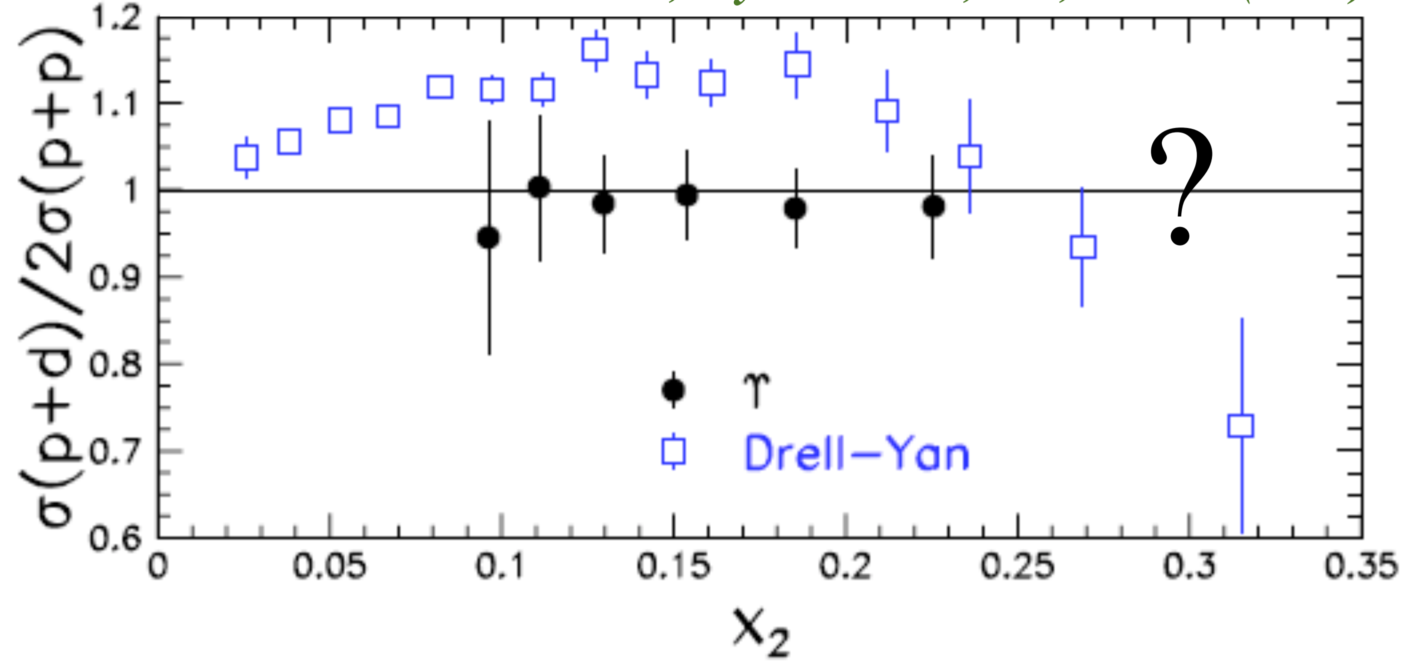
Gluon distribution in the nucleon at large x

Gluon distribution function in the proton: very large uncertainty at large x also at large Q

Unknown for the neutron



E866,Phys.Rev.Lett., 100, 062301 (2008)



Gluon distribution in the nucleon at large x

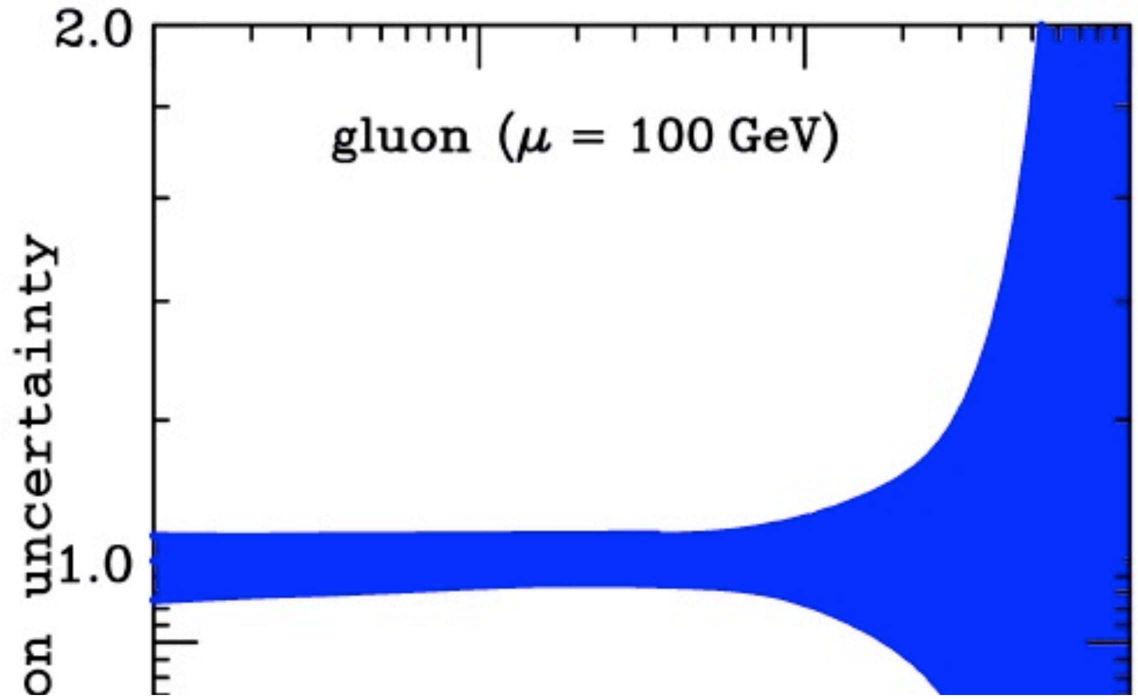
Gluon distribution function in the proton: very large uncertainty at large x also at large Q

Unknown for the neutron

- **Experimental probes @ AFTER**
  - Quarkonia
  - Isolated photons
  - High p_T jets (p_T > 20 GeV/c)

  → to access target x_g = 0.3 - 1 (>1 Fermi motion in nucleus)

- **Target versatility**
  - Hydrogen
  - Deuteron (neutron)



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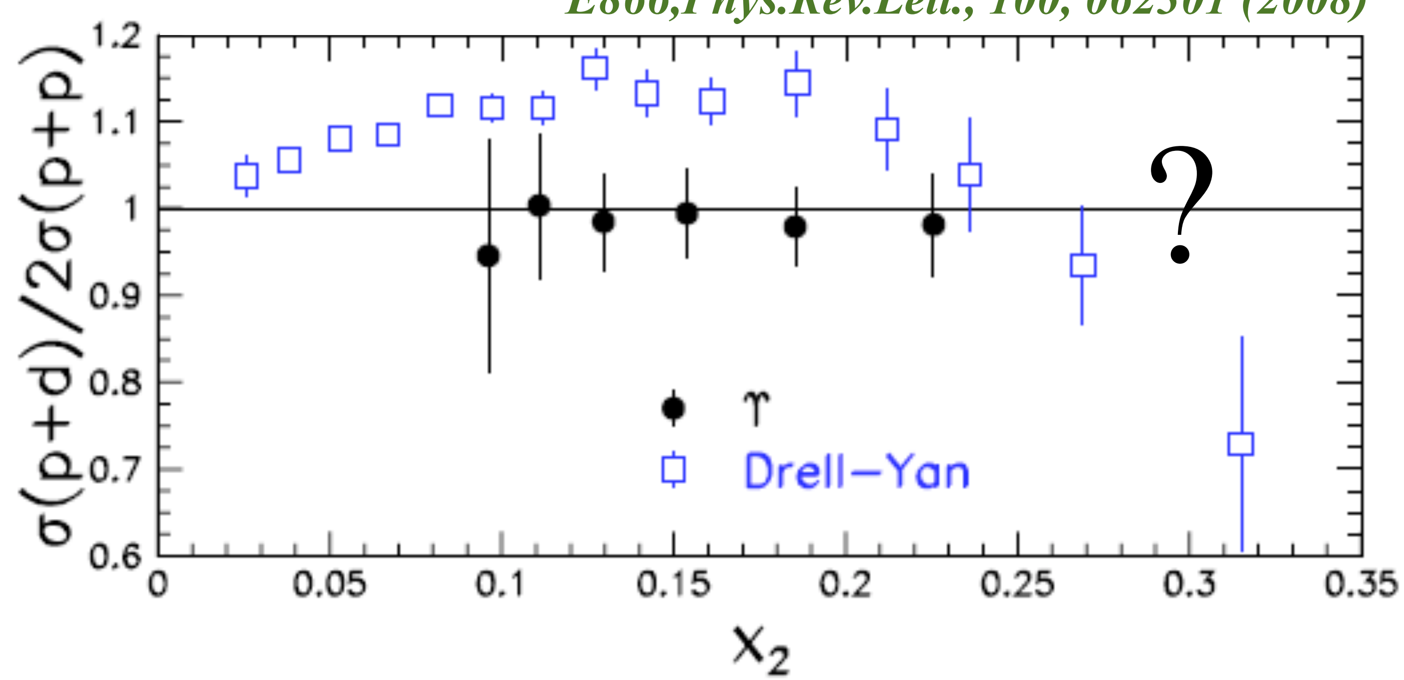
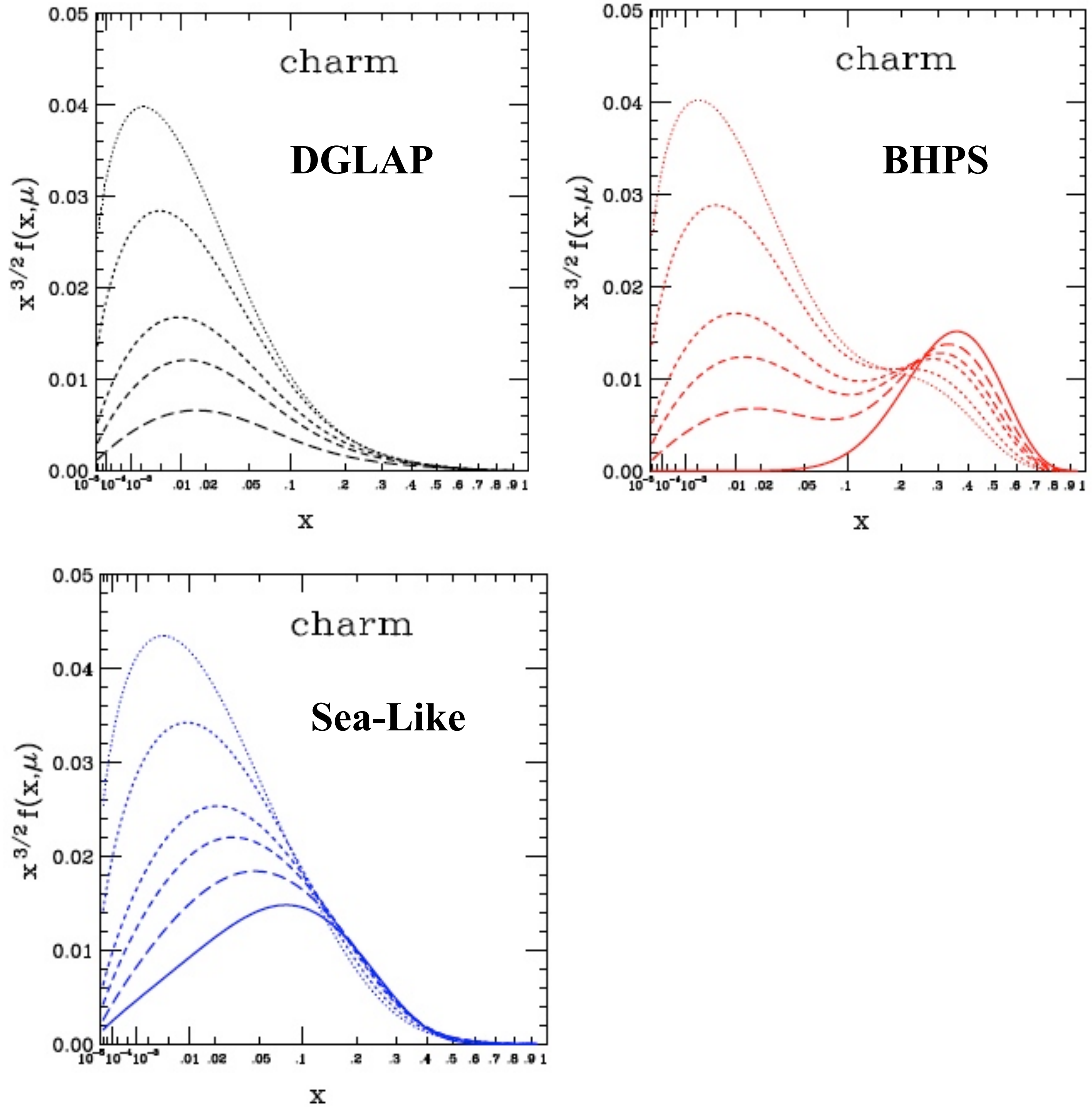


Heavy-quark distribution at large x

Pumplin et al. Phys.Rev. D75 (2007)

Intrinsic charm motivated by non perturbative models of hadron structure

All different charm pdfs (DGLAP or intrinsic charm) in agreement with DIS data



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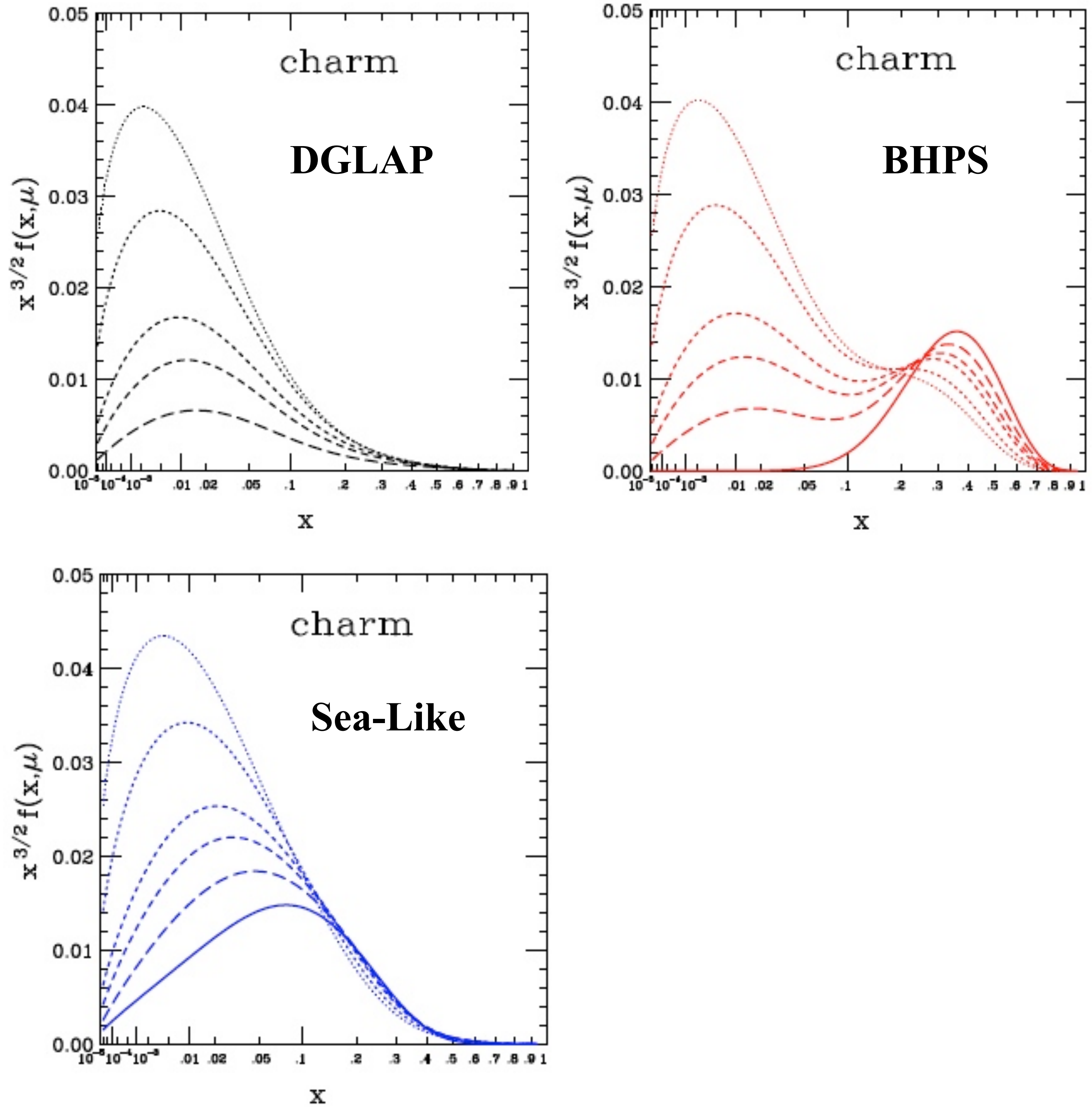
- **Experimental probes @ AFTER**
  - Open charm (D meson or displaced-vertex lepton)
  - Open beauty

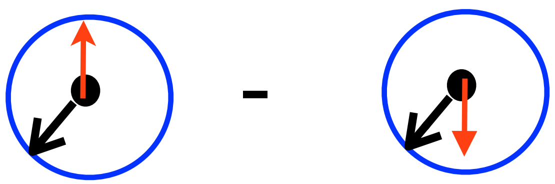
Pumplin et al. Phys.Rev. D75 (2007)



Boer-Mulders effect

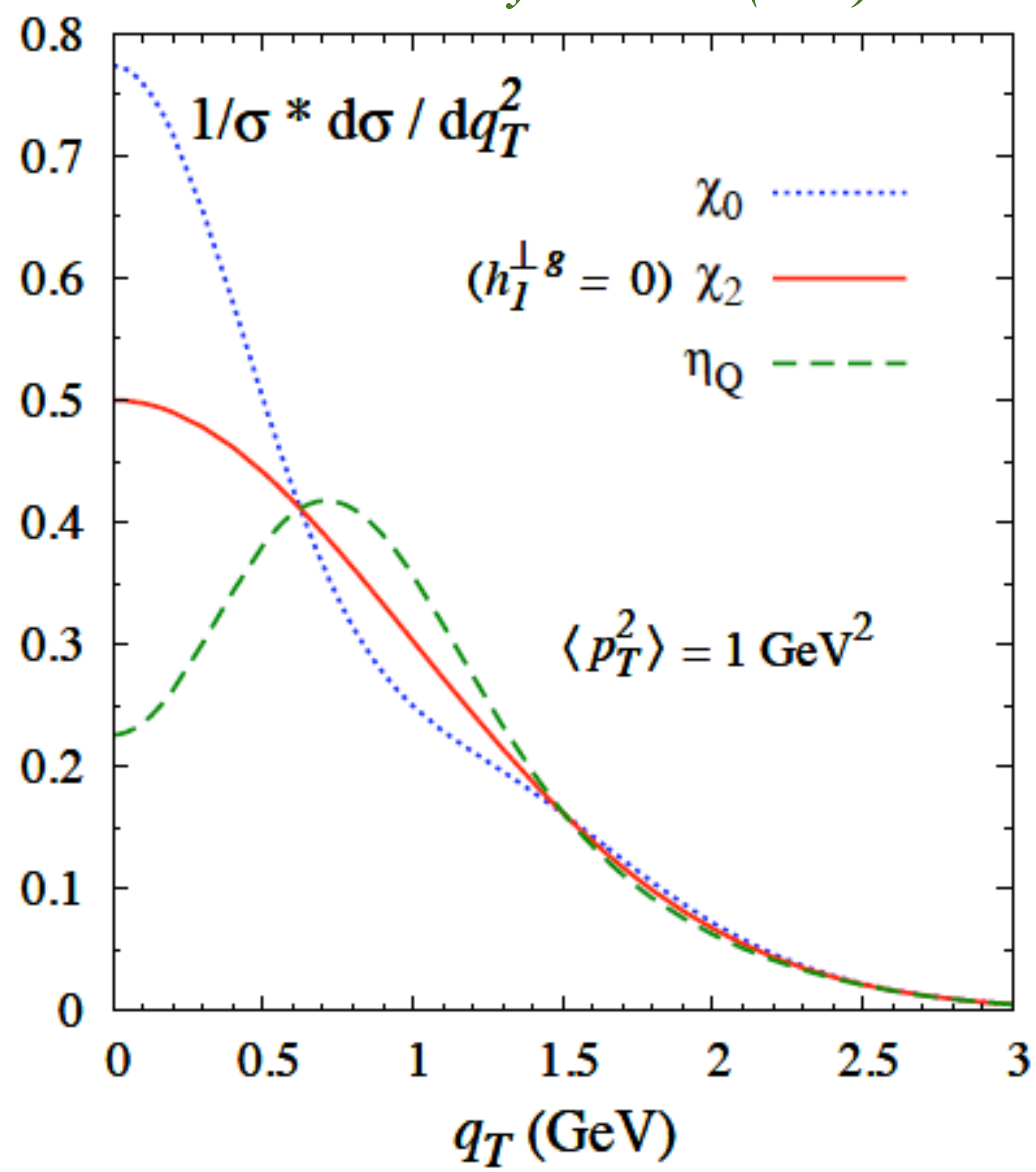
Parton distribution functions pdfs $(x, Q^2) \rightarrow (x, \mathbf{k_T}, Q^2)$: 3D or Transverse Momentum Dependent (TMD) pdfs

Boer-Mulders effect: correlation between the **parton $\mathbf{k_T}$** and **its spin** (in an unpolarized nucleon)



Double-node structure of transverse-momentum distributions predicted for scalar and pseudoscalar quarkonia → give access to the Boer-Mulders TMD pdf for gluons

Boer and Pisano Phys.Rev. D86 (2012) 094007



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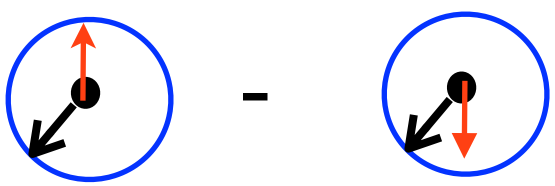

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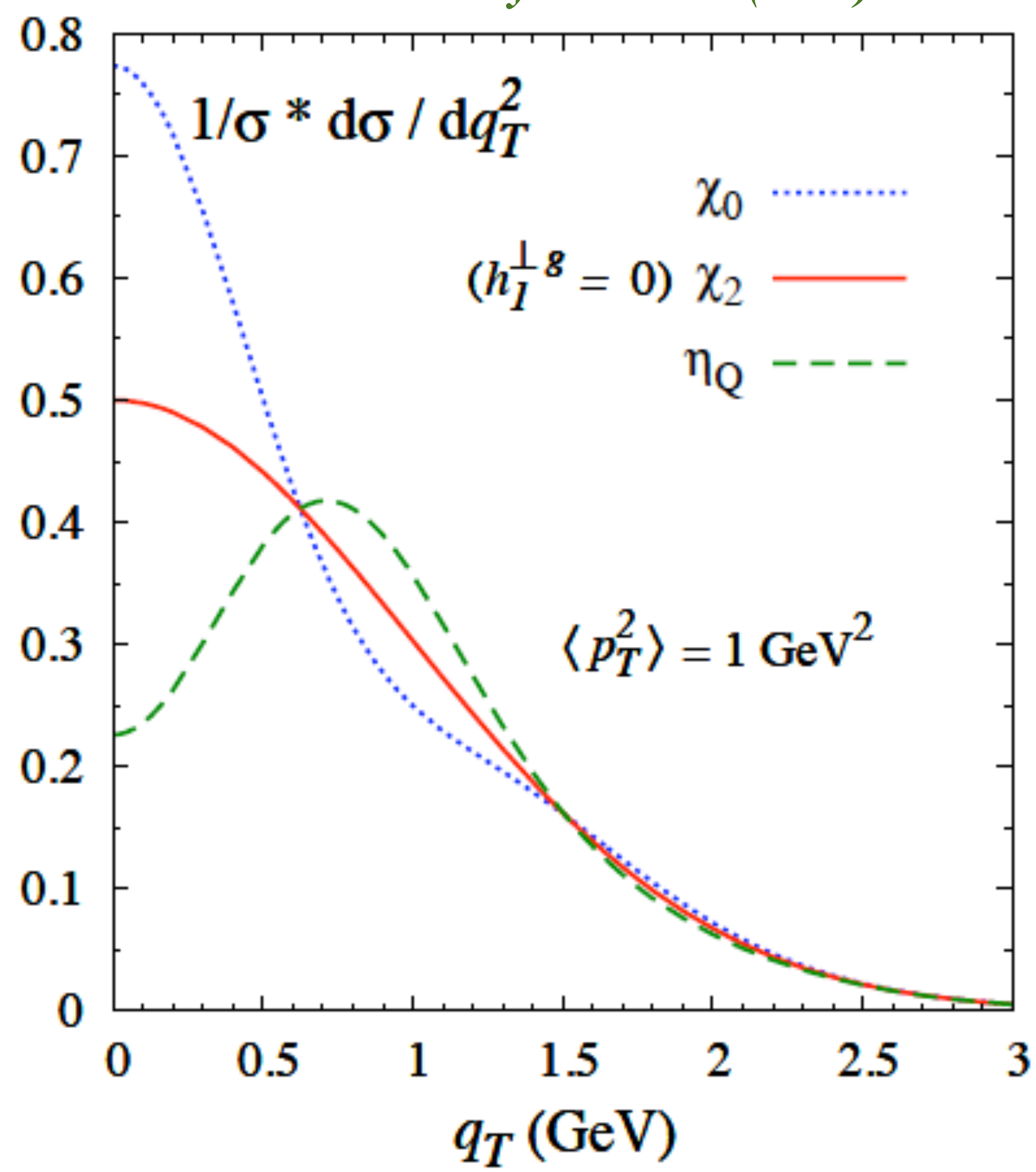
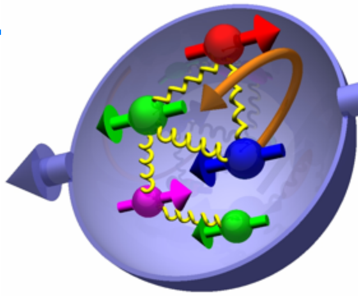
- **Experimental probes @ AFTER**
  - scalar and pseudoscalar quarkonia: χ_{c0}, χ_{b0}, η_c, η_b (PID and modern calorimetry)

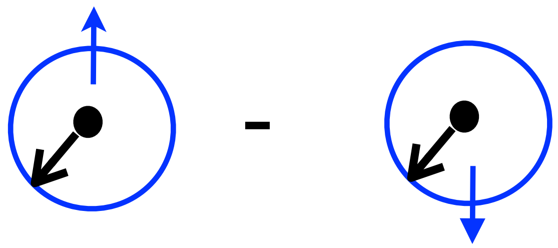
Boer and Pisano Phys.Rev. D86 (2012) 094007



Sivers effect with a transversaly polarized target



Sivers effect in a **transversaly polarized nucleon**: correlation between the **parton k_T** and the **proton spin**



Polarizing the target: measuring asymmetry to access the 3D or Transverse Momentum Dependent (TMD) pdfs.

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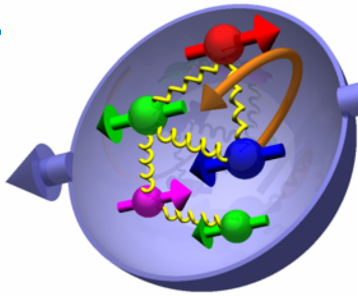

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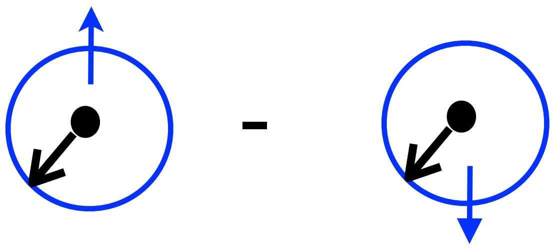

Polarizing the target: measuring asymmetry to access the 3D or Transverse Momentum Dependent (TMD) pdfs.

- **Experimental probes @ AFTER**
  - Drell-Yan → quark Sivers effect
  - Quarkonia, Open Charm and Beauty (B and D mesons), isolated γ and γ-jet → gluon Sivers effect

- **Asymmetries > 5% predicted in Drell-Yan** for the target-rapidity region ($x_F = x_{beam} - x_{target} < 0$) where the k_T-spin correlation is the largest

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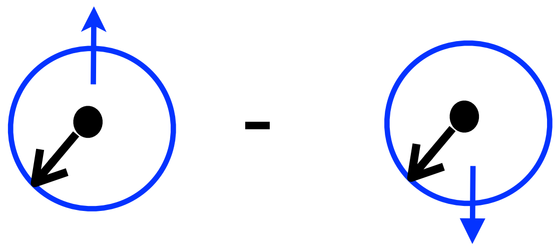

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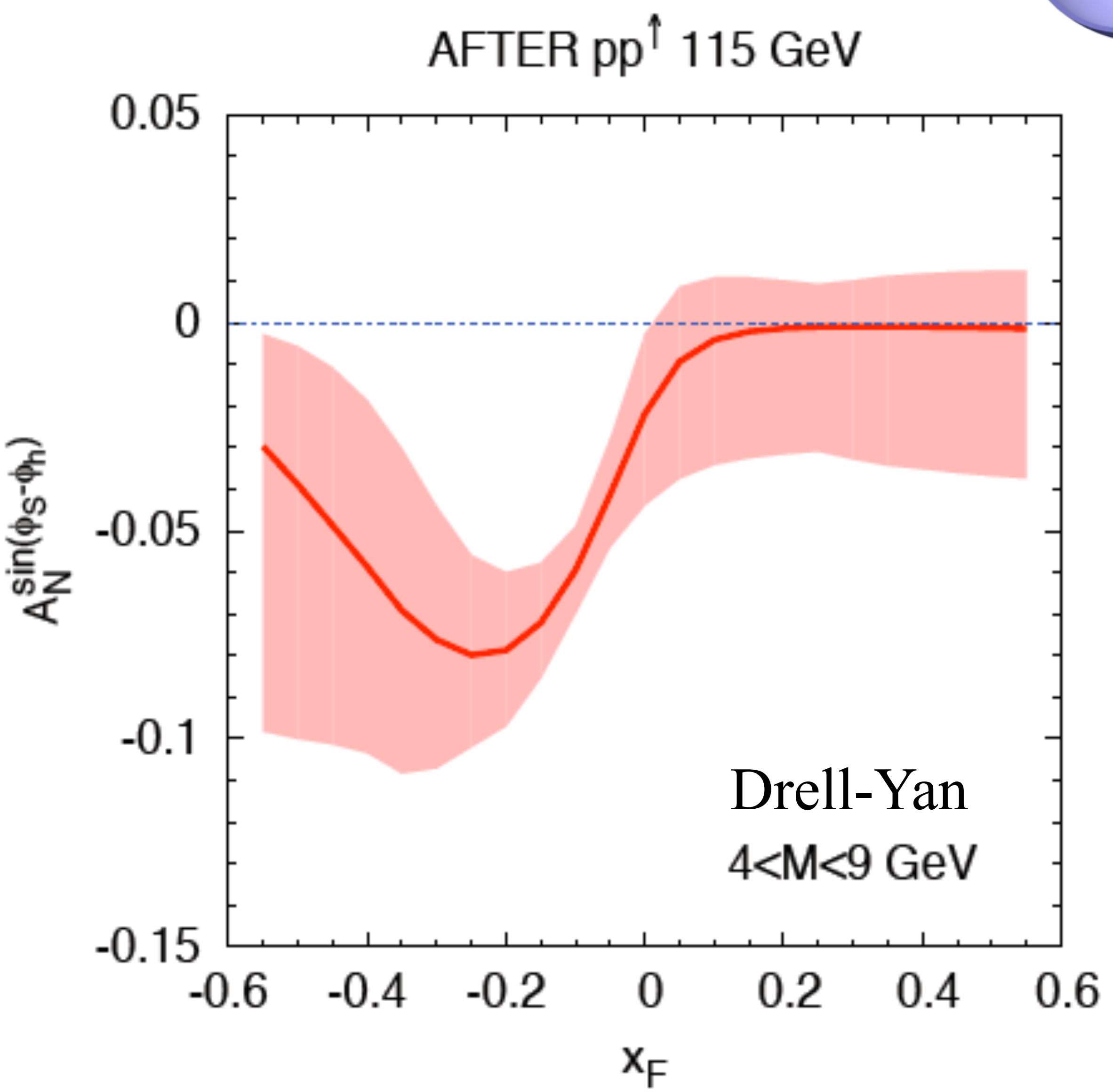
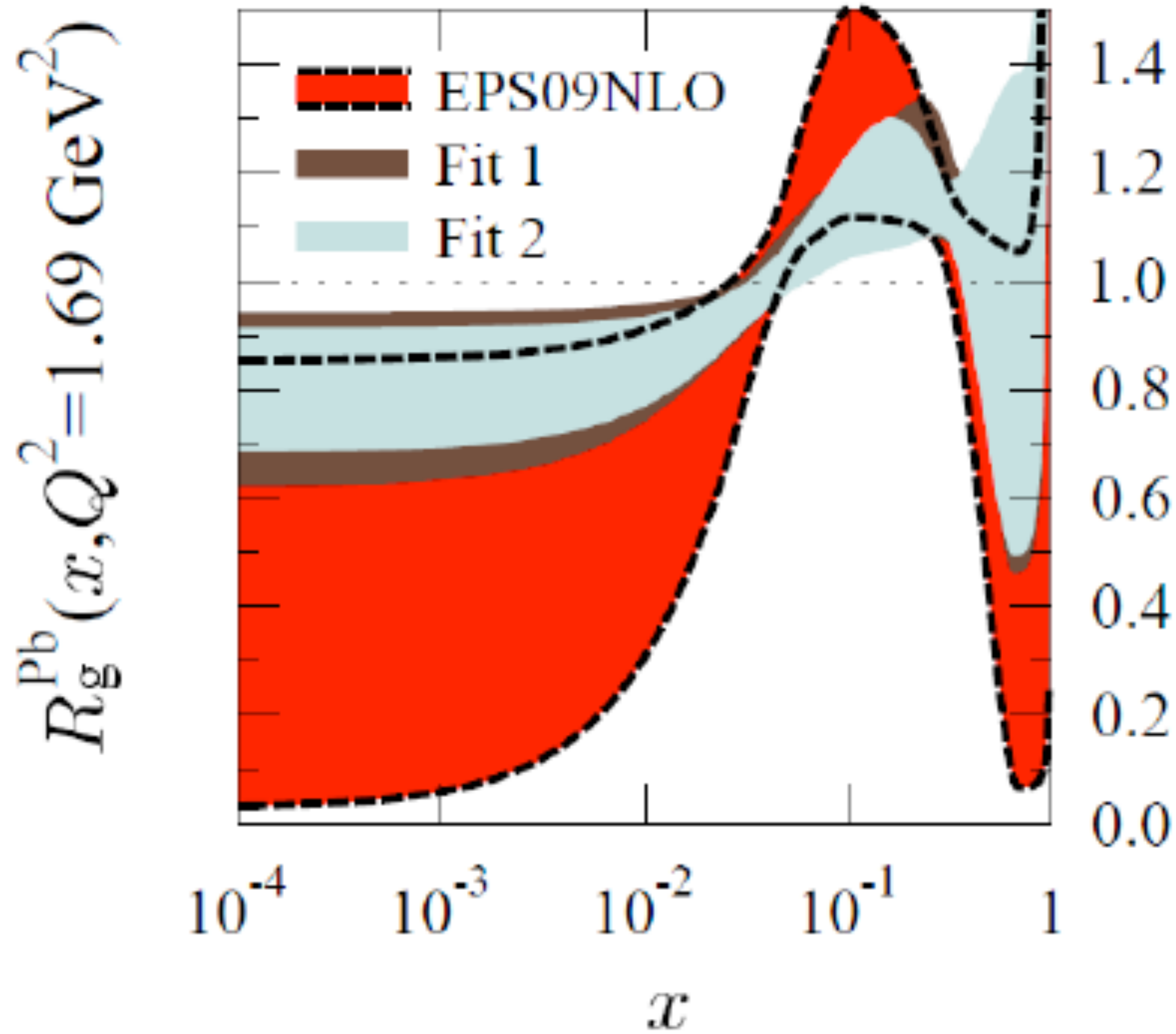
M. Anselmino Trento 2013



see also T. Liu and B.Q. Ma Eur.Phys.J. C72 (2012) 2037

Gluon distribution in nucleus at large x

LHeC CDR J. Phys. G 39 (2012) 075001



Large uncertainty in nuclei at large x

- **Experimental probes @ AFTER**
  – Quarkonia
  – Isolated photons
  – High p_T jets ($p_T > 20$ GeV/c)
  → to access target $x_g = 0.3 - 1$ (>1 Fermi motion in nucleus)

- **Target versatility**
  – Probing the A-dependence of shadowing and nuclear matter effects

W, Z production in the threshold region

With high luminosity fixed-target experiment, W and Z production accessible

Unique opportunity to study the W and Z production near threshold @ AFTER

Very large *x* partons in the nucleon/nucleus target probed

Large NLO and NNLO corrections: QCD laboratory near threshold at large scale

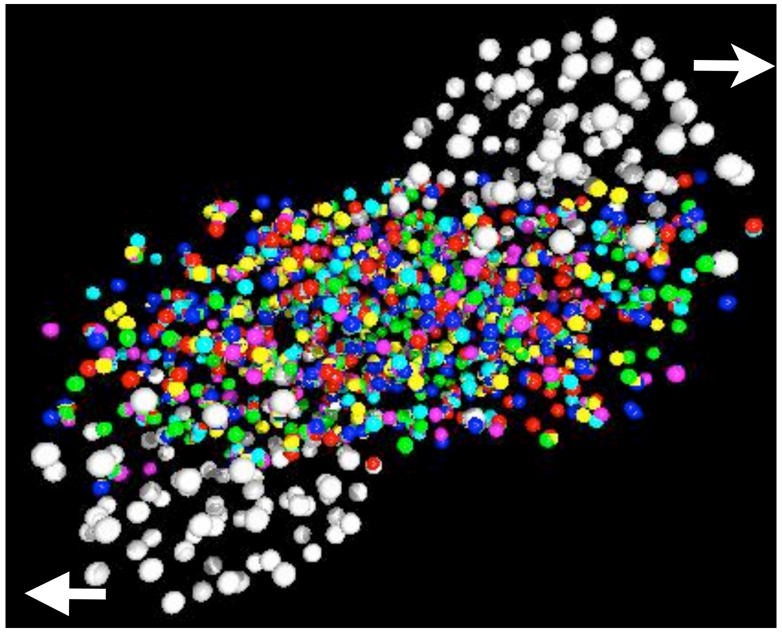
If W'/Z' exists, similar threshold corrections than W and Z

Quark Gluon Plasma

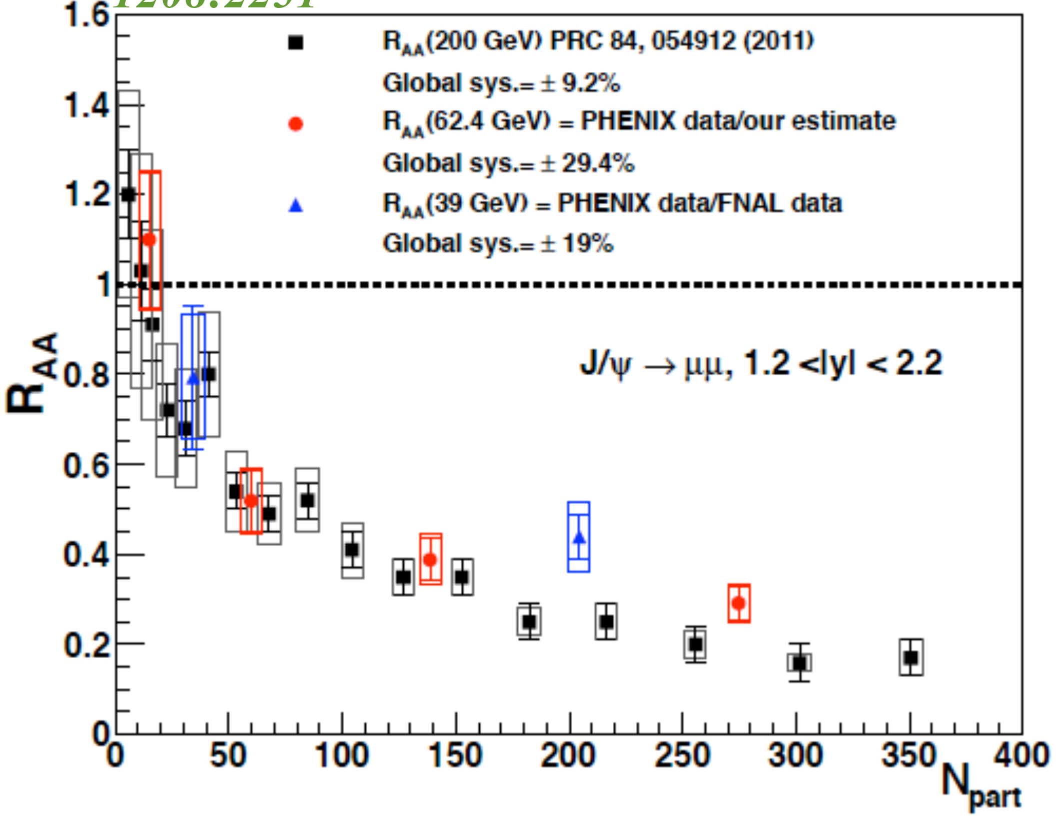
In nucleus-nucleus collisions at high ultra-relativistic energy → Quark Gluon Plasma (QGP) formation

RHIC energy scan shows suppression of particles at $\sqrt{s_{NN}}$ = 39, 62, 200 GeV (π^0, J/Ψ, ...) but low statistics for $\sqrt{s_{NN}}$ < 200 GeV and scarse / no pp and pA reference

Cold Nuclear Matter (i.e not Hot from QGP) measured in pA



PHENIX, Phys.Rev. C86 (2012) 064901, arXiv 1208:2251



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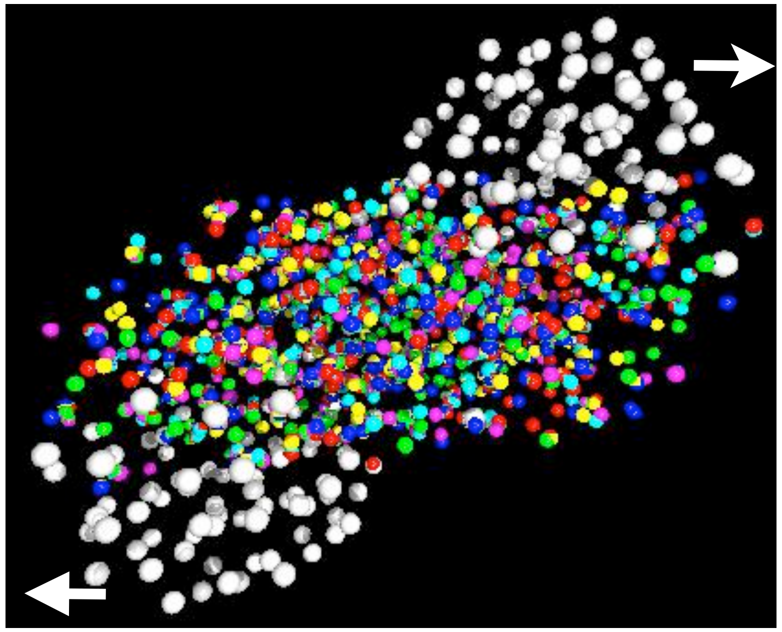
Cold Nuclear Matter (i.e not Hot from QGP) measured in pA

- **Experimental probes @ AFTER $\sqrt{s}$ = 72 GeV**
  - Quarkonia
  - Jets
  - Low mass lepton pairs
  - ...
- **Target versatility**
  - In PbA, different nuclei: A-dependent studies
  - In pA, precise estimate of Cold Nuclear effects



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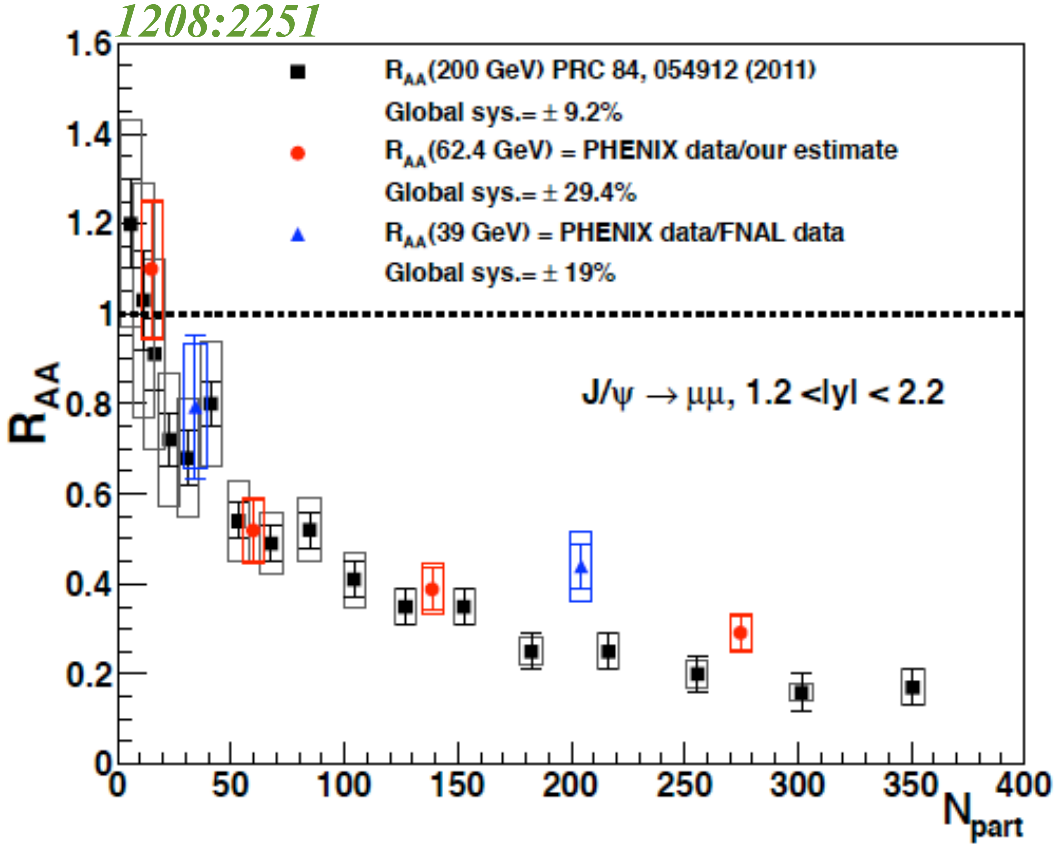
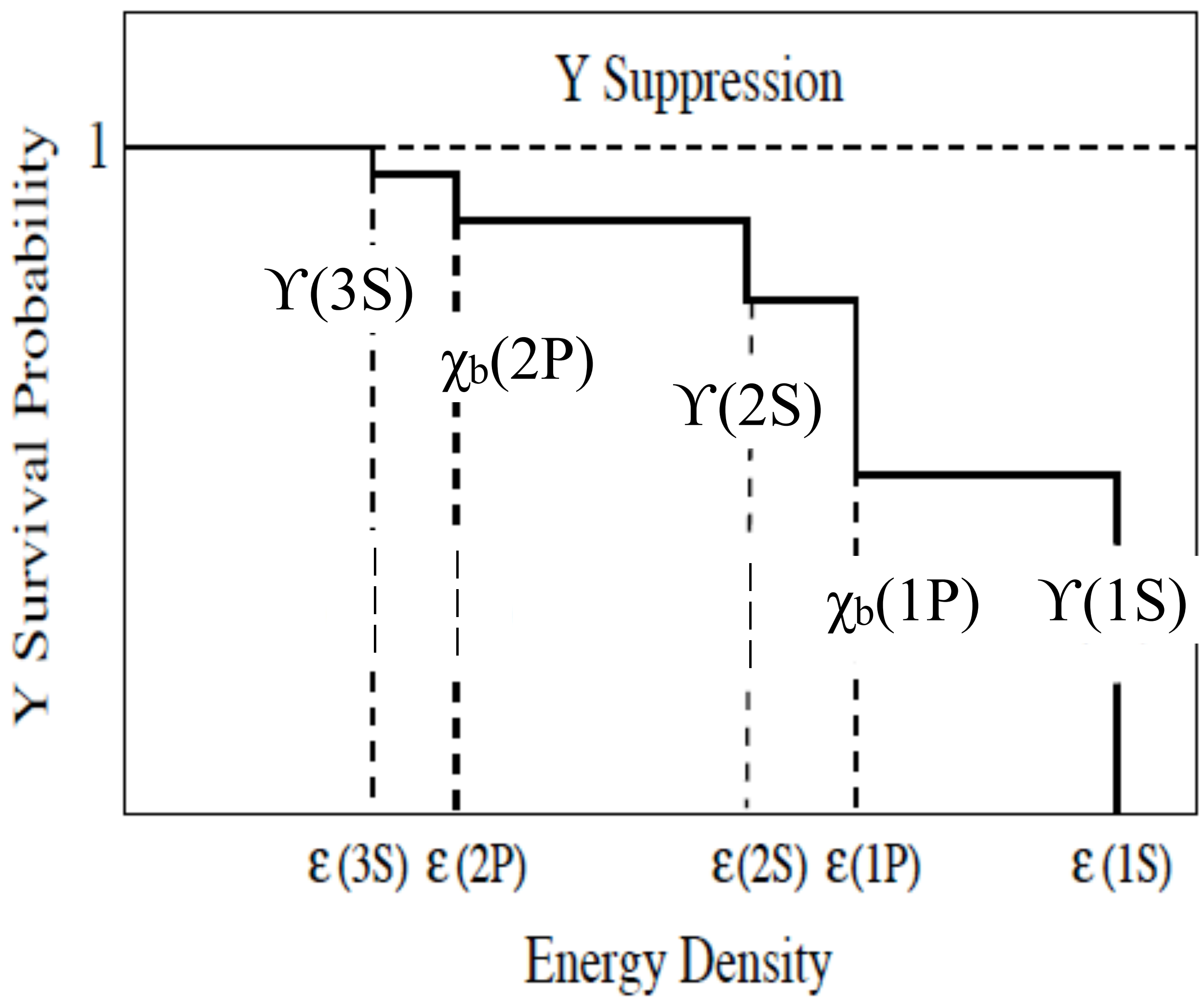
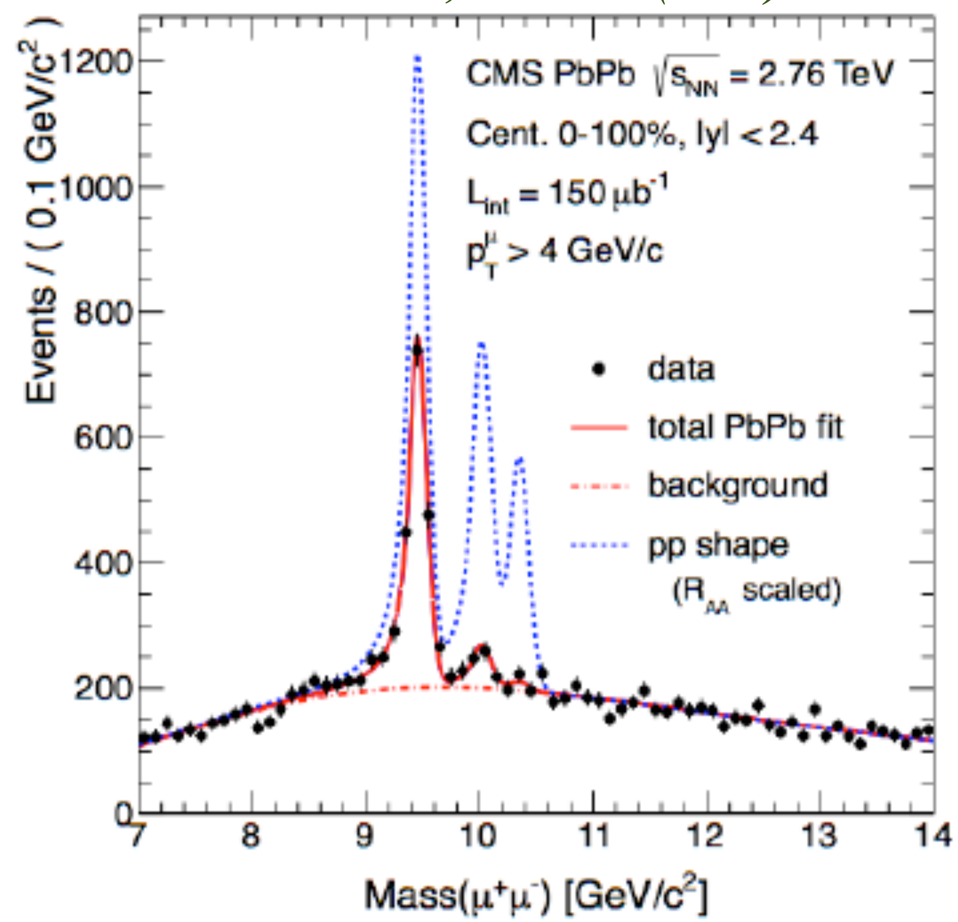


Υ sequential melting in QGP



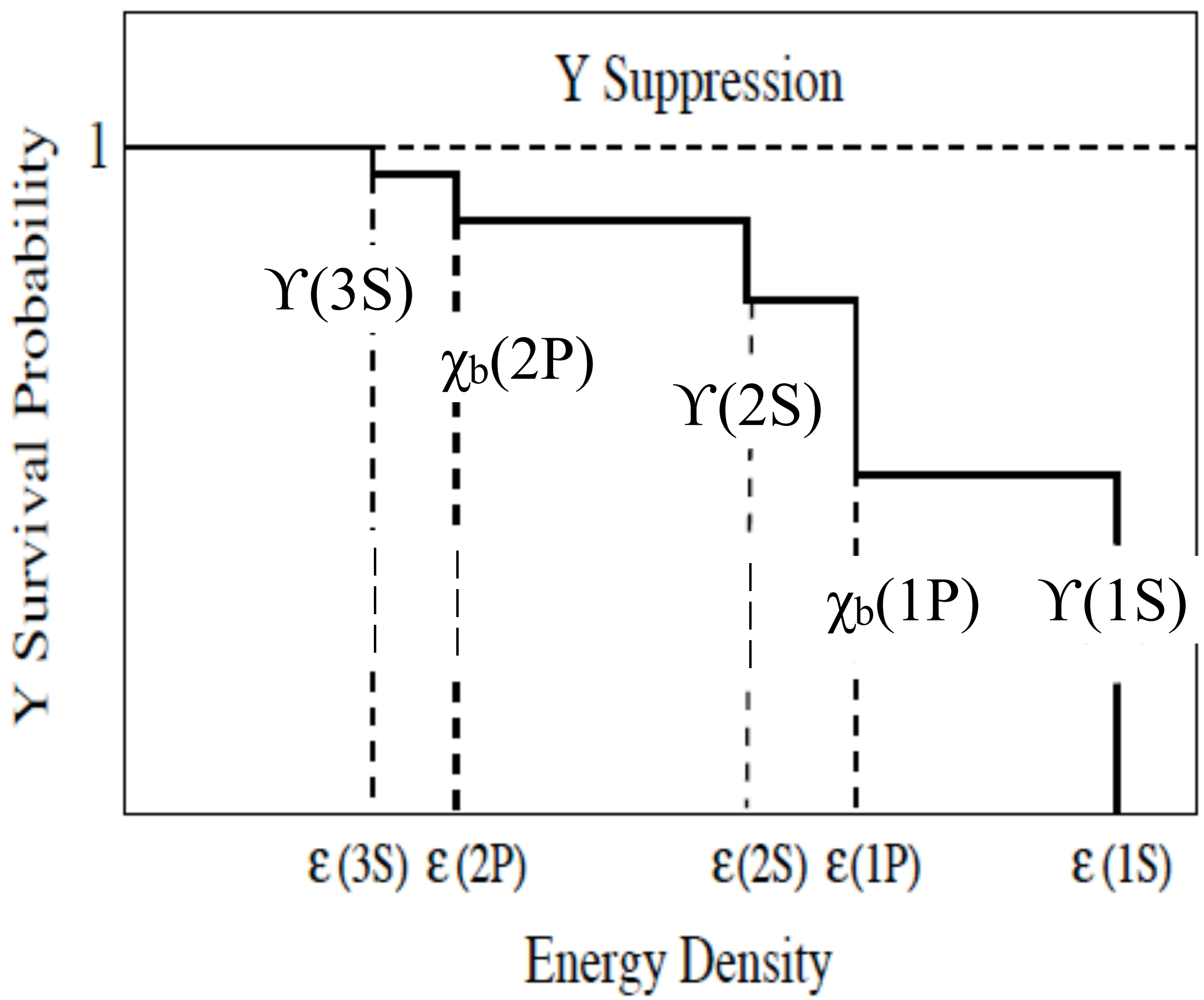
CMS, PRL 109 (2012) 222301



Bottomonium family: five states, detection of the three Υ states separately (good resolution needed) to probe the bottomonium sequential suppression

See Jean-Philippe's talk on friday

ϒ sequential melting in QGP



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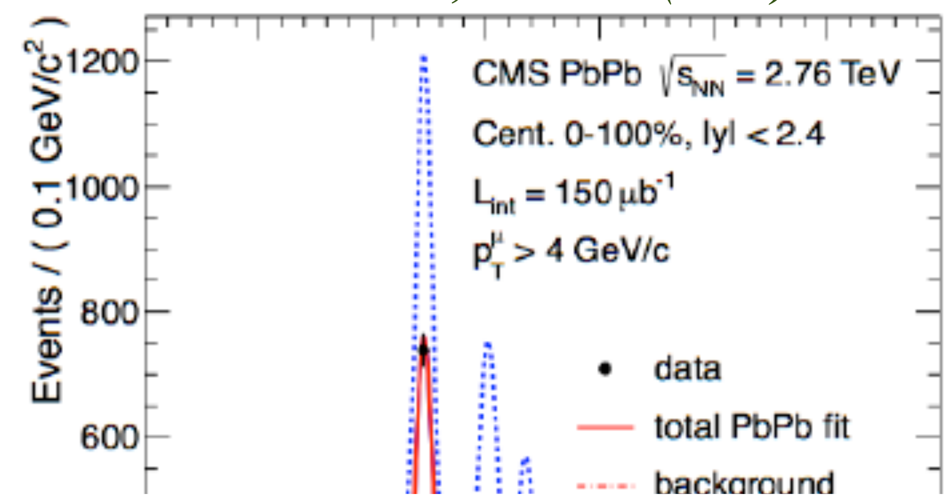
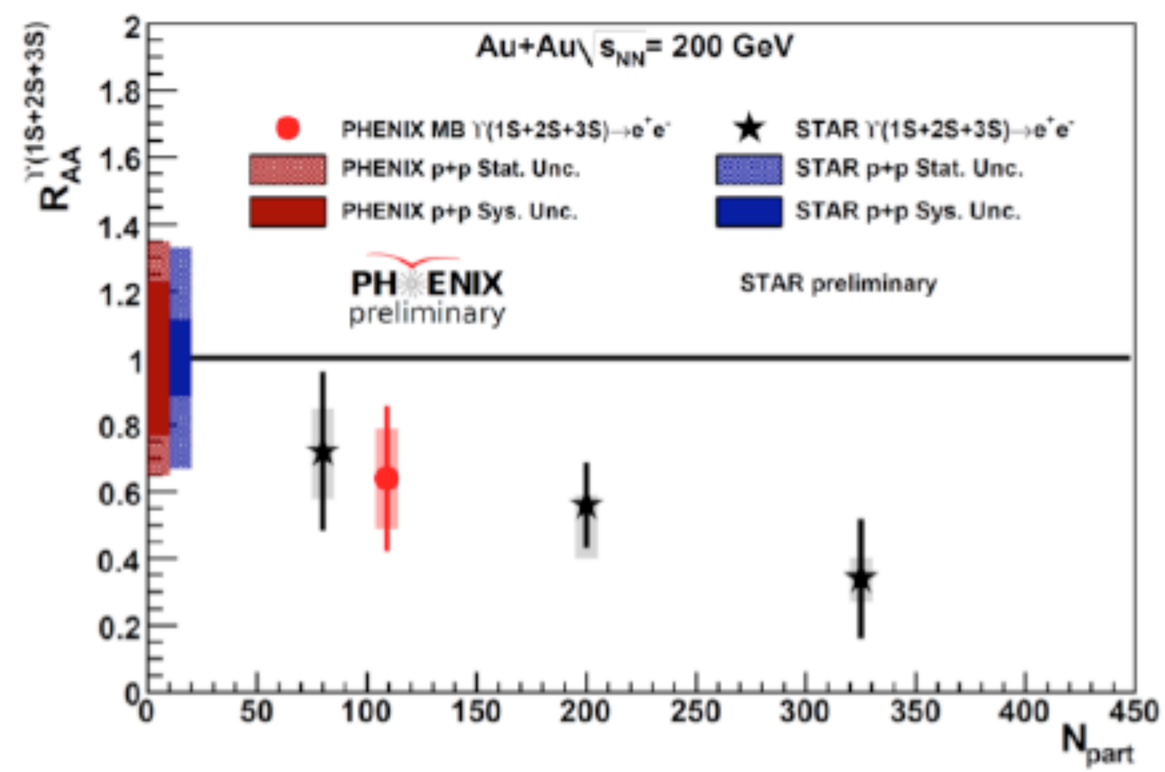


RHIC, QM 2012



Bottomonium family: five states, detection of the three ϒ states separately (good resolution needed) to probe the bottomonium sequential suppression

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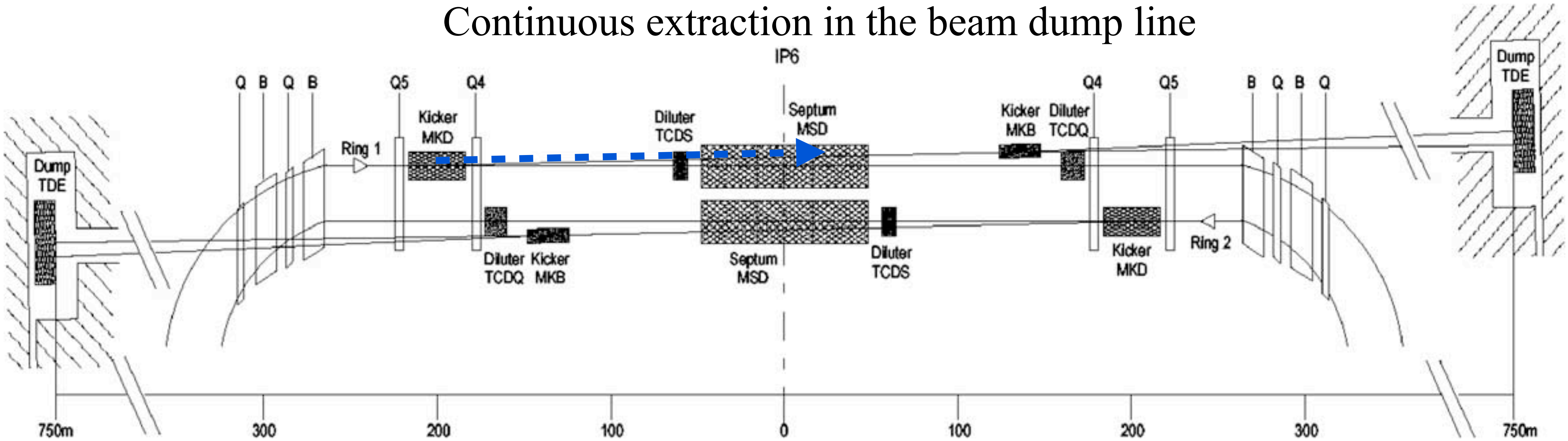
Luminosities in pH, pA, PbH and PbA

A possibility for proton and lead beam extraction at the LHC

E. Uggerhoj and U.I Uggerhoj NIMB 234 (2005) 34

Continuous extraction in the beam dump line



- Proposal for the insertion of a bent crystal in the LHC beam
- Bent, single crystal of Si or Ge - 17cm long crystal
- MKD kicker section at ~200 m from IP6
- Deflection angle = 0.257 mrad (~7 T.m equivalent magnet)
- Distance of 7 σ to the beam to intercept and deflect the beam halo
- No loss in the LHC beam
- Bent crystal acts as a beam collimator

- Proton beam extraction
- Single- or multi pass extraction efficiency of 50%
  - $N_{\text{beam loss LHC}} \sim 10^9$ p/s → $N_{\text{extracted beam}} = 5\ 10^8$ p/s
- Extremely small emittance: beam size in the extraction direction) 950 m after the extraction ~ 0.3 mm

- Ion beam extraction
- Ions extraction tested at SPS, is expected to be also possible at LHC but needs more study
- May require bent diamonds (highly resistant to radiations)

P. Ballin et al, NIMB 267 (2009) 2952

See Andry's talk

Luminosities in pH and pA @ 115 GeV

- **Intensity: N_{beam} = 5.10^8 protons.s^{-1}**
  - Beam: 2808 bunches of 1.15x10^{11} p = 3.2x10^{14} p
  - Bunch: Each bunch passes IP at the rate: ~11 kHz
  - Instantaneous extraction: IP sees 2808 x 11000~3.10^7 bunches passing every second → extract ~16 protons in each bunch at each pass
  - Integrated extraction: Over a 10h run: extract ~5.6% of the protons stored in the beam

- **Instantaneous Luminosity**

  $L = N_{beam} \times N_{Target} = N_{beam} \times (\rho \times \mathbf{e} \times N_A)/A$
  - N_{beam}=5 x 10^8 p$^+$/s
  - **e** (target thickness) = 1 cm
- **Integrated luminosity**
  - 9 months running/year
  - 1 year ~ 10^7 s

Target (1 cm thick)	ρ (g cm^{-3})	A	$\mathcal{L}$ (μb^{-1} s^{-1})	$\int\mathcal{L}$ (pb^{-1} yr^{-1})
solid H	0.088	1	26	260
liquid H	0.068	1	20	200
liquid D	0.16	2	24	240
Be	1.85	9	62	620
Cu	8.96	64	42	420
W	19.1	185	31	310
Pb	11.35	207	16	160

⇒ Large luminosity in pH(A) ranging from 0.1 and 0.6 fb^{-1} for a 1 cm thick target

⇒ Larger luminosity with 50 cm or 1 m H2 or D2 target

Luminosities in PbA @ 72 GeV

- **Intensity: $N_{beam} = 2.10^5$ Pb.s^{-1}**
- – Beam: 592 bunches of 7×10^7 ions = 4.1×10^{10} ions
- – Bunch: Each bunch passes IP at the rate ~ 11 kHz
- – Instantaneous extraction: IP sees 592 x 11000~$6.5.10^6$ bunches passing every second → extract ~0.03 ions in each bunch at each pass
- – Integrated extraction: Over a 10h run: extract ~15% of the ions stored in the beam

- **Instantaneous Luminosity**

$$L = N_{beam} \times N_{Target} = N_{beam} \times (\rho \times e \times N_A)/A$$

- – N_{beam}=2 x 10^5 Pb/s
- – **e** (target thickness) = 1 cm

- **Integrated luminosity**
- – 1 months running/year
- – 1 year ~ 10^6 s

Target (1 cm thick)	ρ (g cm^{-3})	A	$\mathcal{L}$ (mb^{-1} s^{-1})	$\int \mathcal{L}$ (nb^{-1} yr^{-1})
solid H	0.088	1	11	11
liquid H	0.068	1	8	8
liquid D	0.16	2	10	10
Be	1.85	9	25	25
Cu	8.96	64	17	17
W	19.1	185	13	13
Pb	11.35	207	7	7

⇒ AFTER provides a good luminosity to study QGP related measurements

Polarizing the hydrogen target

- **Instantaneous Luminosity**

  $L = N_{beam} \times N_{Target} = N_{beam} \times (\rho \times e \times N_A)/A$

  – N_{beam}=5 x 10^8 p^+/s

  – **e** (target thickness) = 50 cm

$x_p{\uparrow}$ range corresponds to Drell-Yan measurements

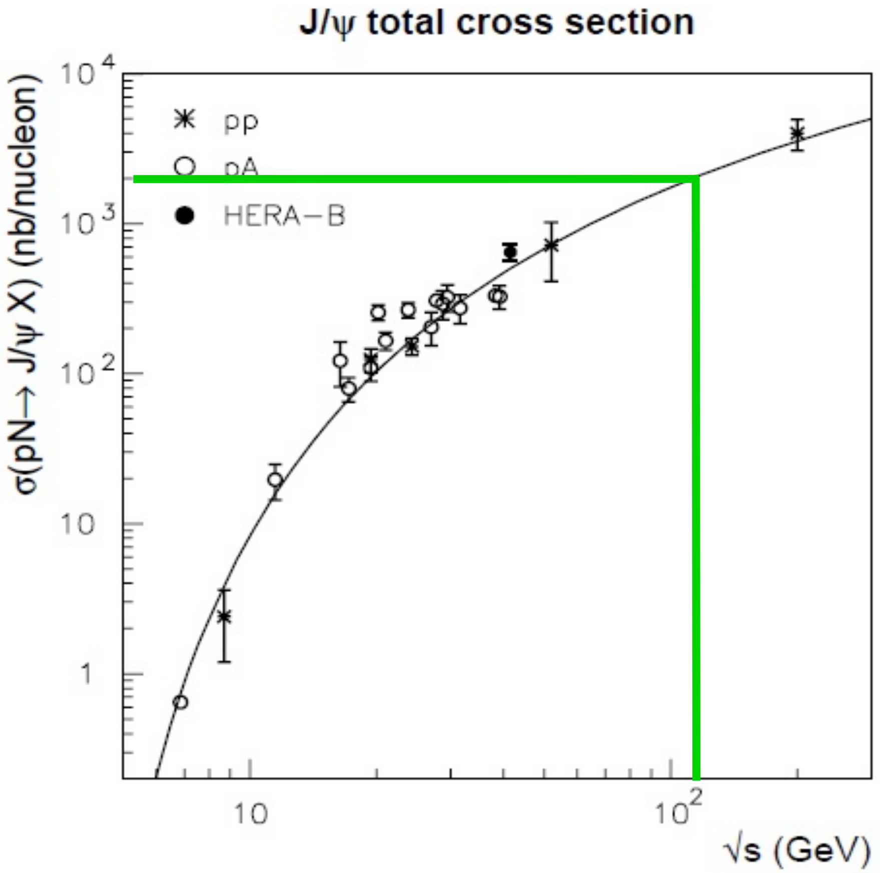
Experiment	particles	energy (GeV)	$\sqrt{s}$ (GeV)	$x_p^{\uparrow}$	$\mathcal{L}$ ($nb^{-1}s^{-1}$)
AFTER	$p+p^{\uparrow}$	7000	115	$0.01 \div 0.9$	1
COMPASS	$\pi^{\pm}+p^{\uparrow}$	160	17.4	$0.2 \div 0.3$	2
COMPASS (low mass)	$\pi^{\pm}+p^{\uparrow}$	160	17.4	~ 0.05	2
RHIC	$p^{\uparrow}+p$	collider	500	$0.05 \div 0.1$	0.2
J–PARC	$p^{\uparrow}+p$	50	10	$0.5 \div 0.9$	1000
PANDA (low mass)	$\bar{p}+p^{\uparrow}$	15	5.5	$0.2 \div 0.4$	0.2
PAX	$p^{\uparrow}+\bar{p}$	collider	14	$0.1 \div 0.9$	0.002
NICA	$p^{\uparrow}+p$	collider	20	$0.1 \div 0.8$	0.001
RHIC Int.Target 1	$p^{\uparrow}+p$	250	22	$0.2 \div 0.5$	2
RHIC Int.Target 2	$p^{\uparrow}+p$	250	22	$0.2 \div 0.5$	60

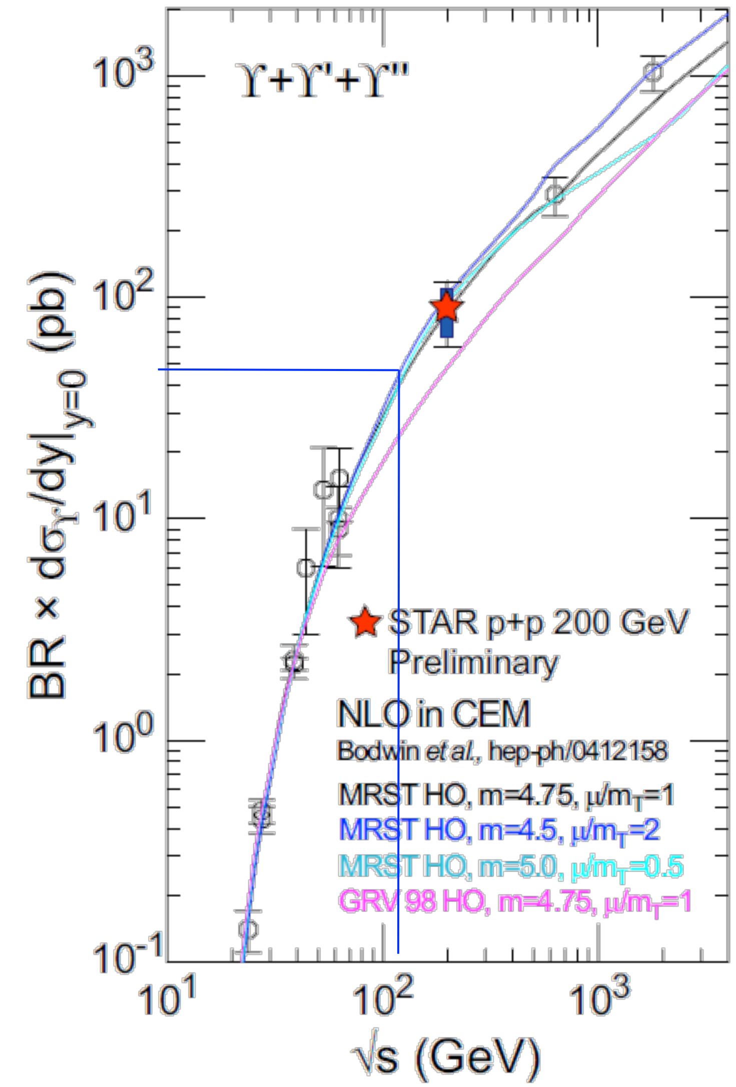
⇒ AFTER provides a good luminosity to study target spin related measurements

⇒ Complementary x_p range with other spin physics experiments

Quarkonium case: annual yields

Quarkonium cross-sections at AFTER energy





Inclusive pp cross-sections

B_{ll} dσ/dy$|_{y=0}$ @ 115 GeV

J/ψ = 20 nb

Y = 40 pb

Inclusive pp cross-sections

B_{ll} dσ/dy$|_{y=0}$ @ 72 GeV

J/ψ = 10 nb

Y = 15 pb

Quarkonium yields in pH and pA @ 115 GeV

In pp

⇒ RHIC @ 200 GeV x 100 with 10 cm thick H target
⇒ Comparable to LHCb if 1m H target
⇒ Detailed studies of quarkonium production (p_T, y, polarization, different quarkonium states, ...)

In pA

⇒ RHIC @ 200 GeV x 100 with 1 cm Pb target
⇒ Detailed studies of cold nuclear matter effect in pA (p_T, y, A, ...)

Geometrical Acceptance

Simulations using ALICE as a fixed target experiment at LHC quotes a Geometrical Acceptance of 8% for J/ψ (4 π) → $\mu^+\mu^-$ (2.5< y < 4) using the Forward Muon Spectrometer @ 115 GeV

Kurepin et al. Phys.Atom.Nucl. 74 (2011)

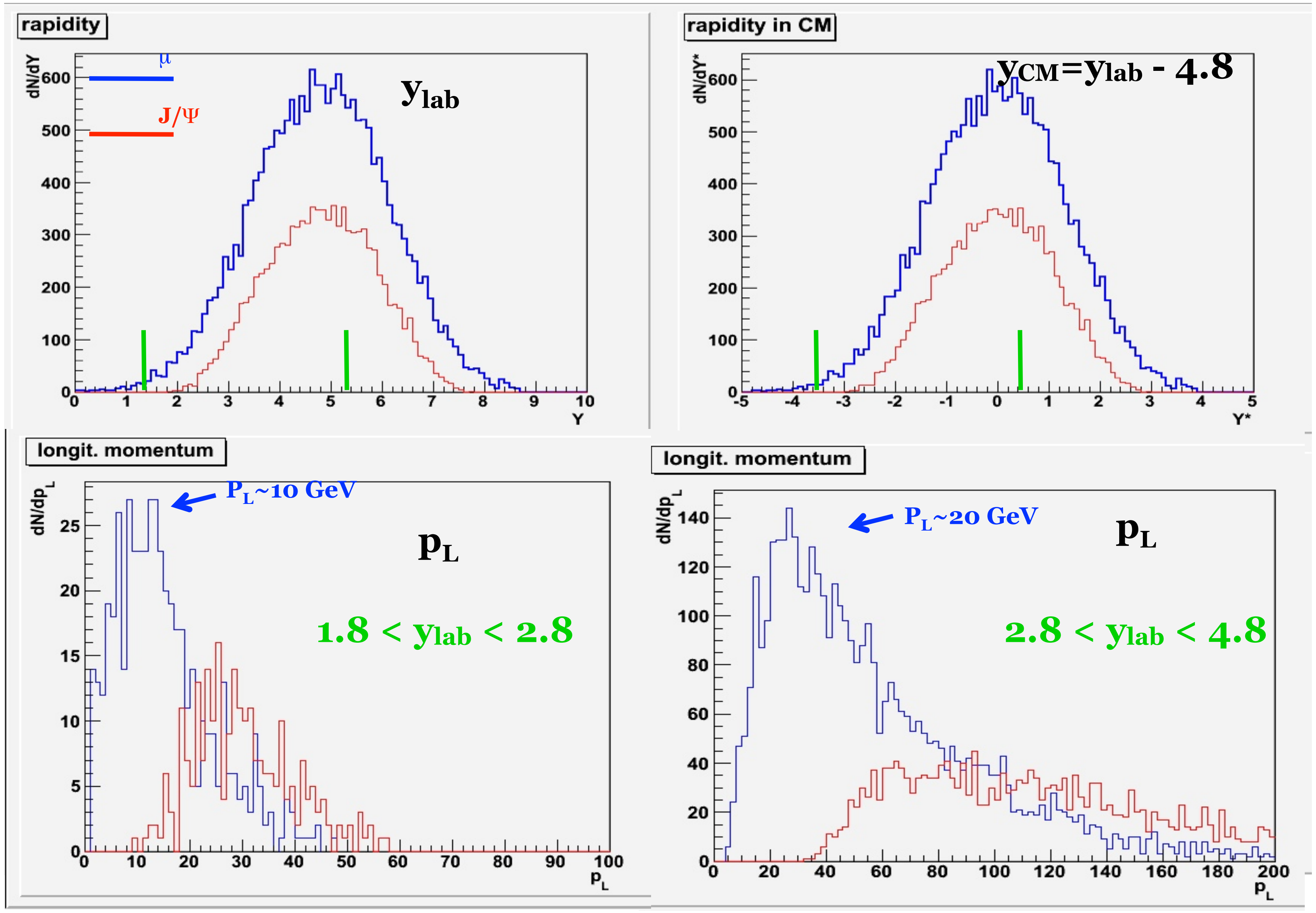
Target	$\int dt\mathcal{L}$	$\mathcal{B}_{\ell\ell}\frac{dN_{J/\psi}}{dy}\Big\|_{y=0}$	$\mathcal{B}_{\ell\ell}\frac{dN_{\Upsilon}}{dy}\Big\|_{y=0}$
10 cm solid H	2.6	$5.2\ 10^7$	$1.0\ 10^5$
10 cm liquid H	2	$4.0\ 10^7$	$8.0\ 10^4$
10 cm liquid D	2.4	$9.6\ 10^7$	$1.9\ 10^5$
1 cm Be	0.62	$1.1\ 10^8$	$2.2\ 10^5$
1 cm Cu	0.42	$5.3\ 10^8$	$1.1\ 10^6$
1 cm W	0.31	$1.1\ 10^9$	$2.3\ 10^6$
1 cm Pb	0.16	$6.7\ 10^8$	$1.3\ 10^6$
pp low P_T LHC (14 TeV)	0.05	$3.6\ 10^7$	$1.8\ 10^5$
	2	$1.4\ 10^9$	$7.2\ 10^6$
pPb LHC (8.8 TeV)	10^{-4}	$1.0\ 10^7$	$7.5\ 10^4$
pp RHIC (200 GeV)	$1.2\ 10^{-2}$	$4.8\ 10^5$	$1.2\ 10^3$
*d*Au RHIC (200 GeV)	$1.5\ 10^{-4}$	$2.4\ 10^6$	$5.9\ 10^3$
*d*Au RHIC (62 GeV)	$3.8\ 10^{-6}$	$1.2\ 10^4$	$1.8\ 10^1$

Luminosity per year in fb^{-1}

Quarkonium distributions in pp @ 115 GeV

Pythia 6.4.21: p (7 TeV) + p ⟶ J/ψ (isub=86)
J/Ψ ⟶ $\mu^+\mu^-$

μ from J/ψ for $1.3 < y_{lab} < 5.3$
$P_T \sim$ 1.7 GeV
$P_L \sim$ 62 GeV



Longitudinal muon momentum
$1.3 < y_{lab} < 3.3$
p_L (max) ~ 16 (50) GeV
$3.3 < y_{lab} < 4.3$
p_L (max)~ 45 (150) GeV
$4.3 < y_{lab} < 5.3$
p_L (max)~ 120 (300) GeV

Accessing the large x gluon pdf

PYTHIA simulation
σ(y) / σ(y=0.4)
statistics for one month
5% acceptance considered

Statistical relative uncertainty
Large statistics allow to access very backward region

Gluon uncertainty from MSTWPDF
- only for the gluon content of the target
- assuming

$$x_g = M_{J/\Psi}/\sqrt{s}\, e^{-y_{CM}}$$

J/Ψ

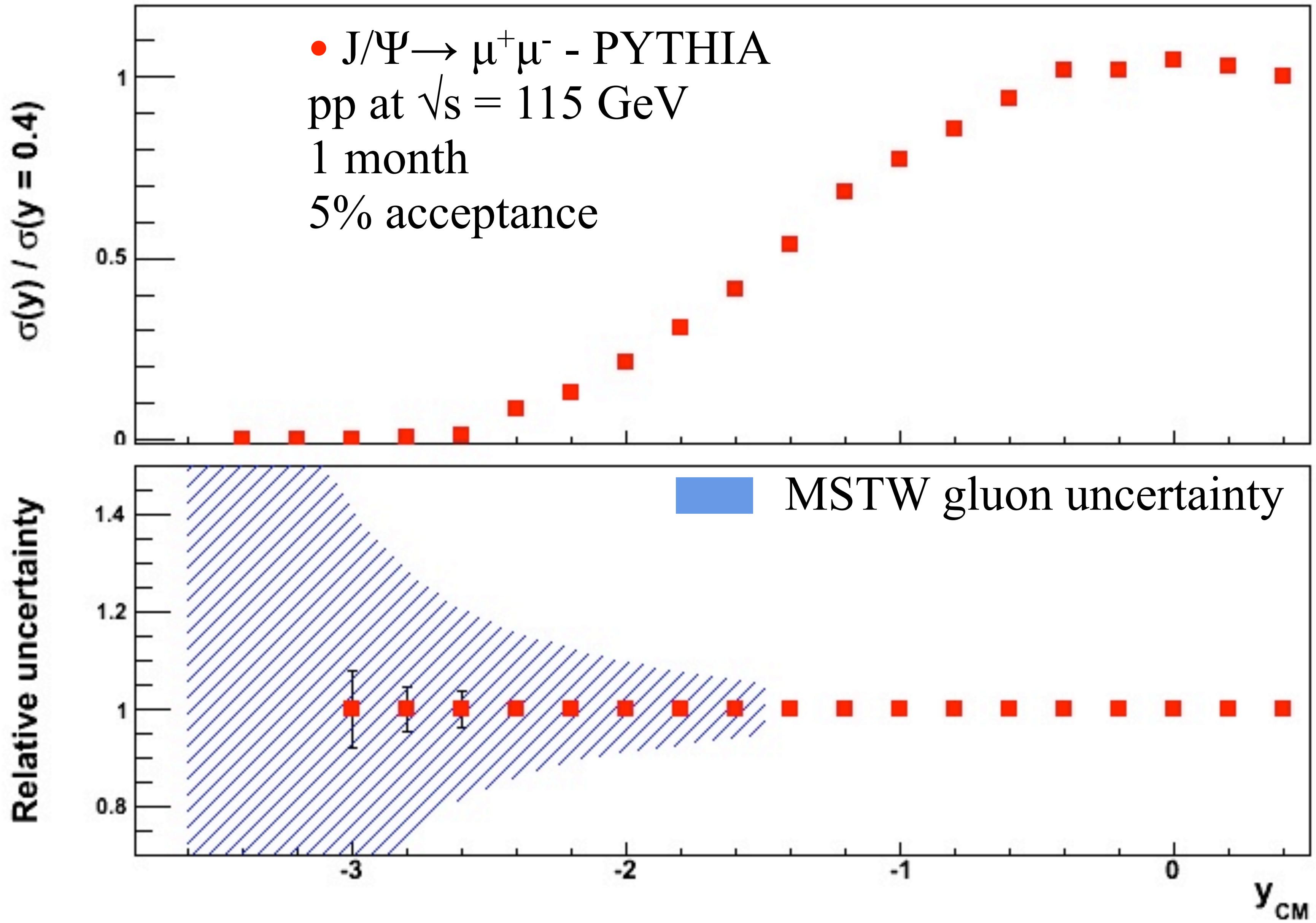
$y_{CM} \sim 0 \rightarrow x_g = 0.03$

$y_{CM} \sim -3.6 \rightarrow x_g = 1$

Υ: larger x_g for same y_{CM}

$y_{CM} \sim 0 \rightarrow x_g = 0.08$

$y_{CM} \sim -2.4 \rightarrow x_g = 1$



⇒ Backward measurements allow to access large x gluon pdf

Simulations needed !

Quarkonium yields in PbA @ 72 GeV

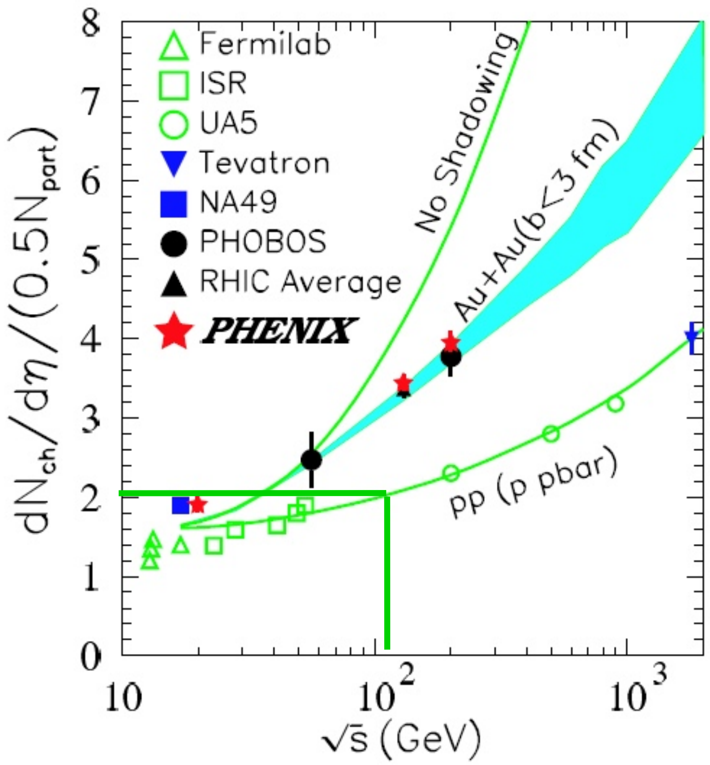
PbA
⇒ Same statistics than RHIC @ 200 GeV and LHC and 2 orders of magnitude larger than RHIC @ 62 GeV

⇒ Detailed studies possible for quarkonium states (ψ', χ_c, A-dependence, ...)

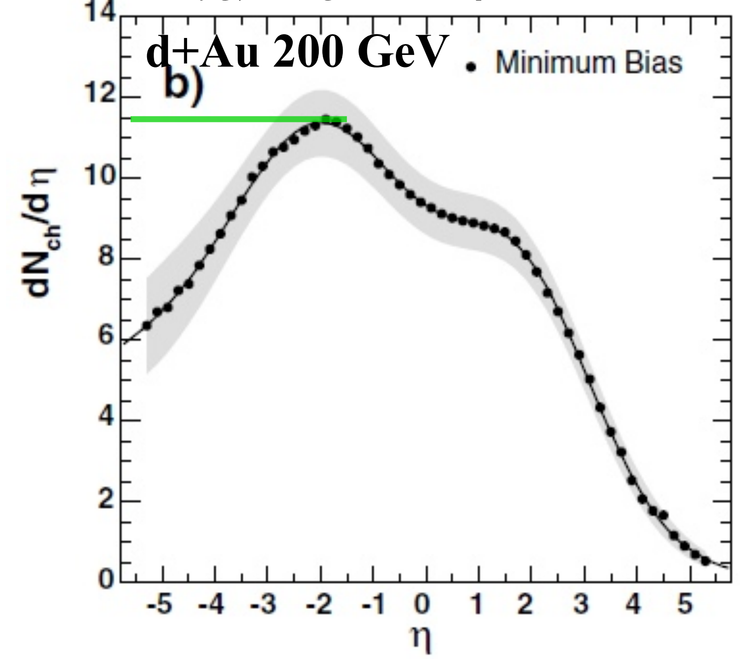
Target	$\int dt\mathcal{L}$	$\mathcal{B}_{\ell\ell}\frac{dN_{J/\psi}}{dy}\Big\|_{y=0}$	$\mathcal{B}_{\ell\ell}\frac{dN_{\Upsilon}}{dy}\Big\|_{y=0}$
10 cm solid H	110	4.3 10^5	8.9 10^2
10 cm liquid H	83	3.4 10^5	6.9 10^2
10 cm liquid D	100	8.0 10^5	1.6 10^3
1 cm Be	25	9.1 10^5	1.9 10^3
1 cm Cu	17	4.3 10^6	0.9 10^3
1 cm W	13	9.7 10^6	1.9 10^4
1 cm Pb	7	5.7 10^6	1.1 10^4
*d*Au RHIC (200 GeV)	150	2.4 10^6	5.9 10^3
*d*Au RHIC (62 GeV)	3.8	1.2 10^4	1.8 10^1
AuAu RHIC (200 GeV)	2.8	4.4 10^6	1.1 10^4
AuAu RHIC (62 GeV)	0.13	4.0 10^4	6.1 10^1
*p*Pb LHC (8.8 TeV)	100	1.0 10^7	7.5 10^4
PbPb LHC (5.5 TeV)	0.5	7.3 10^6	3.6 10^4

Luminosity per year in fb^{-1}

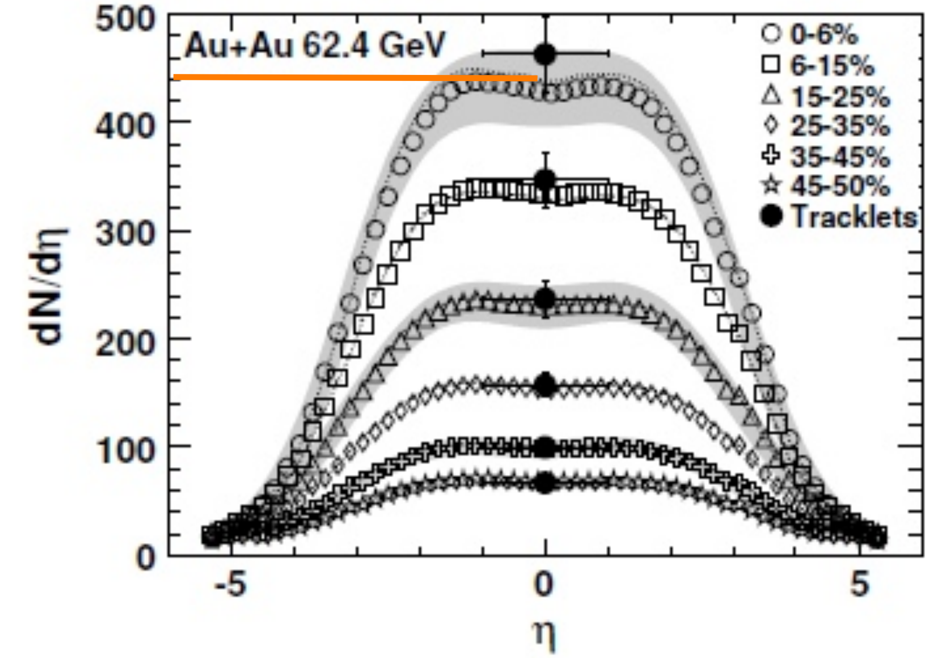
Multiplicity in PbA



PRL 93, 082301 (2004)



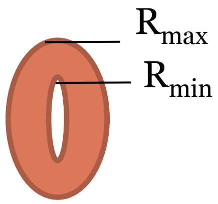
PRC 74, 021901(R) (2006)



Charged particles per unit of rapidity: (x 1.5 = charged+neutral)

p+p @ 115 GeV ~ 2 **d+Au @ 200 GeV : max ~11** **Au+Au @ 62.4 GeV : max ~ 450**

→ A highly granular detector is needed



y <|0.5|	R_{min} (cm)	R_{max} (cm)	Surface (cm²)
Vertex	1.5	10	~ 300
Calo	10	40	~4700

Vertex ~ 450 part.

$$1\% \sim \frac{450}{300\times\left(\frac{1}{0.8\times0.8\ \mathrm{mm}^2}\right)}$$

$$0.1\% \sim \frac{450}{300\times\left(\frac{1}{0.25\times0.25\ \mathrm{mm}^2}\right)}$$

Calo ~ 700 part.

$$\frac{700}{4700\times\left(\frac{1}{1\times1\ \mathrm{cm}^2}\right)} \sim 14\%$$

$$\frac{700}{4700\times\left(\frac{1}{0.5\times0.5\ \mathrm{cm}^2}\right)} \sim 3.7\%$$

Conclusion

- LHC proton and lead beams continuous extraction with bent crystal offers many physics opportunities

- Large luminosities provide access to large and very large parton x measurements for quarks and gluons: QCD laboratory at large x

- Fixed-target mode allows for target versatility: hydrogen, deuteron, nucleus (nuclear effect and QGP), polarized target (spin physics)

- AFTER designed as a multi-purpose experiment

AFTER @ LHC

http://after.in2p3.fr

M. Anselmino (Torino), R. Arnaldi (Torino), S.J. Brodsky (SLAC), V. Chambert (IPN), J.P. Didelez (IPN), B. Genolini (IPN), E.G. Ferreiro (USC), F. Fleuret (LLR), C. Hadjidakis (IPN), J.P Lansberg (IPN), C. Lorcé (IPN), A. Rakotozafindrabe (CEA), P. Rosier (IPN), I. Schienbein (LPSC), E. Scomparin (Torino), U.I. Uggerhøj (Aarhus)

Looking for partners!

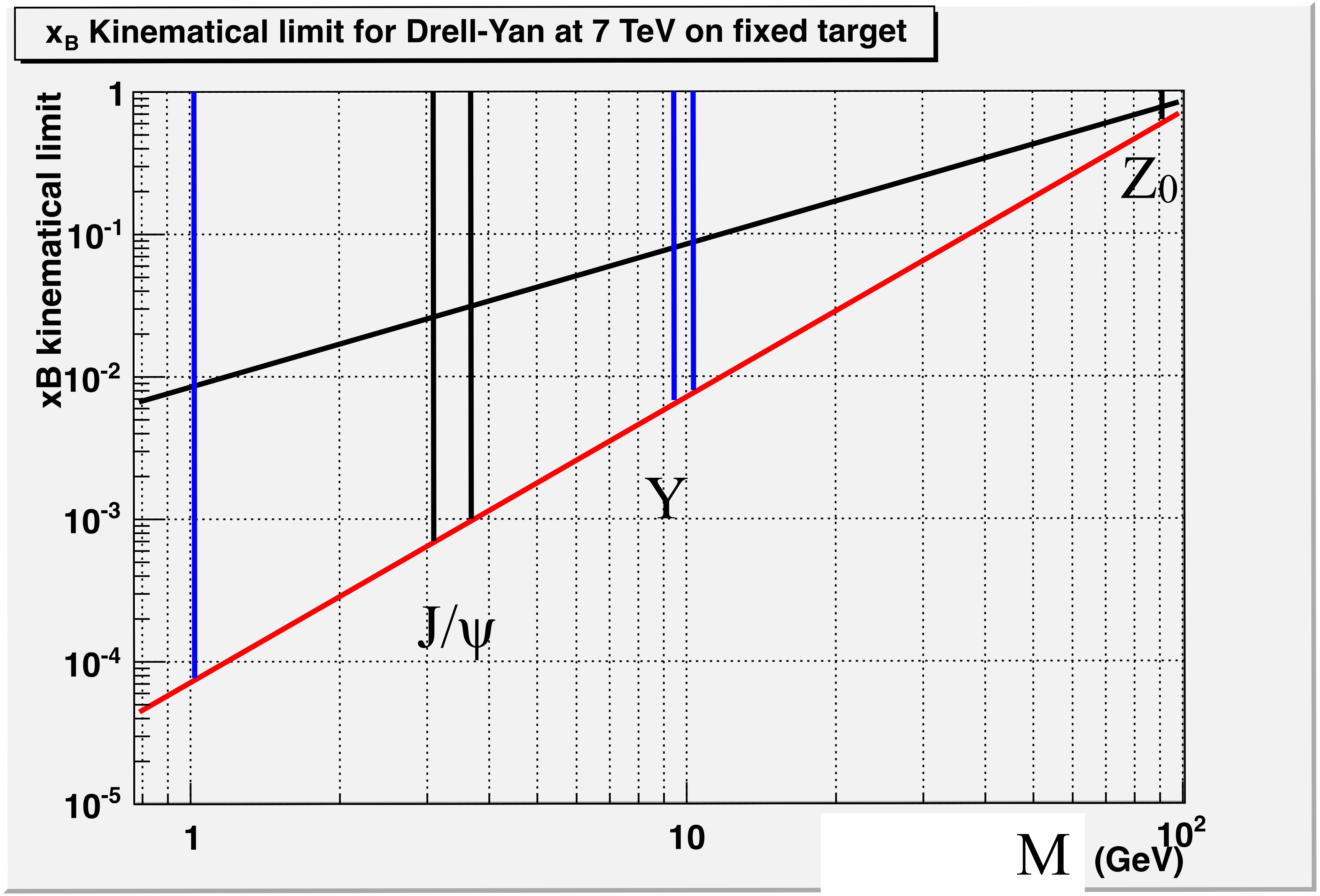
Drell-Yan continuum

backward region
forward region

x_{target}
x_{beam}

$x_{target} = x_{beam}$

x_{beam}
x_{target}



Tentative design for AFTER

Rapidity boost in a fixed target mode

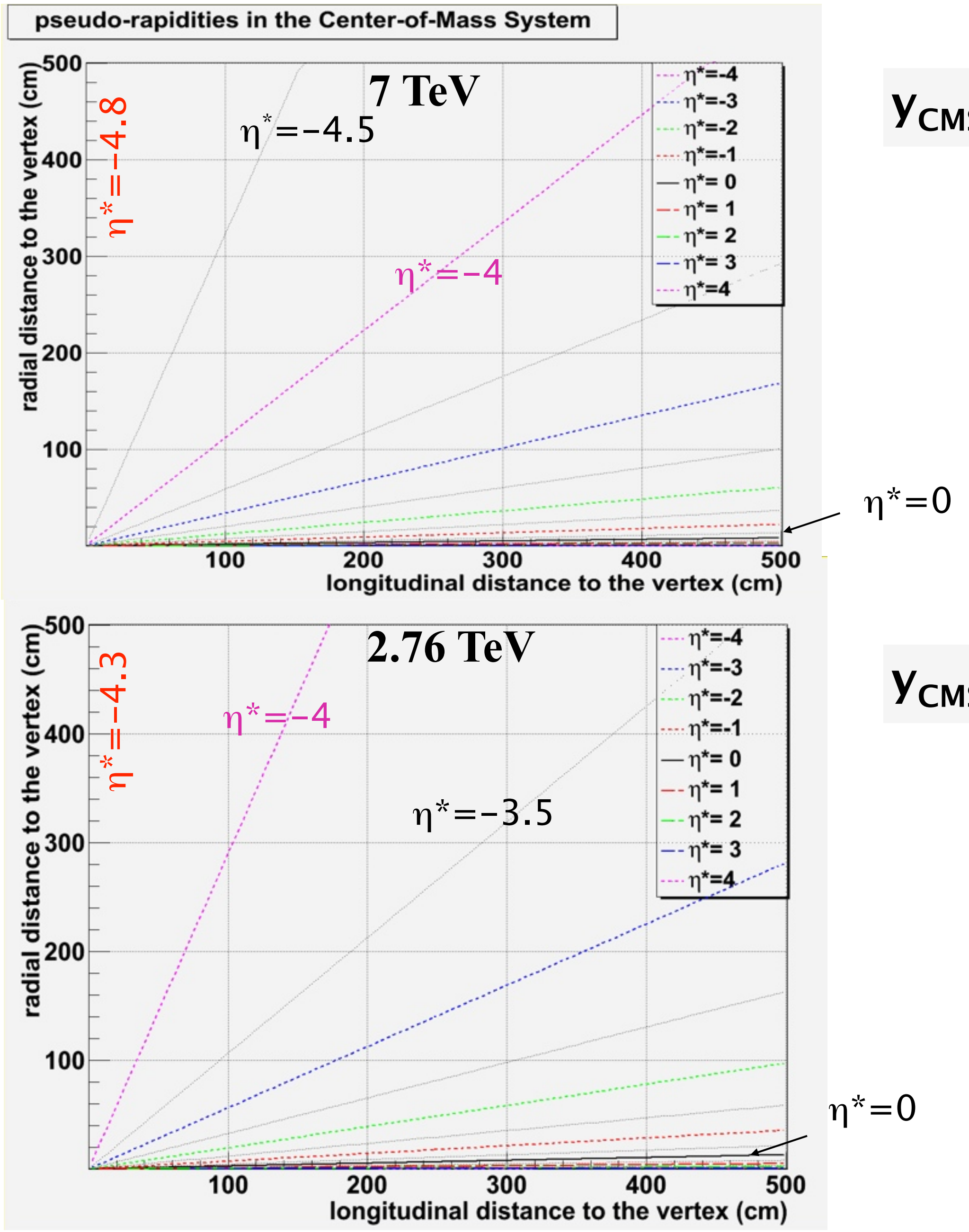
- **Very high boost:**
  - With 7 TeV beam
    $\gamma = \sqrt{s}/(2m_p) = 61.1$ and $y_{CMS} = 4.8$
  - With 2.76 TeV beam
    $\gamma = 38.3$ and $y_{CMS} = 4.3$

- $\eta_{CM} = \eta_{lab} - y_{CMS}$
  forward region: $\eta_{CM} > 0$
  backward region: $\eta_{CM} < 0$

- $\eta = -\ln\tan\theta/2$
  $\rightarrow \theta\ (y_{CM}=0) \sim 0.9°$ (16 mrad)
  - $y_{lab}(J/\Psi) \sim 4.8 \rightarrow x_2(J/\Psi) = 0.03$
  - $y_{lab}(\Upsilon) \sim 4.8 \rightarrow x_2(\Upsilon) = 0.08$

- **Taking $x_2 = M/\sqrt{s}\ e^{-y_{CM}}$**
  - $x_2(J/\Psi) = 1 \rightarrow y_{lab}(J/\Psi) \sim 1.2$
  - $x_2(\Upsilon) = 1 \rightarrow y_{lab}(\Upsilon) \sim 2.4$

- **Very well placed to access backward physics**

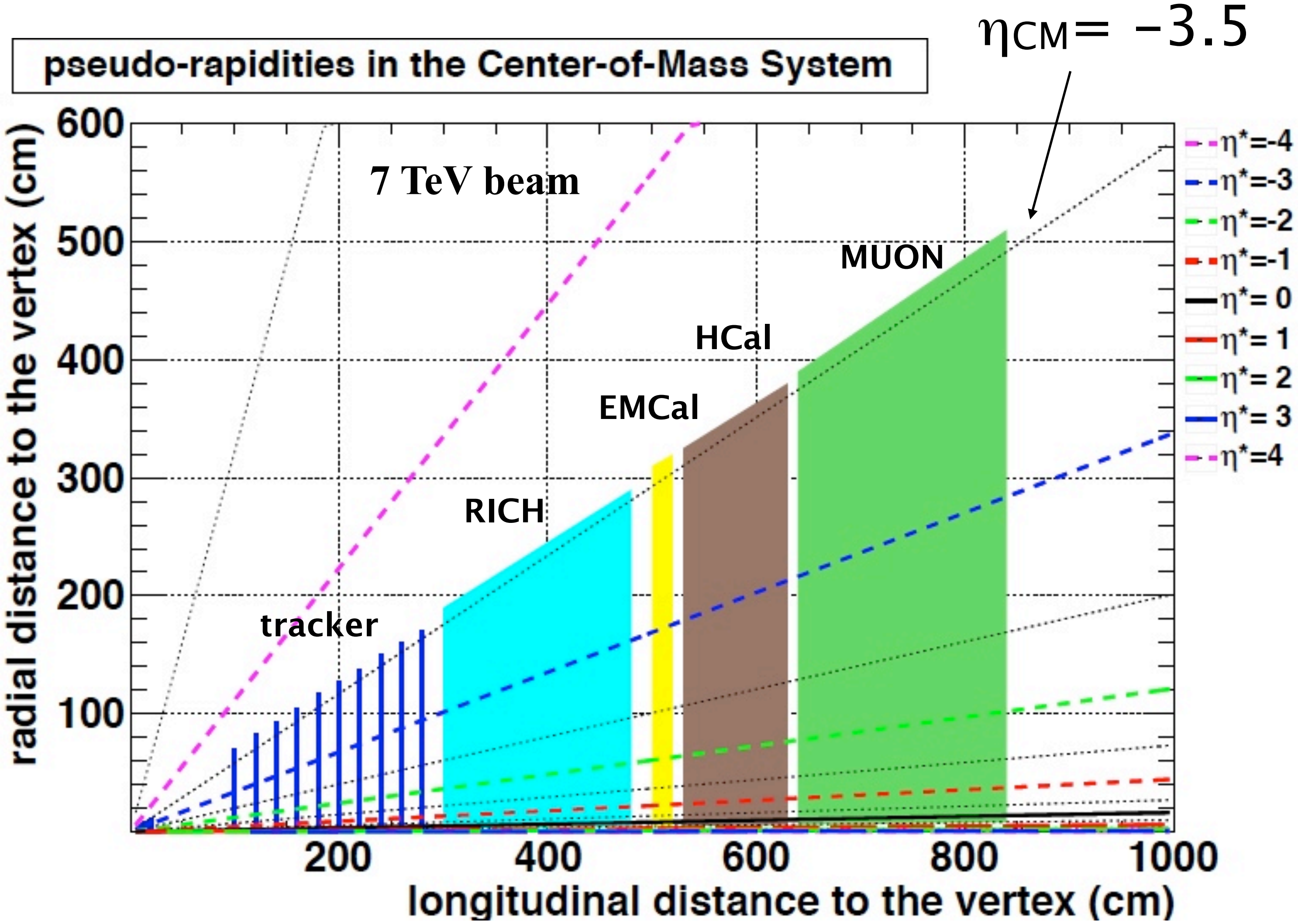


$y_{CMS} = 4.8$

$y_{CMS} = 4.3$

A tentative design for AFTER

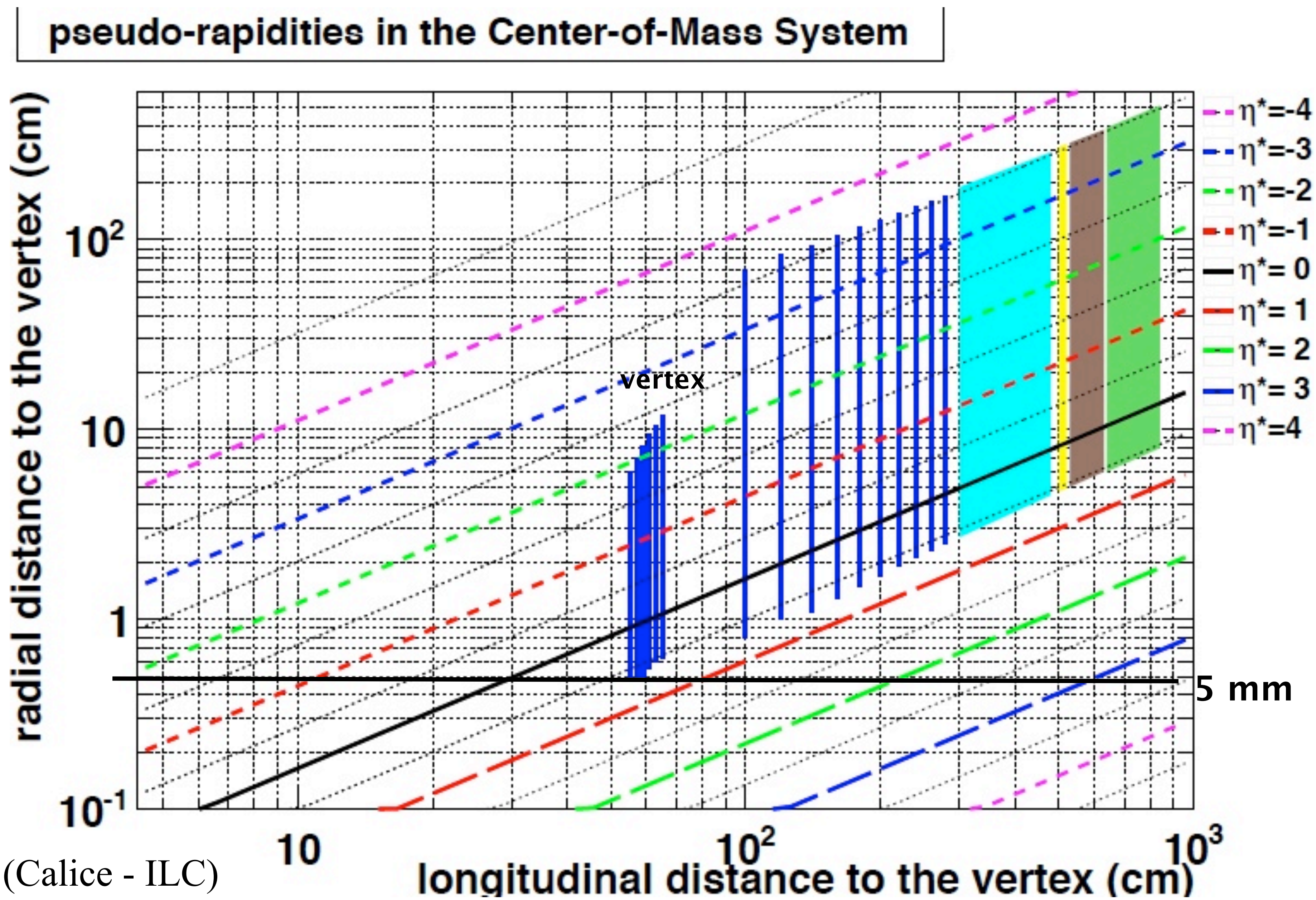
- **Tentative design** $1.3 < y_{lab} < 5.3$
  - With 7 TeV beam : $-3.5 < y_{CM} < 0.5$
  - With 2.76 TeV beam: $-3 < y_{CM} < 1$
  - $\theta_{min} = 10$ mrad
- **Multi-purpose detector**
  - Vertex
  - Tracking (+ dipole magnet)
  - RICH
  - Calorimetry
  - Muons
- **High boost** → forward and as compact as possible detector



Detector dimension

$1.3 < y_{lab} < 5.3$
$\theta_{min} = 10$ mrad

Detector	Z_{min}/Z_{max}	R_{min}/R_{max}
Vertex	55/65 cm	0.5/12 cm
Tracker	100/180 cm	0.8/170 cm
RICH	300/480 cm	2.7/290 cm
EMCal	500/520 cm	4.7/320 cm
HCal	530/630 cm	5.0/380 cm
Muons	640/840 cm	8/510 cm



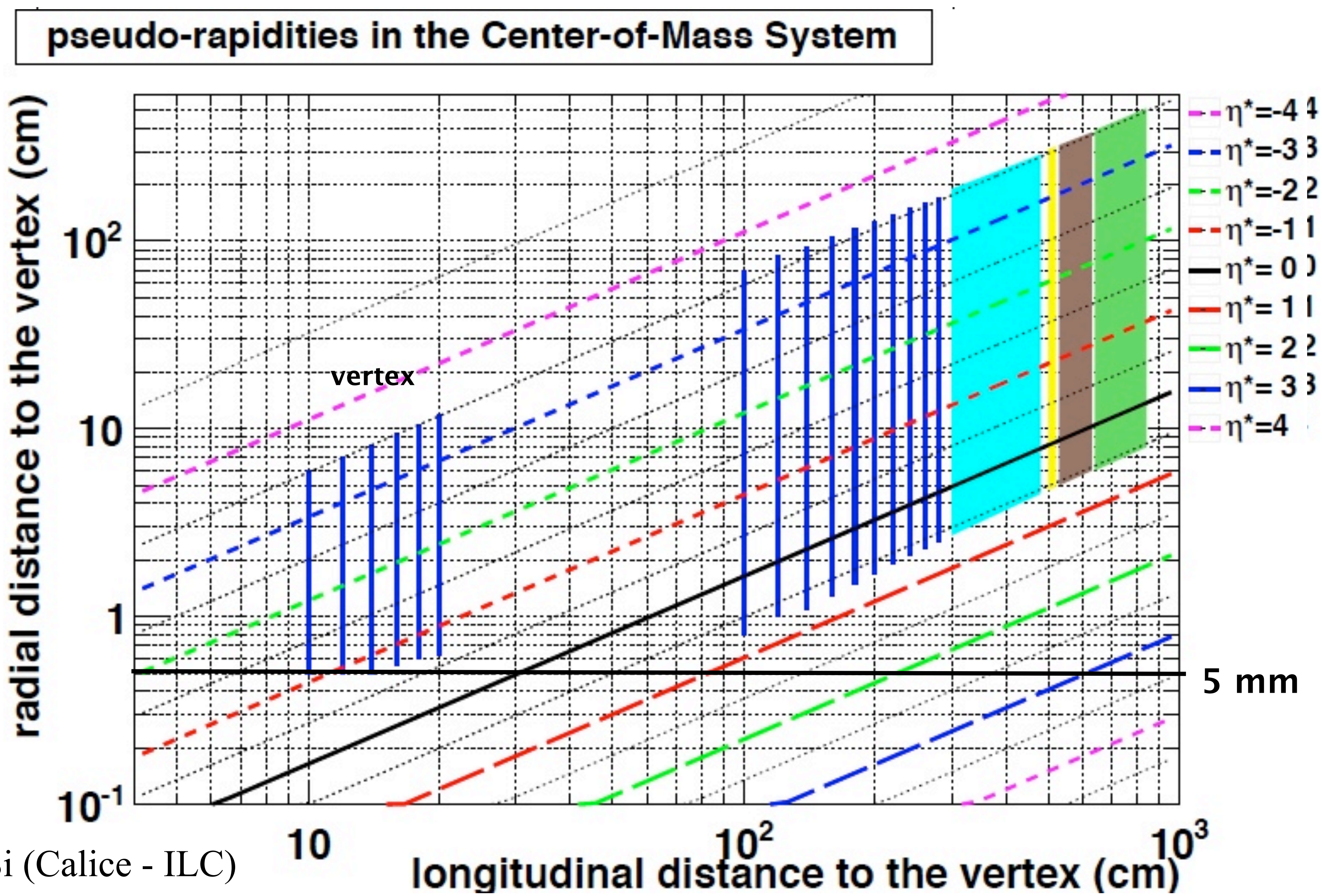
- **Technology**

- Vertex, tracker: pixel detectors
- Ultra-granular EMCal: Tungsten/Si (Calice - ILC)
- Muons: Magnetize Fe (Minos)
- ...

Detector dimension

$1.3 < y_{lab} < 5.3$
$\theta_{min} = 10$ mrad

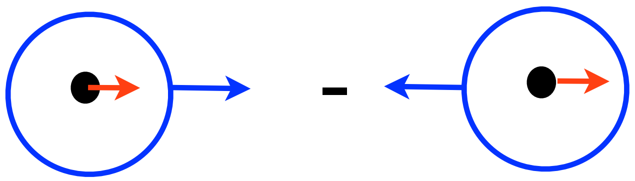
Detector	Z_{min}/Z_{max}	R_{min}/R_{max}
Vertex	10/20 cm	0.5/12 cm
Tracker	100/180 cm	0.8/170 cm
RICH	300/480 cm	2.7/290 cm
EMCal	500/520 cm	4.7/320 cm
HCal	530/630 cm	5.0/380 cm
Muons	640/840 cm	8/510 cm

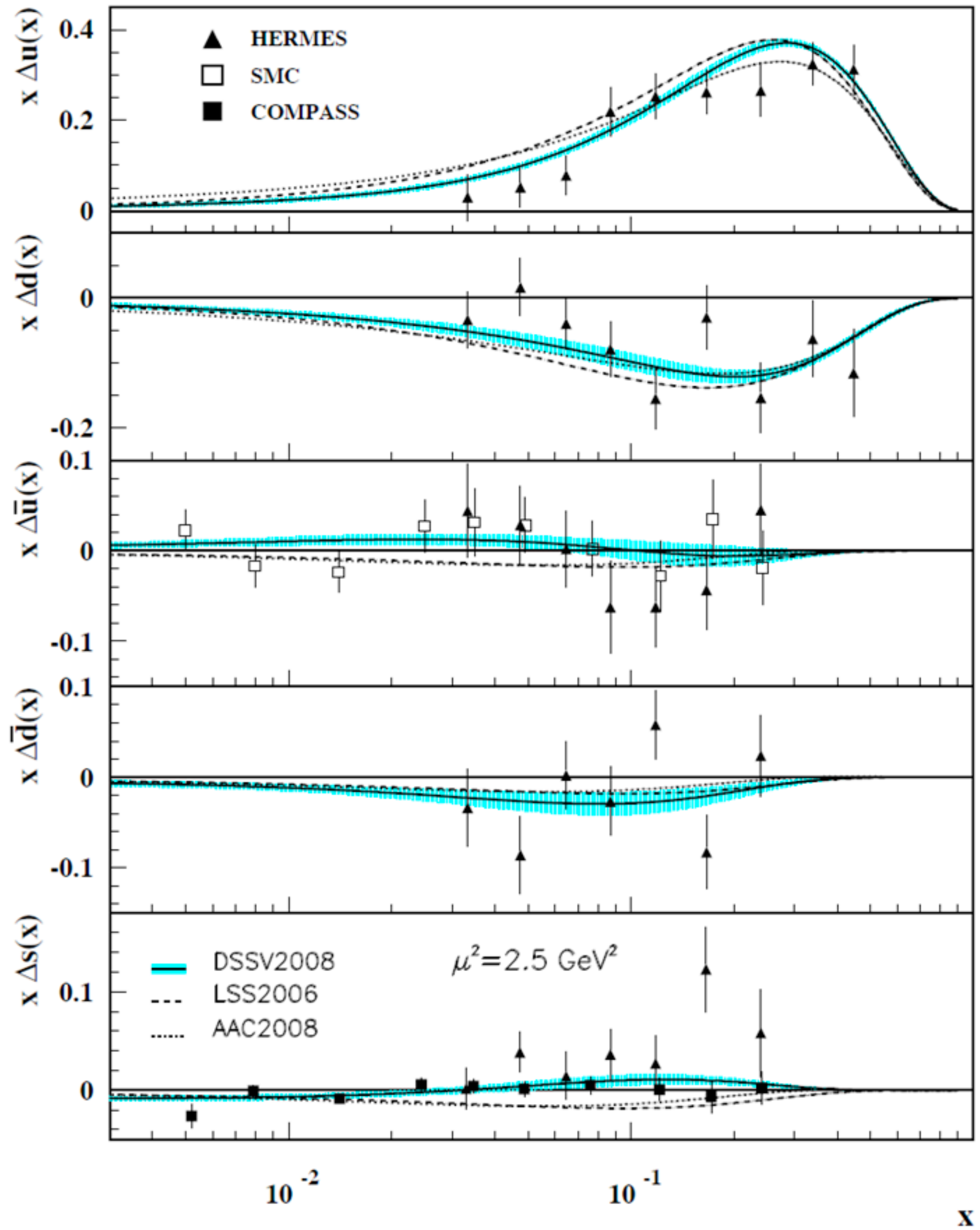


- **Technology**
- Vertex, tracker: pixel detectors
- Ultra-granular EMCal: Tungsten/Si (Calice - ILC)
- Muons: Magnetize Fe (Minos)
- ...

Longitudinal polarized target: helicity distr.

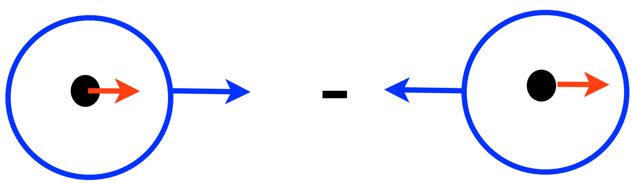
parton helicity distribution in a **longitudinally polarized nucleon**:





Longitudinal polarized target: helicity distr.

parton helicity distribution in a **longitudinally polarized nucleon**:



- **Experimental probes @ AFTER**
  - $W^{+/-}$ → individual helicity distribution of quark and anti-quark