News from AFTER @ LHC

A Fixed Target ExpeRiment using LHC beams

AFTER @ LHC

M. Anselmino (Torino), R. Arnarldi (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)

Andry Rakotozafindrabe
CEA (Saclay) IRFU

Irfu - CEA Saclay
Institut de recherche
sur les lois fondamentales
de l'Univers

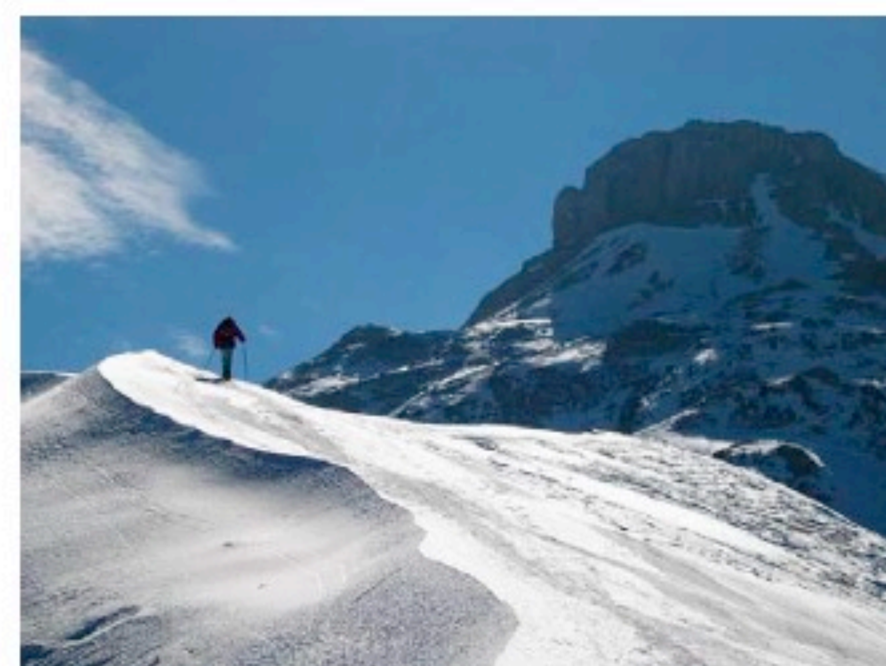
Annual meeting GdR PH-QCD – Saclay, France, Nov. 2013

About 40 participants
Institutes from Denmark, France, Germany, Italy, Japan, Mexico, Poland, Spain, Switzerland, Turkey, UK, USA

ECT* 'exploratory' workshop: "Physics at a fixed target experiment using the LHC beams"

- February 4 - February 13, 2013

'This is an exploratory workshop which aims at studying in detail the opportunity and feasibility of fixed-target experiments using the LHC beam.'



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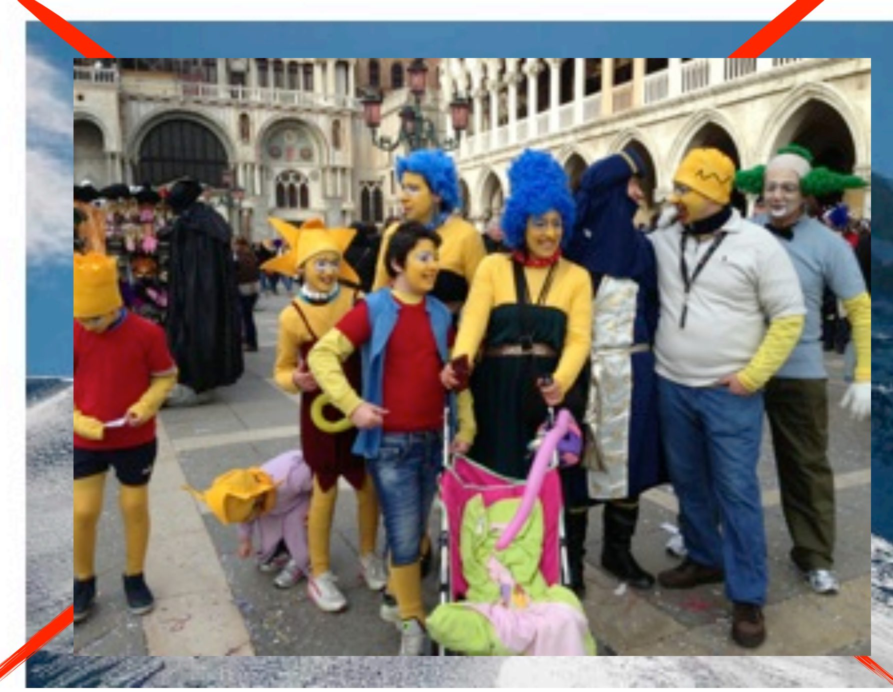

Joint meeting IPNO-LAL LUA9-AFTER

18-20 novembre 2013
Orsay
Europe/Paris timezone

- Overview
- Scientific Programme
- Timetable
- Contribution List
- Author index
- Registration
  - Registration Form
- List of registrants

The most convenient and efficient way to obtain a beam for a fixed target experiment from the LHC is, to our knowledge, to use bent-crystal beam extraction. The idea is therefore to position a bent crystal in the halo of the beam such that a few protons (or lead) per bunch per pass would be channelled in the lattice of the crystal and would be deviated by a couple of mrad w.r.t. to the axis of the beam. Such a method also has the virtue of better collimating the beam, allowing one to increase the luminosity of the collider experiments. Tests of this technique will soon be carried out by the LUA9 collaboration following the recommandation of the LHCC.

During this meeting, we will discuss:

- the status of bent-crystal beam collimation and extraction
- the status of future test at the LHC by LUA9
- the physics opportunities offered by a fixed target experiment on the LHC beams extracted by a bent crystal (AFTER@LHC)
- the possible synergies between LUA9 and AFTER, as well as between LAL and IPNO in this context.

This meeting is one of the actions of the French GDR PH-QCD.

Démarre 18 nov. 2013 14:15
Finit 20 nov. 2013 13:00
Europe/Paris

Orsay
IPN (Monday-Tuesday) - LAL (Wednesday)

Dr. Lansberg, Jean-Philippe
Dr. Hadjidakis, Cynthia
Mrs. Puill, Véronique
Dr. Alessandro Variola, Alessandro Variola

A Fixed Target ExpeRiment at LHC

Use LHC beams on fixed target :

- LHC 7 TeV proton beam
  - $\sqrt{s} \sim 115$ GeV : p–p, p–d, p–A

- LHC 2.76 TeV lead beam
  - $\sqrt{s} \sim 72$ GeV : Pb–p, Pb–A

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spin physics

PDF and nPDF at large x_B

heavy quarkonium prod. and Cold Nuclear Matter effects

W, Z prod. near threshold

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UPC

QGP studies, high precision heavy quarkonium observatory, high p_T jets

diffractive physics

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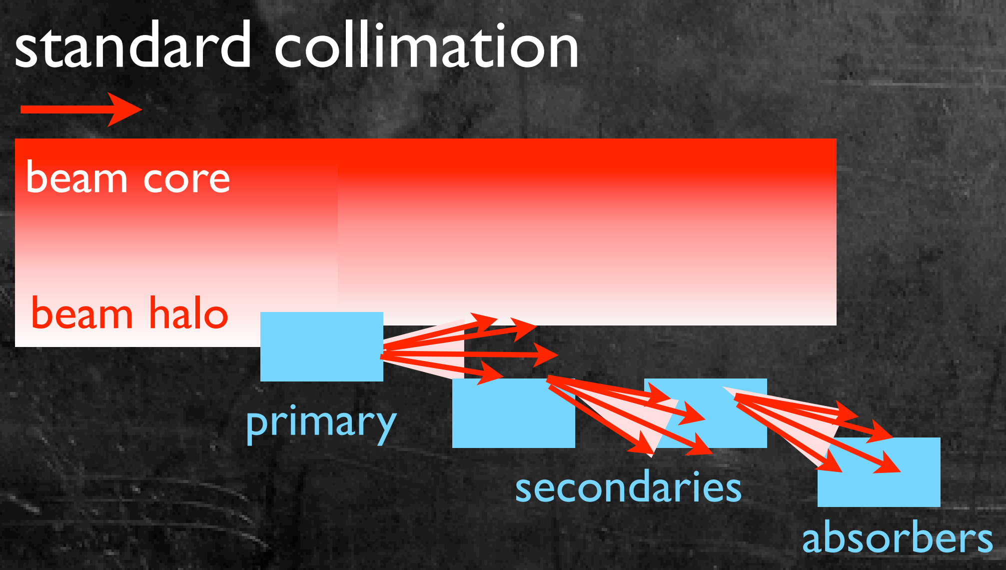
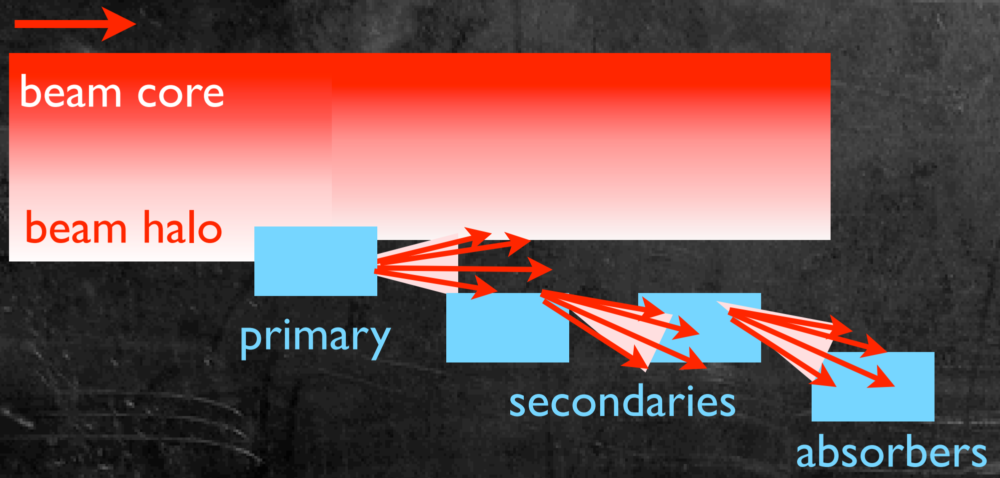


From beam collimation ...

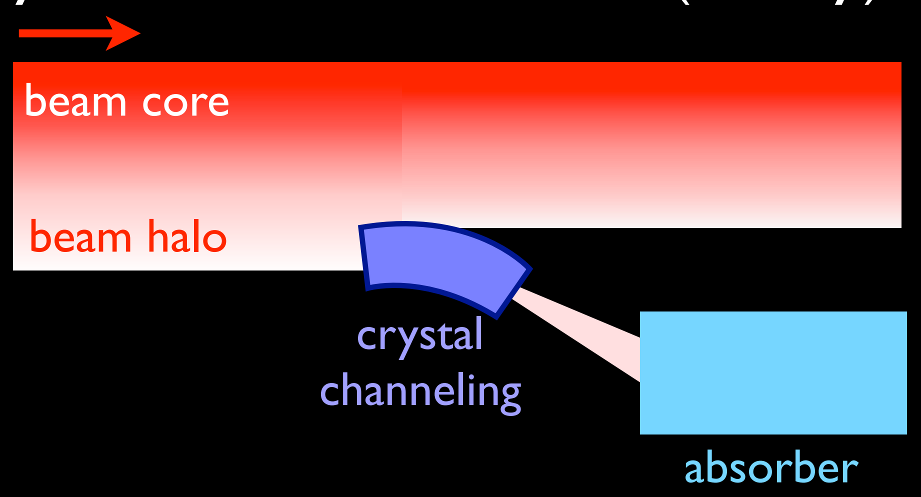
Bent crystal channeling

From beam collimation ...

standard collimation



crystal-based collimation (ideally)



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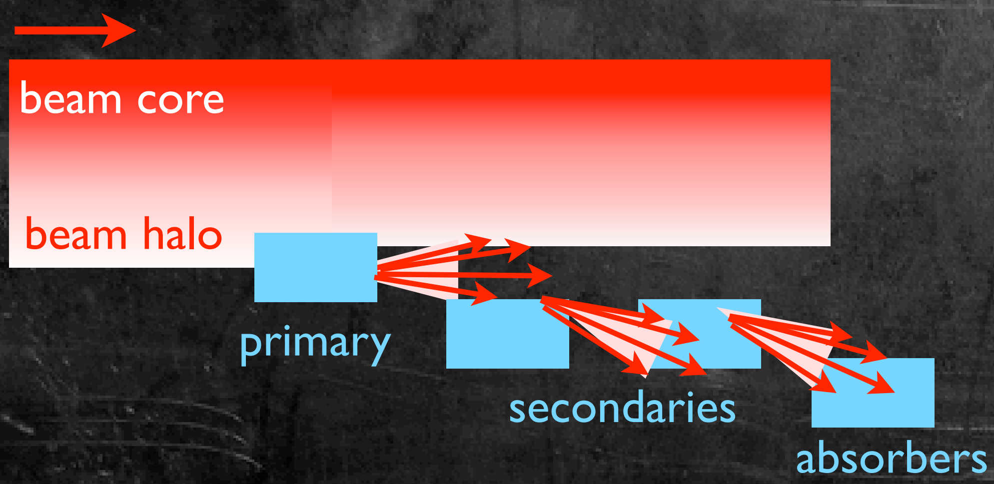

RD22 @ SPS (1990 - 95)
E853 @ Tevatron (1993 - 98)
@ RHIC (2001 - 2005)
@ Tevatron (2005 - 2011)

UA9 @ SPS (2008 - ...)
LUA9 @ LHC (approved by the LHCC in end 2011)

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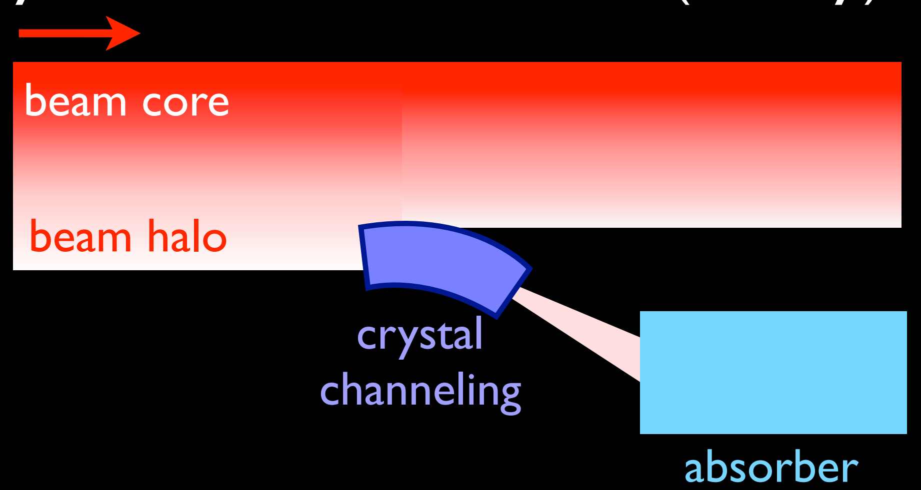

Joint meeting

[W. Scandale, Joint LUA9-AFTER meeting, Nov. 2013]

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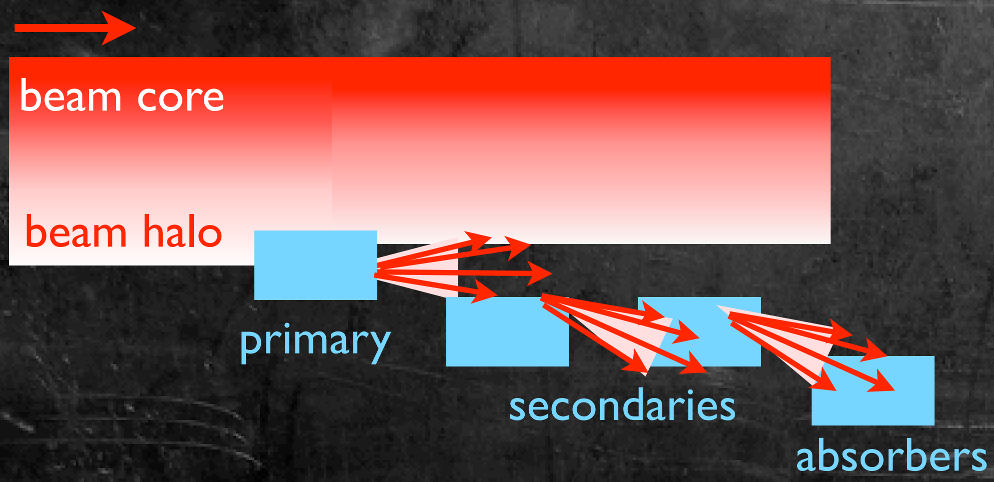

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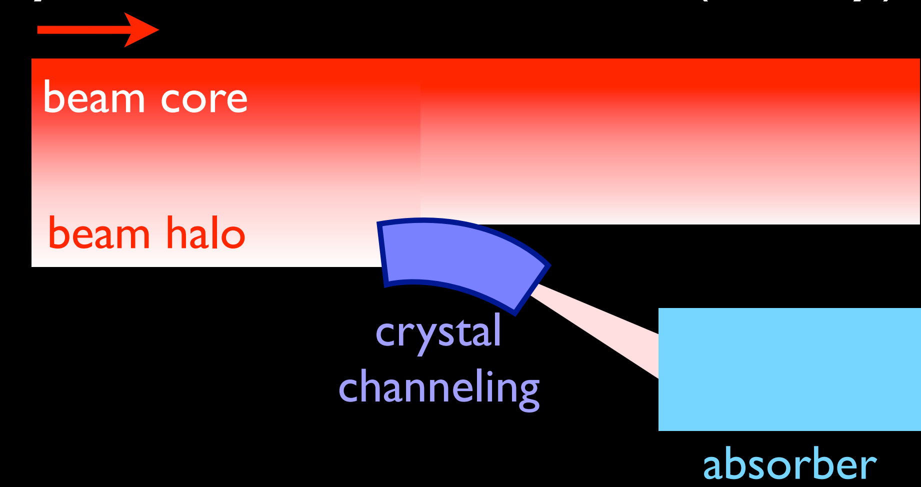


Joint meeting

[W. Scandale, Joint LUA9-AFTER meeting, Nov. 2013]

... to beam extraction

- CRYSBEAM
- AFTER @ LHC

UA9 @ SPS

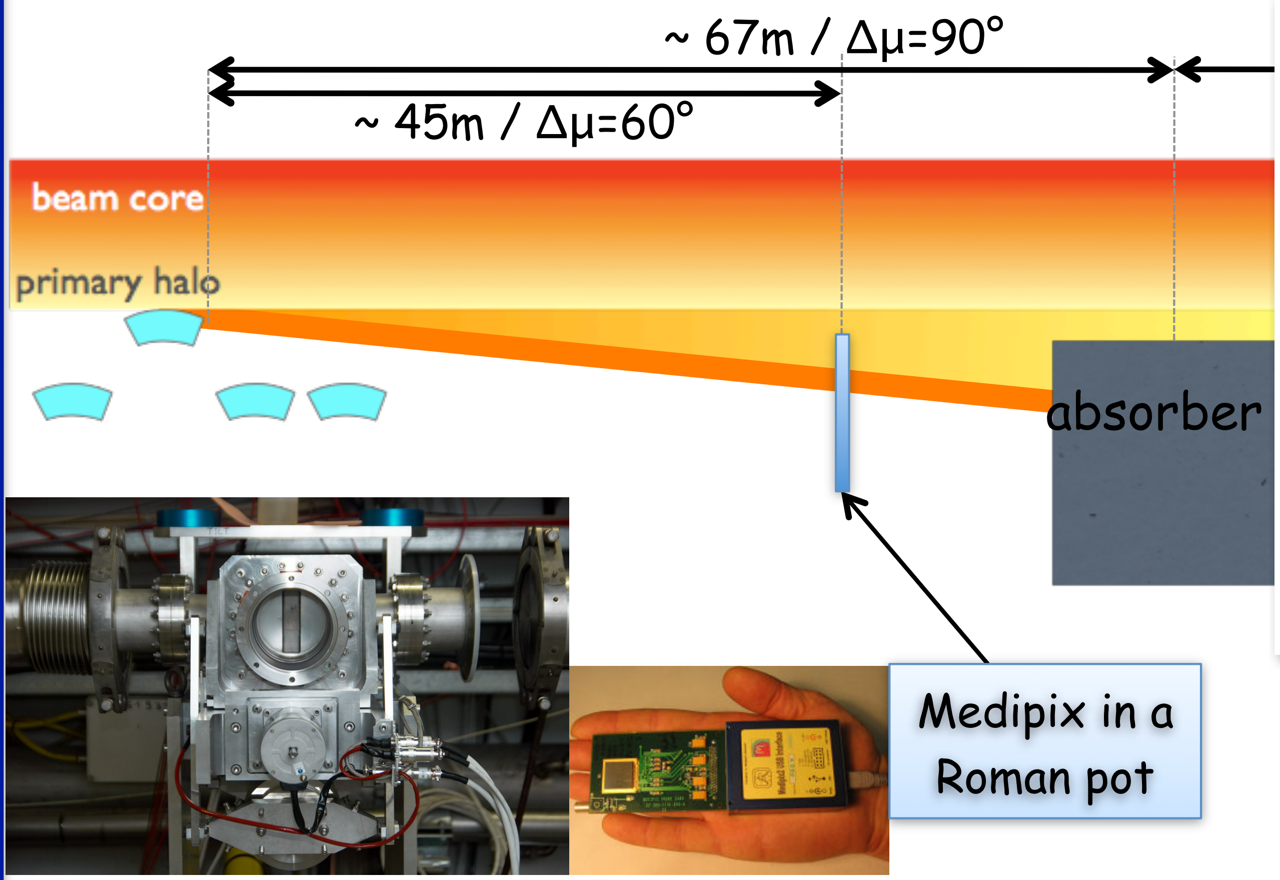
Goal : assess the possibility to use bent crystals as primary collimators in hadronic accelerators and colliders

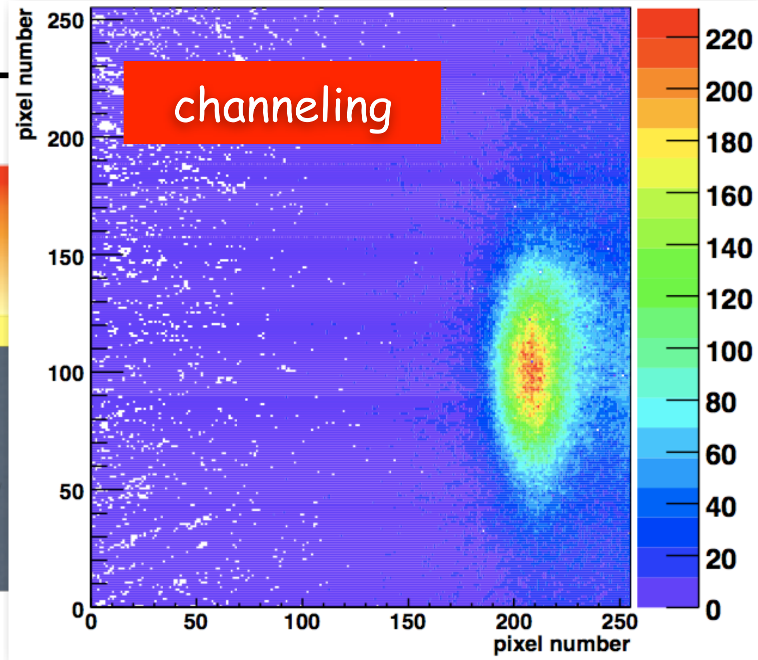
UA9 installation in the SPS

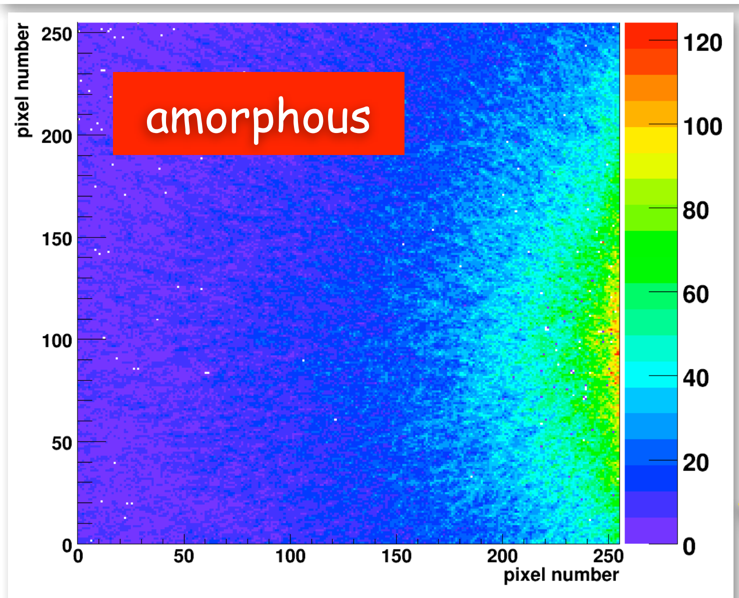
[S. Montesano, Physics at AFTER using LHC beams, ECT Trento, Feb. 2013]*

UA9 @ SPS

Direct view of channeled beam







Medipix pixel detector in a Roman pot:

- Intensity, profile and angle of the deflected beam
- Efficiency of channeling (with multi-turn effect) (needs information on circulating beam current)

Joint meeting

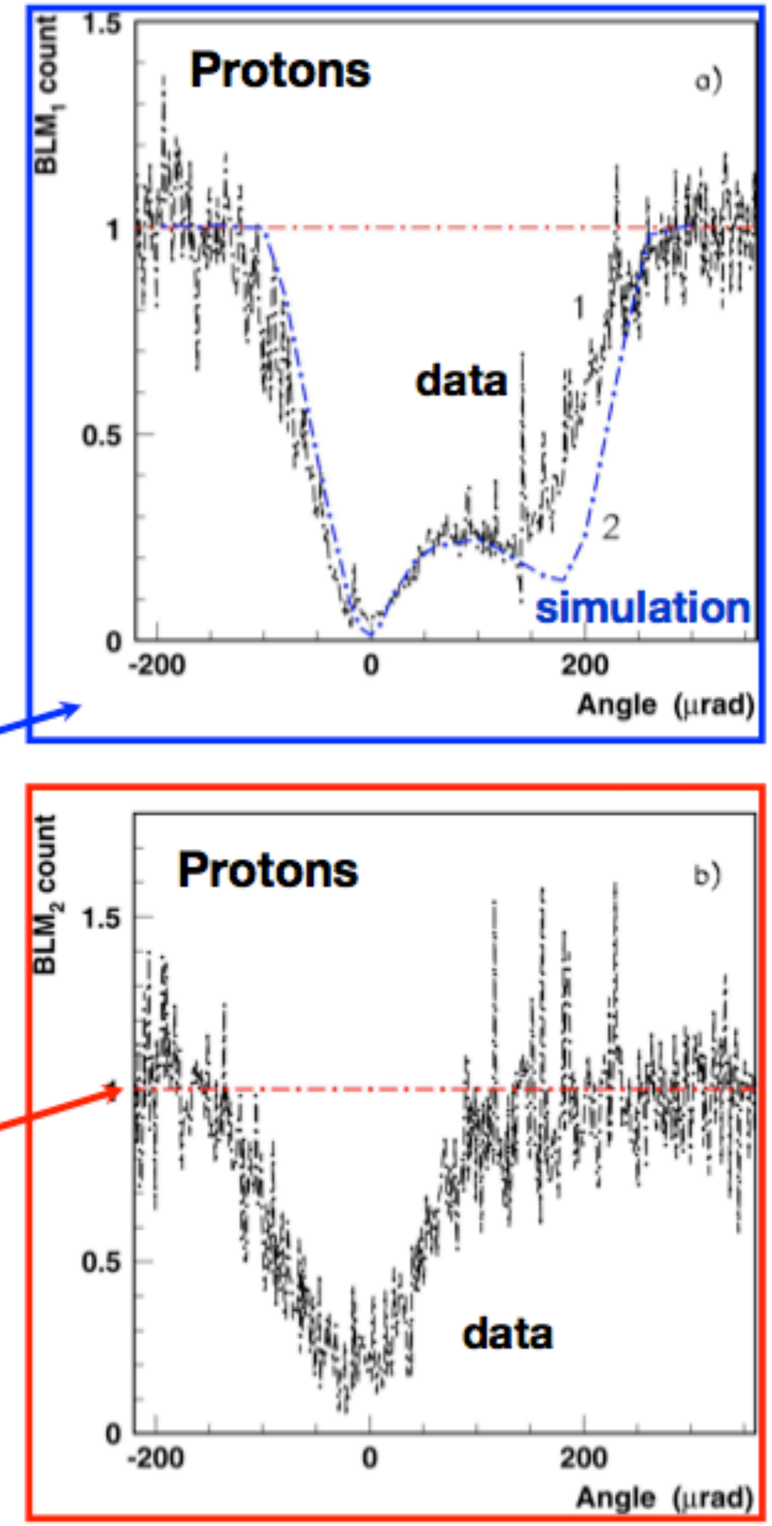
[W. Scandale, Joint LUA9-AFTER meeting, Nov. 2013]

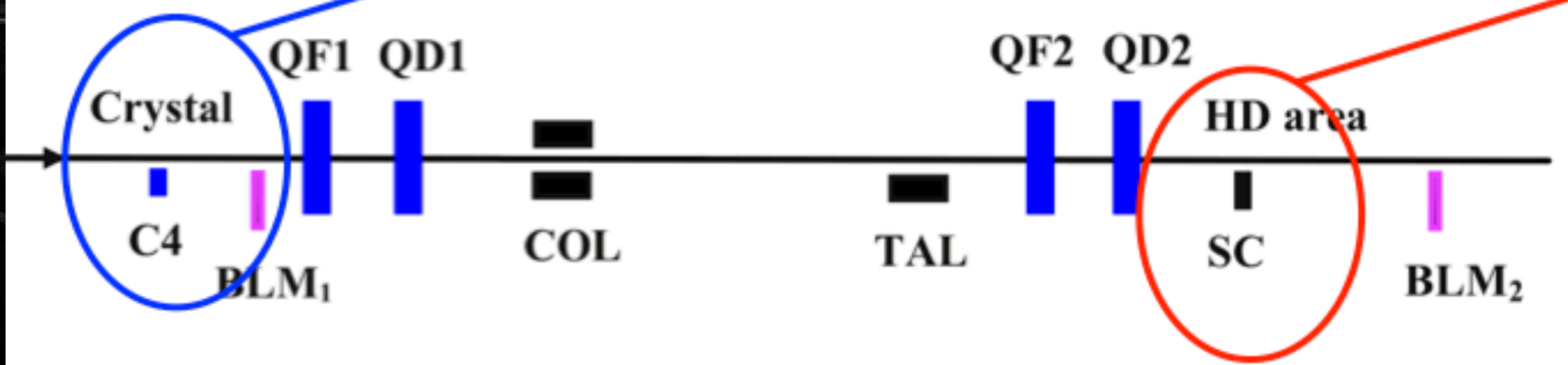
Joint meeting

[S. Montesano, Joint LUA9-AFTER meeting, Nov. 2013]

Main SPS achievements

- **Alignment** (linear and angular) of the crystal is fast and well reproducible.
- **Multi-turn channeling efficiency**: 70÷80% for protons, 50÷70% for ions.
- **Channeled beam observed** with the Medipix.
- **Loss rate reduction at crystal**: 20x for protons, 7x for ions.
- **Off-momentum loss reduction**: 6x for protons, 7x for ions.
  → *This is what matters for the LHC, limited by dispersion losses!*
- **Loss maps**: consistent reduction of the losses around the full ring when comparing crystal in channeling and crystal in amorphous.
- **Dependence of the off-momentum leakage on the clearance between crystal and absorber**.
- **Test multi-strip crystals in volume-reflection**





[S. Montesano, Joint LUA9-AFTER meeting, Nov. 2013]

Joint meeting

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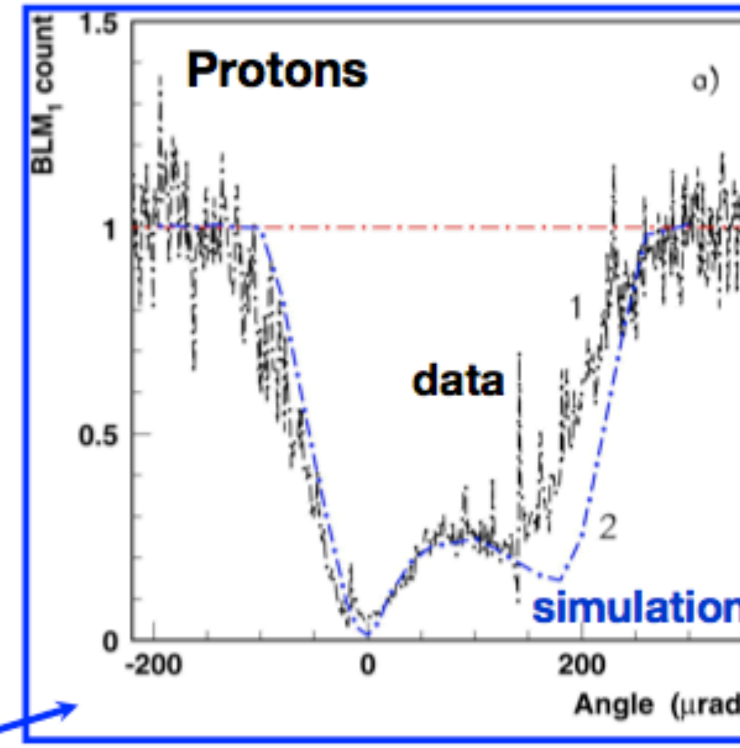
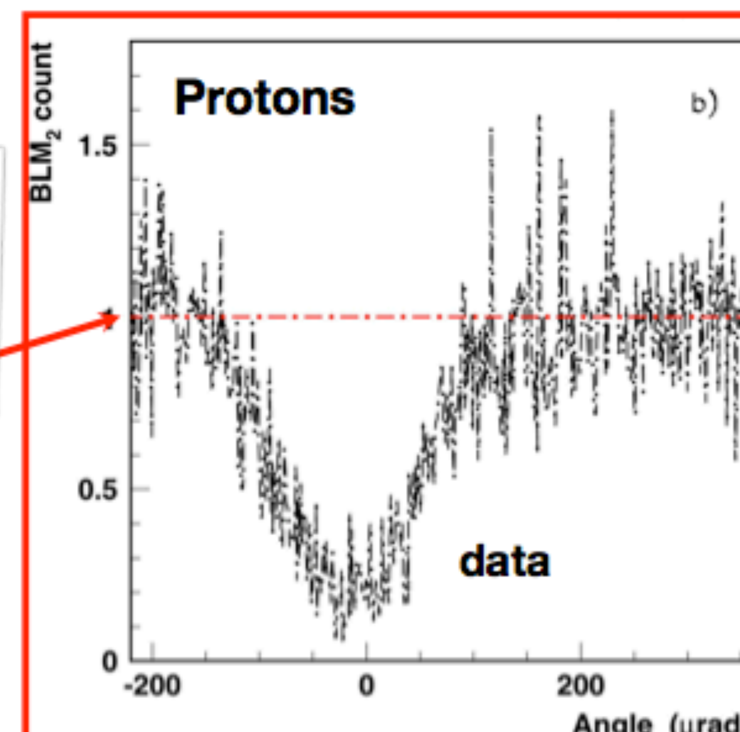
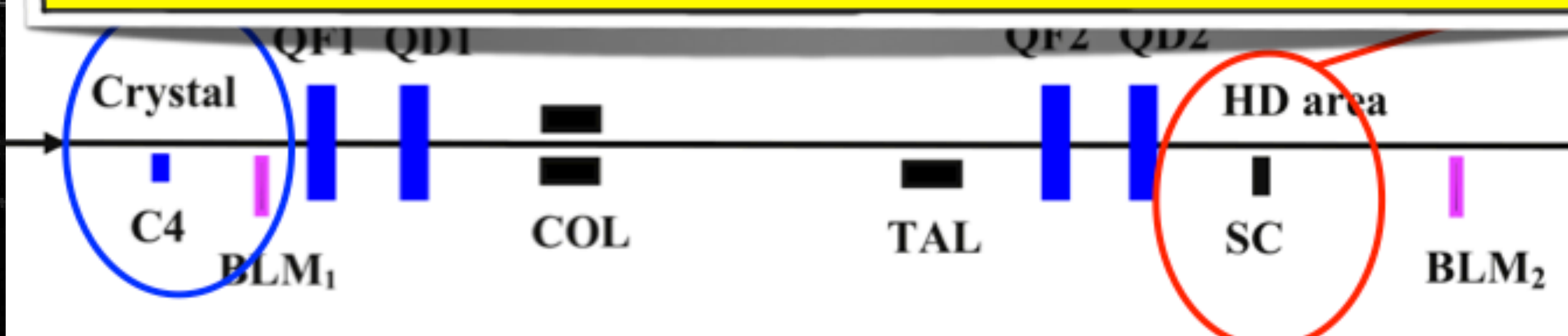
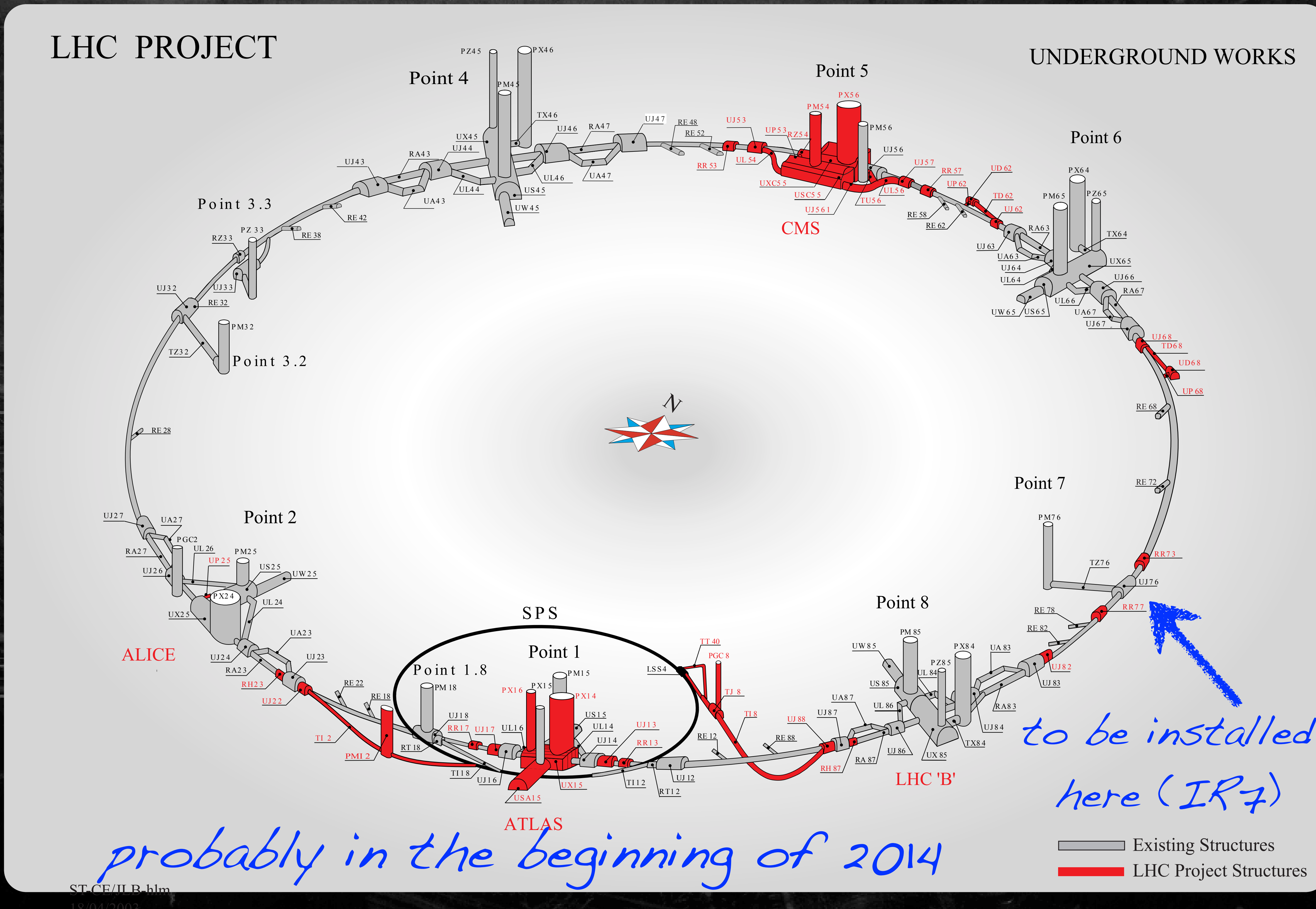




A complete crystal collimation prototype is installed in the SPS



LUA9 @ LHC


LHC PROJECT
UNDERGROUND WORKS
Point 4
Point 5
Point 6
Point 3.3
Point 3.2
Point 2
Point 7
Point 8
SPS
Point 1
Point 1.8
CMS
ALICE
ATLAS
LHC 'B'
N
to be installed here (IR7)
probably in the beginning of 2014
Existing Structures
LHC Project Structures
ST-CE/JLB-hlm
18/04/2003

Overview on LHC tests

Preliminary tests possible after LS1:

- during the 2015
  - ✓ Machine Development (MD) devoted to high priority tests for the Machine Commissioning
  - ✓ possibility to get few hours for first conceptual tests of channeling extraction at the LHC
- during the 2016
  - ✓ possibility to get few dedicated MD on the LHC (like in the SPS during the past years)

Preliminary plan for machine conditions during the first tests in 2016 (with the LHC dedicated to us):

- low intensity
- top energy (main goal) & injection
- full chain of secondary collimators (TCSG) in place

then…

- higher intensity (still within safe boundaries ➔ total circulating intensity: ~5e11 p @ 450GeV / ~5e9 p @ 7TeV)
- possibility "to play" with the TCSGs settings

Scope of the tests:

- ➢ Can crystal collimation compete with the present very good cleaning system?
- ➢ Uncertainty for the scaling to higher energy (e.g.: single diffractive losses).
- ➢ Operational challenges much more complex than at the SPS (ramp, squeeze, etc...).
- ➢ Some outstanding machine protection concerns must be addressed.

[S. Montesano, Joint LUA9-AFTER meeting, Nov. 2013]

Joint meeting

Overview on LHC tests

A minimal prototype system has been designed for LHC :

- integration studies on-going
- probable physical installation in 2014
- first tests with beam possibly in 2015/2016

✓ Machine Devel
✓ possibility to g
✓ possibility to

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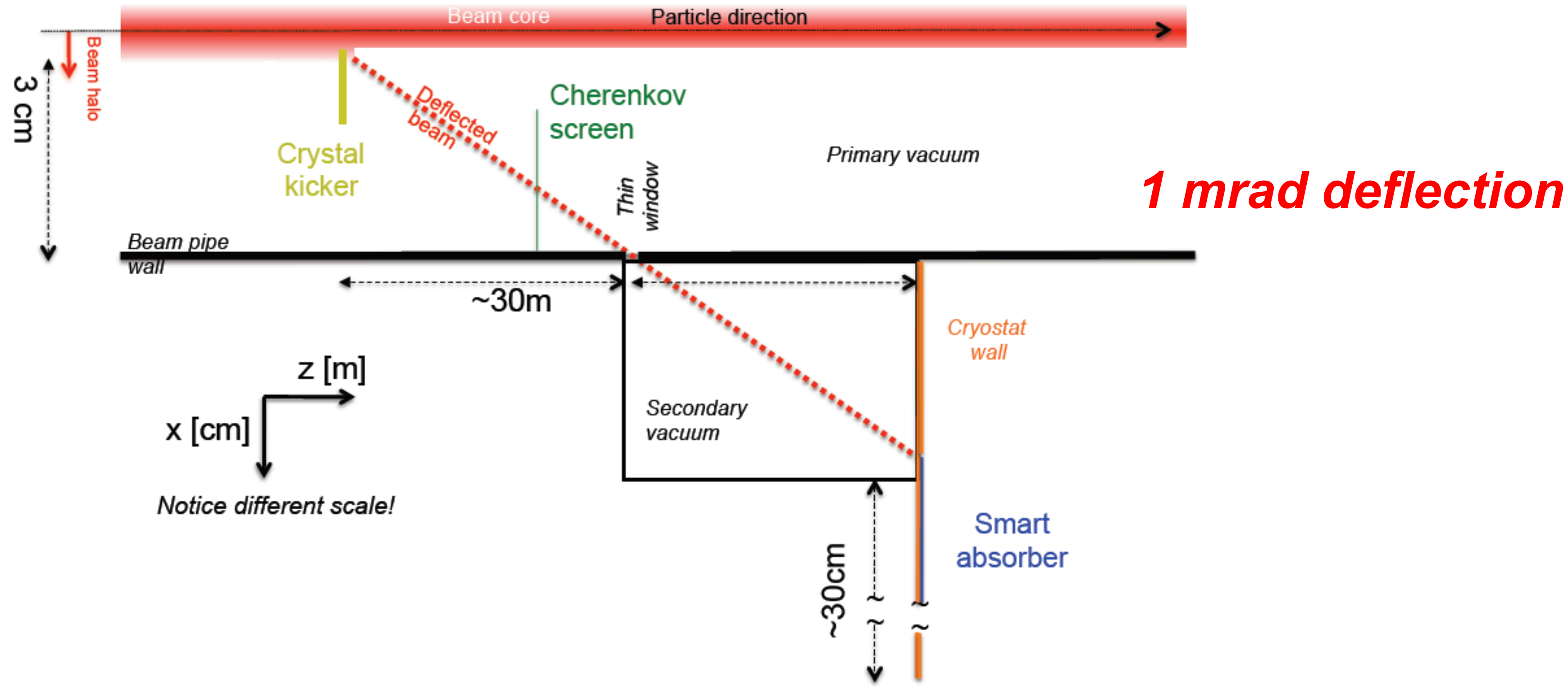
Joint meeting

UA9 2.0: CRYSBEAM

– A possible setup to extract a hadron beam (not for for collimation but sharing the same difficulties)
– Meant to work at high luminosity (high current)



CRYStal channeling to extract a high energy hadron **BE**am from an **A**ccelerator **M**achine

Presented for FP7 ERC CoG call

ECT* Trento

2/11/13 Gianluca Cavoto 3

[G. Cavoto, Physics at AFTER using LHC beams, ECT Trento, Feb. 2013]*

CRYSBEAM could be ready for LS2

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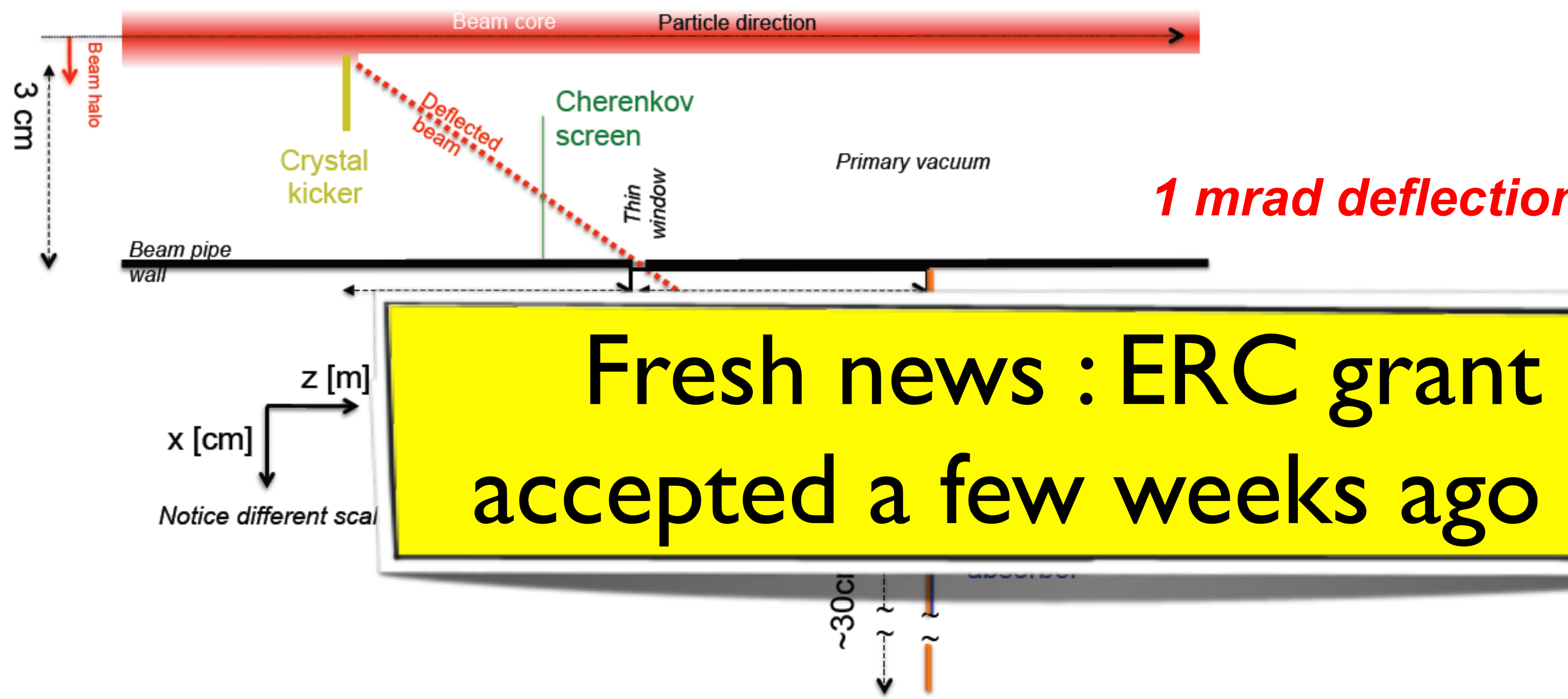

Fresh news : ERC grant accepted a few weeks ago !!!

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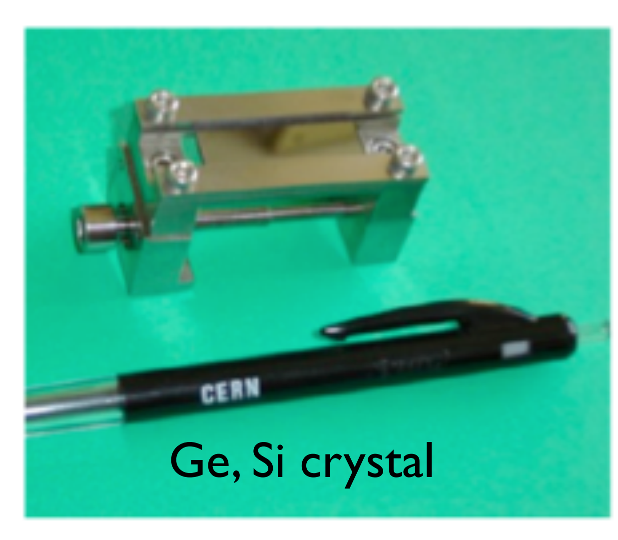
LHC beam extraction

Use strong crystalline field in bent crystals :

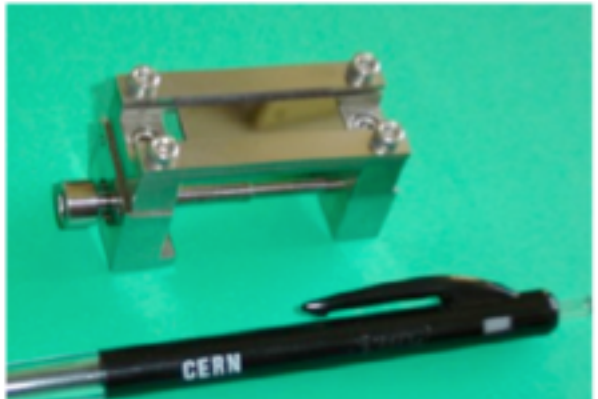


Ge, Si crystal

LHC beam extraction

Use strong crystalline field in bent crystals :

- mature technique
  - successful for proton beam : RD22 @ SPS (1990), ..., Tevatron (2005), UA9 @ SPS (2008) *[W. Scandale et al., JINST 6 (2011) T10002]*
  - test @ LHC recommended by LHCC ☛ LUA9
  - ion beam : test at SPS *[W. Scandale et al., PLB 703 (2011) 547]*



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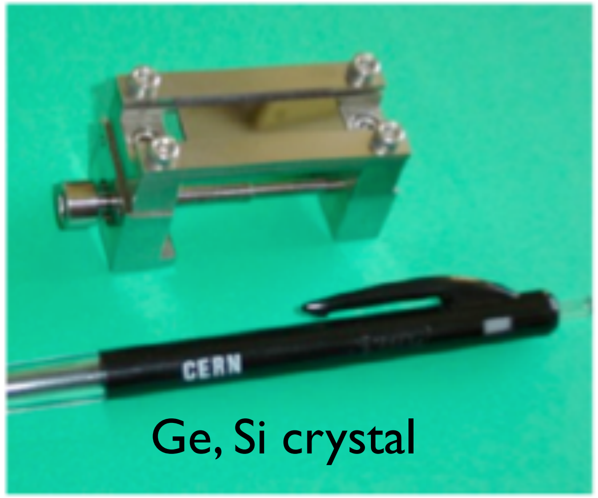

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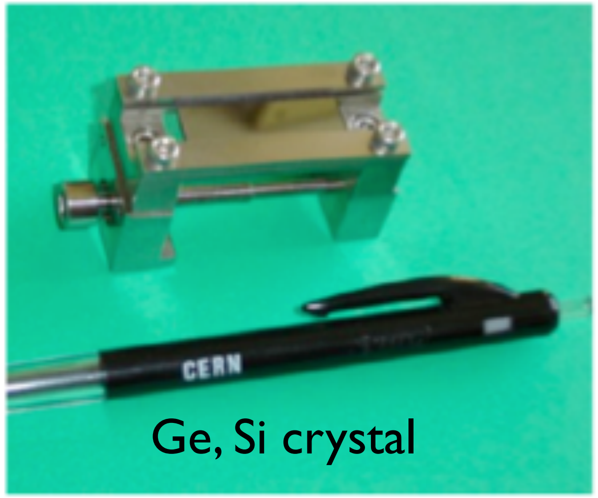

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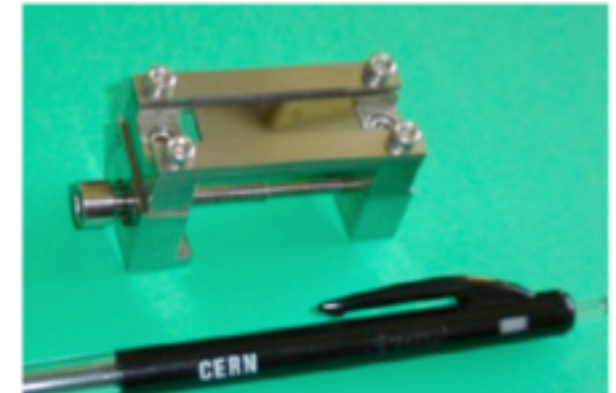
  - here with a deflection 0.275 mrad [E Uggerhoj and U.I. Uggerhoj, NIM B 234 (2005) 31]
  - extraction eff. (multi pass) ~ 50% LHC beam loss ⇛ 5.10^8 p/s extracted
  - yearly luminosity (1 cm thick target) : 0.1 to 0.6 fb^{-1} in p−H(A), 7 to 25 nb^{-1} in Pb−A [S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

LHC beam extraction



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no performance decrease of the LHC

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Luminosity in pH, pA

in units of (fb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 115 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

	Target	$\int dt\mathcal{L}$	
AFTER	10 cm solid H	2.6	
	10 cm liquid H	2	
	10 cm liquid D	2.4	
	1 cm Be	0.62	
	1 cm Cu	0.42	
	1 cm W	0.31	
	1 cm Pb	0.16	
LHC	pp low P_T LHC (14 TeV)	0.05	ALICE
		2	LHCb
	pPb LHC (8.8 TeV)	10^{-4}	
RHIC	pp RHIC (200 GeV)	$1.2\ 10^{-2}$	
	dAu RHIC (200 GeV)	$1.5\ 10^{-4}$	
	dAu RHIC (62 GeV)	$3.8\ 10^{-6}$	

RHIC lumi. from PHENIX decadal plan (run plan 2011-2015)

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	dAu RHIC (62 GeV)	$3.8\ 10^{-6}$	

pp : 100 x RHIC, comparable to LHCb

RHIC lumi. from PHENIX decadal plan (run plan 2011-2015)

Luminosity in pH, pA

in units of (fb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 115 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

	Target	$\int dt \mathcal{L}$	
AFTER	10 cm solid H	2.6	
	10 cm liquid H	2	
	10 cm liquid D	2.4	
	1 cm Be	0.62	
	1 cm Cu	0.42	
	1 cm W	0.31	
	1 cm Pb	0.16	
LHC	pp low P_T LHC (14 TeV)	0.05	ALICE
		2	LHCb
	pPb LHC (8.8 TeV)	10^{-4}	
RHIC	pp RHIC (200 GeV)	$1.2\ 10^{-2}$	
	dAu RHIC (200 GeV)	$1.5\ 10^{-4}$	
	dAu RHIC (62 GeV)	$3.8\ 10^{-6}$	

pp : 100 x RHIC, comparable to LHCb

pA : 10^2-10^3 x RHIC

RHIC lumi. from PHENIX decadal plan (run plan 2011-2015)

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pp : 100 x RHIC, comparable to LHCb

pA : 10^2-10^3 x RHIC

RHIC lumi. from PHENIX decadal plan (run plan 2011-2015)

Recycle the LHC beam loss → a luminosity comparable to the LHC itself !

Luminosity in PbA

in units of (nb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

	Target	$\int dt \mathcal{L}$
AFTER	10 cm solid H	110
	10 cm liquid H	83
	10 cm liquid D	100
	1 cm Be	25
	1 cm Cu	17
	1 cm W	13
	1 cm Pb	7
RHIC	dAu RHIC (200 GeV)	150
	dAu RHIC (62 GeV)	3.8
	AuAu RHIC (200 GeV)	2.8
	AuAu RHIC (62 GeV)	0.13
LHC	pPb LHC (8.8 TeV)	100
	PbPb LHC (5.5 TeV)	0.5

Luminosity in PbA

in units of (nb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

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RHIC	*d*Au RHIC (200 GeV)	150
	*d*Au RHIC (62 GeV)	3.8
	AuAu RHIC (200 GeV)	2.8
	AuAu RHIC (62 GeV)	0.13
LHC	*p*Pb LHC (8.8 TeV)	100
	PbPb LHC (5.5 TeV)	0.5

PbA :

same stat. w.r.t. RHIC @ 200 GeV and LHC

Luminosity in PbA

in units of (nb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

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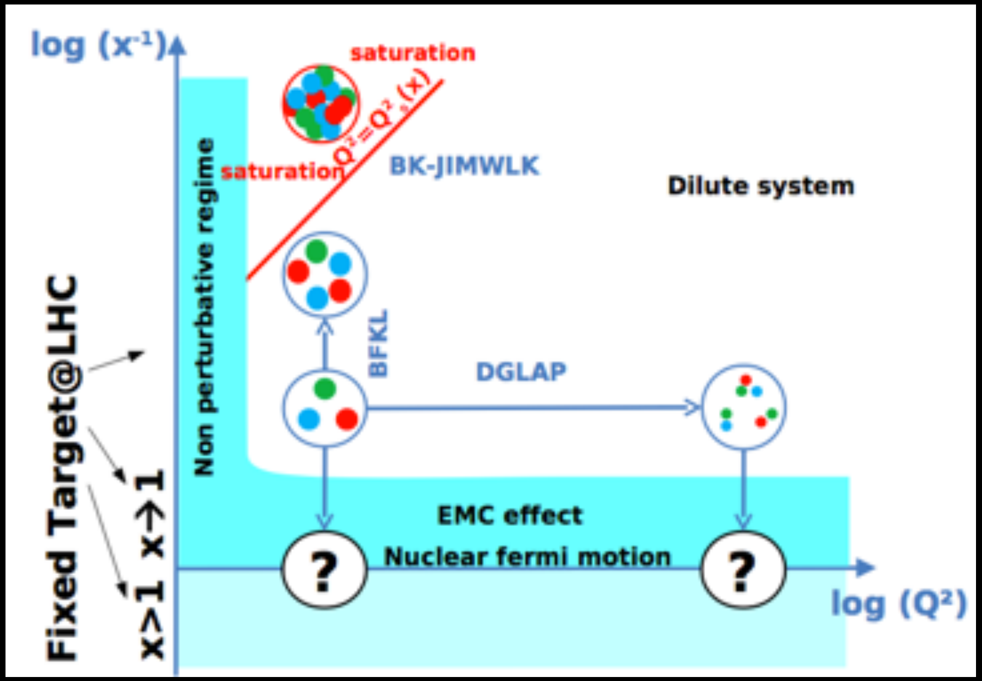
same stat. w.r.t. RHIC @ 200 GeV and LHC

10^2 x RHIC @ 62 GeV

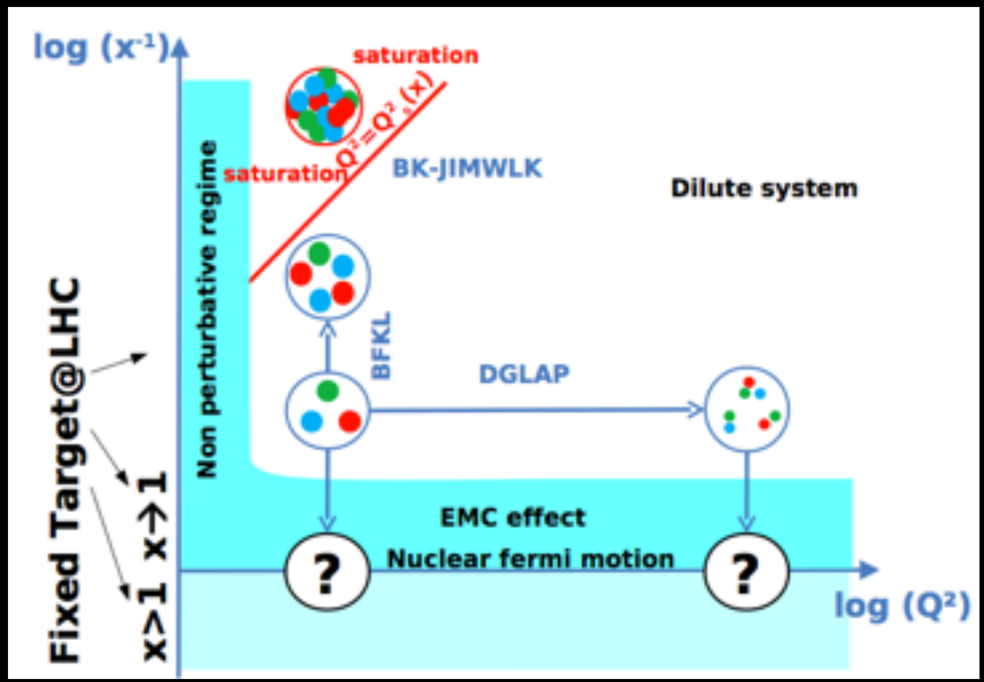
QCD near the high x frontier



Test the high x frontier of QCD
$x = 0.3 - 1$

- Nucleon partonic structure (PDF)
- Correlations between partons (spatial position, momentum, spin ...)
  ➠ nucleon 3D structure

QCD near the high x frontier



Test the high x frontier of QCD

x = 0.3 – 1

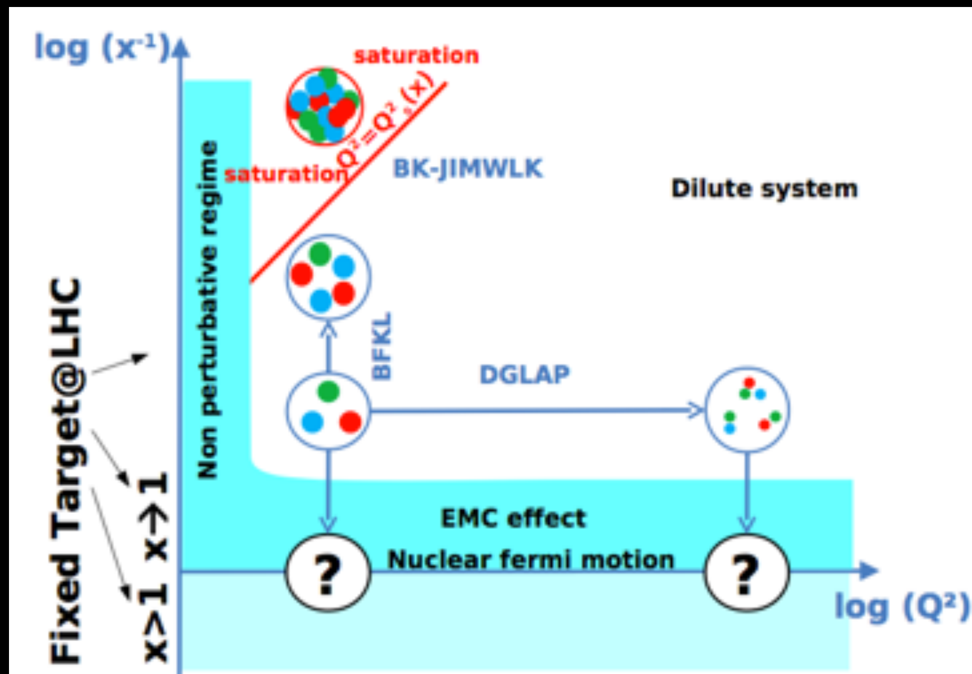
- Nucleon partonic structure (PDF)
- Correlations between partons (spatial position, momentum, spin ...)
  ➠ nucleon 3D structure

A Fixed Target ExpeRiment @ LHC :

- very energetic unpolarised p beam
- polarised or unpolarised nuclear target, where $(x^{\uparrow} = x_2)$
- full backward access, up to $(x_F \to -1) \Leftrightarrow (x^{\uparrow} \to 1)$
  - the target rapidity region corresponds to high $x^{\uparrow}$

high luminosity
&
scan in x_F

QCD near the high x frontier



Test the high x frontier of QCD
x = 0.3 – 1

- Nucleon partonic structure (PDF)
- Correlations between partons (spatial position, momentum, spin ...) ➠ nucleon 3D structure

A Fixed Target ExpeRiment @ LHC :

- workshop @ ECT* Trento : confirmation of strong physics cases for spin physics
  - flavor separation
  - complementarity with JLAB (intermediate to large x) and LHeC (very low x)
- target : rather low heating (~50μW) due to the extracted LHC hadron beam ⇒ run duration up to ~23 days

[J.P. Didelez, Physics at AFTER using LHC beams, ECT Trento, Feb. 2013]*

More details

- on the website : after.in2p3.fr

AFTER @ LHC

- in Phys. Rept. :

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

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ELSEVIER

Physics opportunities of a fixed-target experiment using LHC beams

S.J. Brodsky [a], F. Fleuret [b], C. Hadjidakis [c], J.P. Lansberg [c,*]

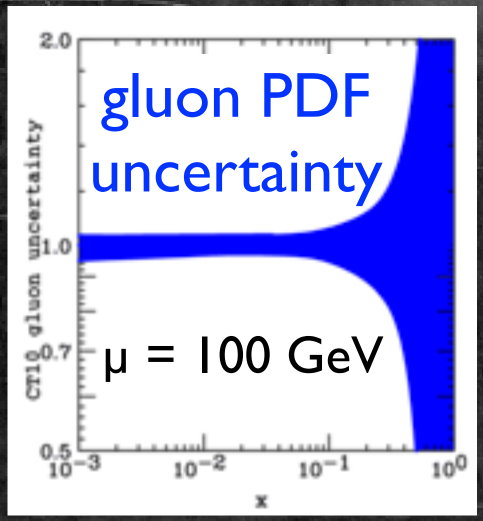
[a] *SLAC National Accelerator Laboratory, Stanford University, Menlo Park, CA 94025, USA*

[b] *Laboratoire Leprince Ringuet, Ecole polytechnique, CNRS/IN2P3, 91128 Palaiseau, France*

[c] *IPNO, Université Paris-Sud, CNRS/IN2P3, 91406 Orsay, France*

Gluon PDF

p-p



gluon PDF at high x :

with large uncertainties for proton

need high luminosity to reach large x

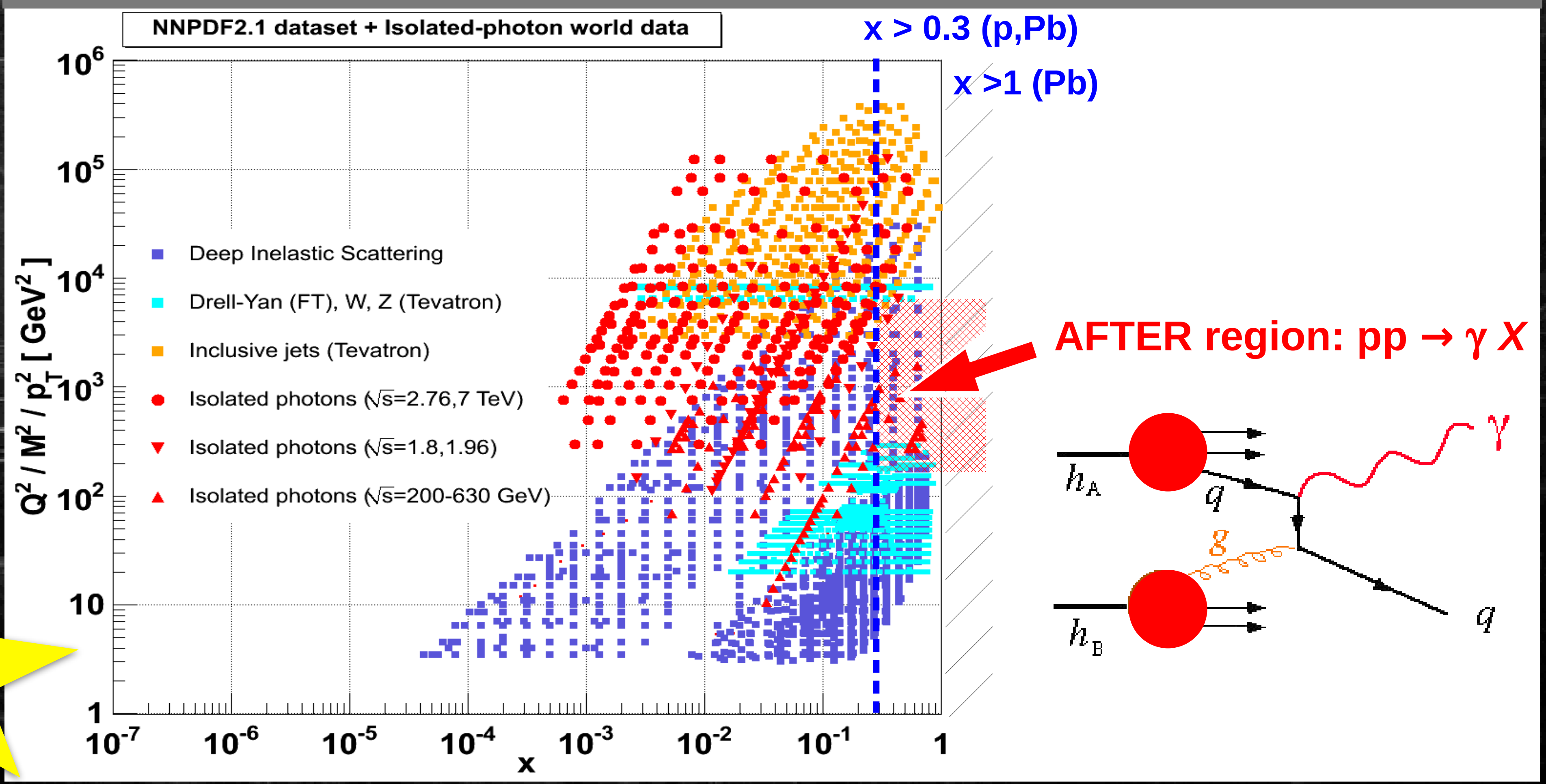
exp. probes :

- heavy quarkonia (gg fusion at high energy)
- isolated photons (gq fusion)
- high p_T jets (p_T >20 GeV, accessible up to 40 GeV)

for isolated photons :

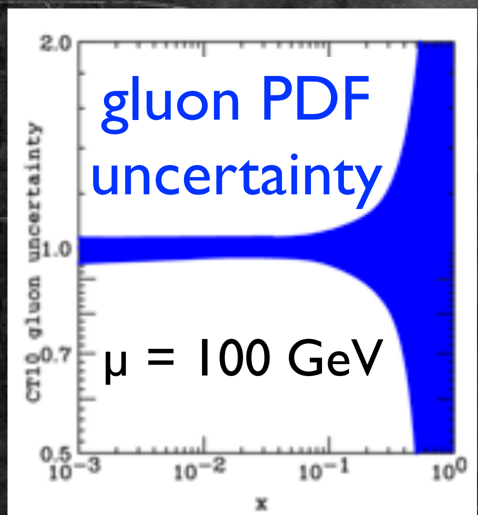
to access x > 0.3, one needs isolated photon with $p_T = x_T \sqrt{s}/2$ > 10-20 GeV

[D. D'Enterria, Physics at AFTER using LHC beams, ECT* Trento, Feb. 2013]



Gluon PDF

p-p



gluon PDF at high x :

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[D. D'Enterria, Physics at AFTER using LHC beams, ECT Trento, Feb. 2013]*

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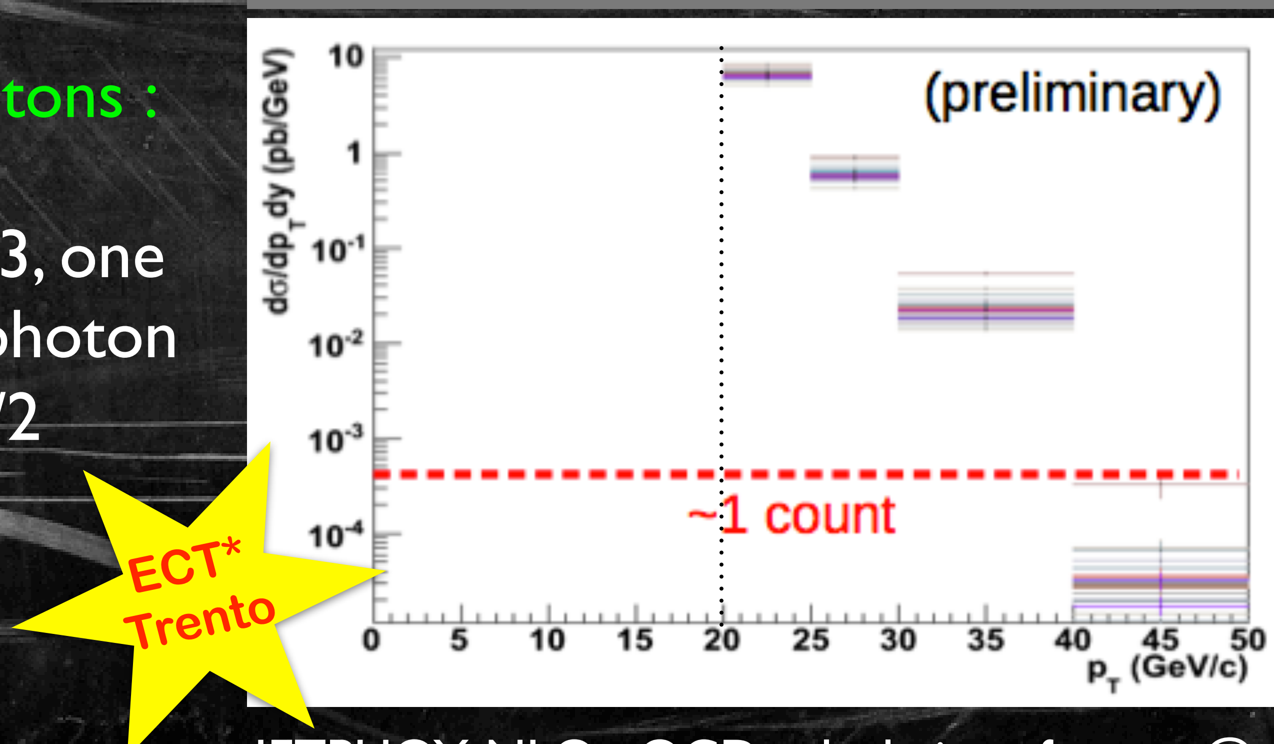
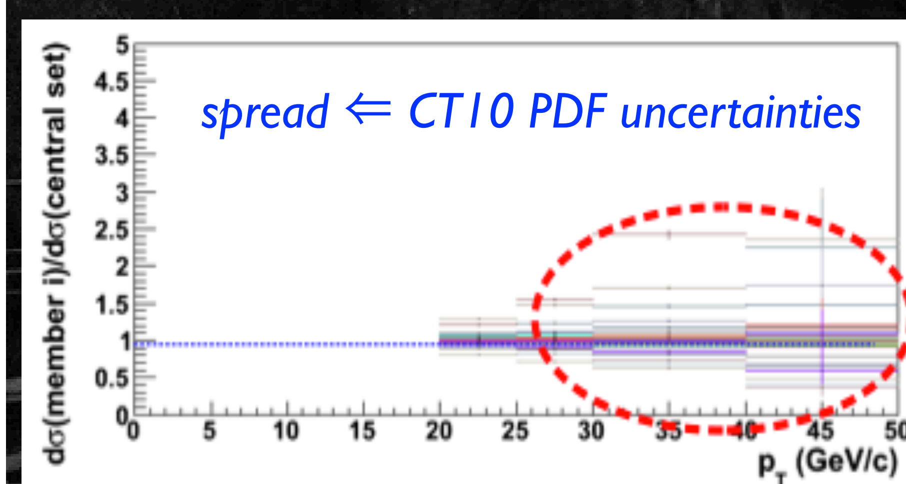


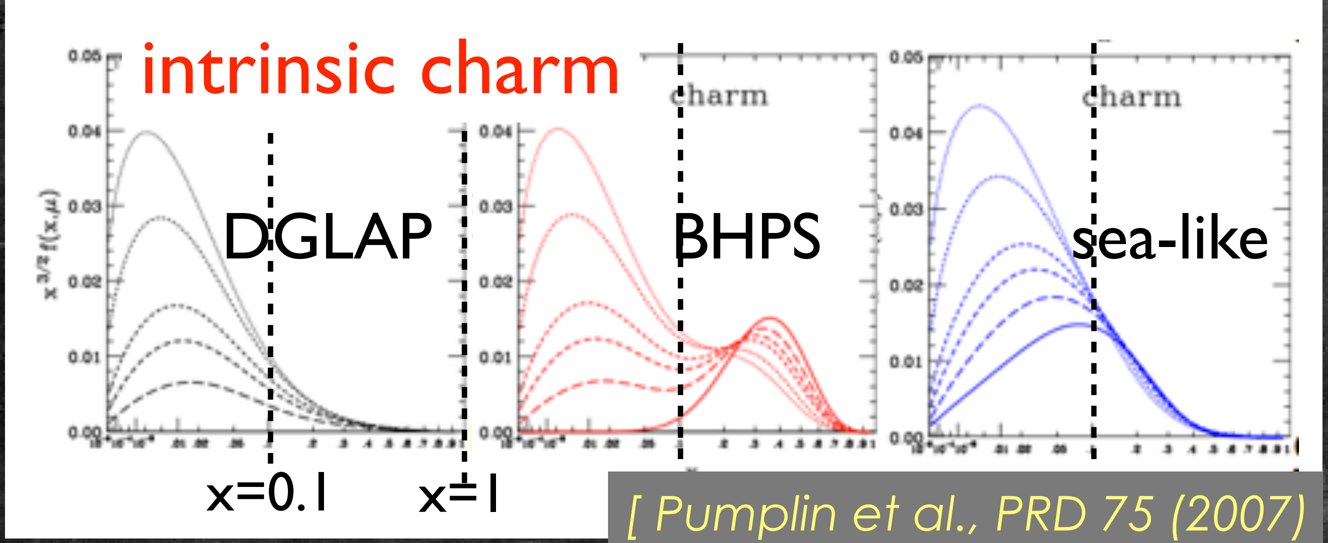


JETPHOX NLO pQCD calculations for p-p @ $\sqrt{s}$ = 115 GeV, |y| < 0.5

Luminosity ~ 2. 10^3 pb^{-1}/year, with a10 cm H_2-target

Heavy quark PDF

p-p



[Pumplin et al., PRD 75 (2007) 054029]

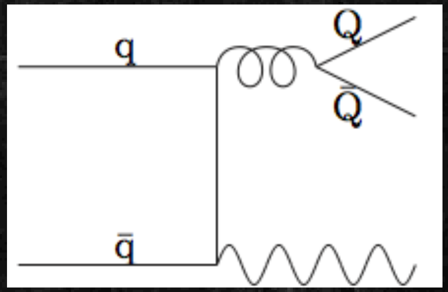
charm (and bottom) PDF at high x :
discriminate all charm PDFs currently in agreement with DIS data

exp. probes :

- open charm, open beauty
- new open c, b hadrons at high x_F ?

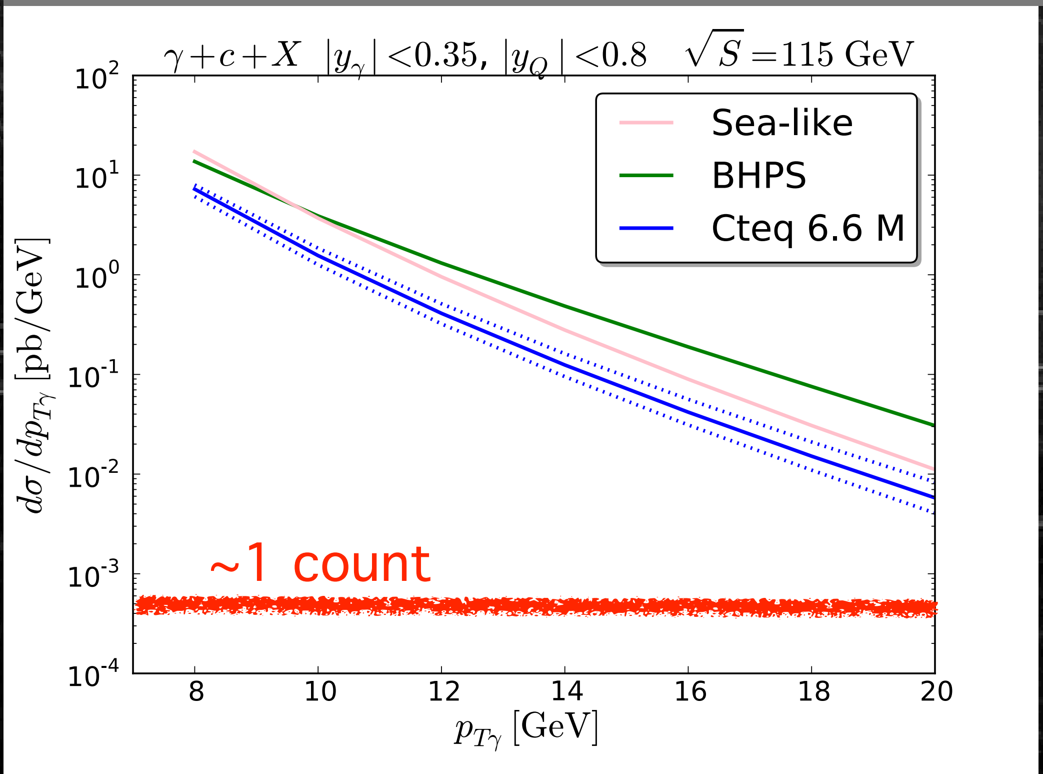
[Chang and Peng, PLB 704 (2011) 197]

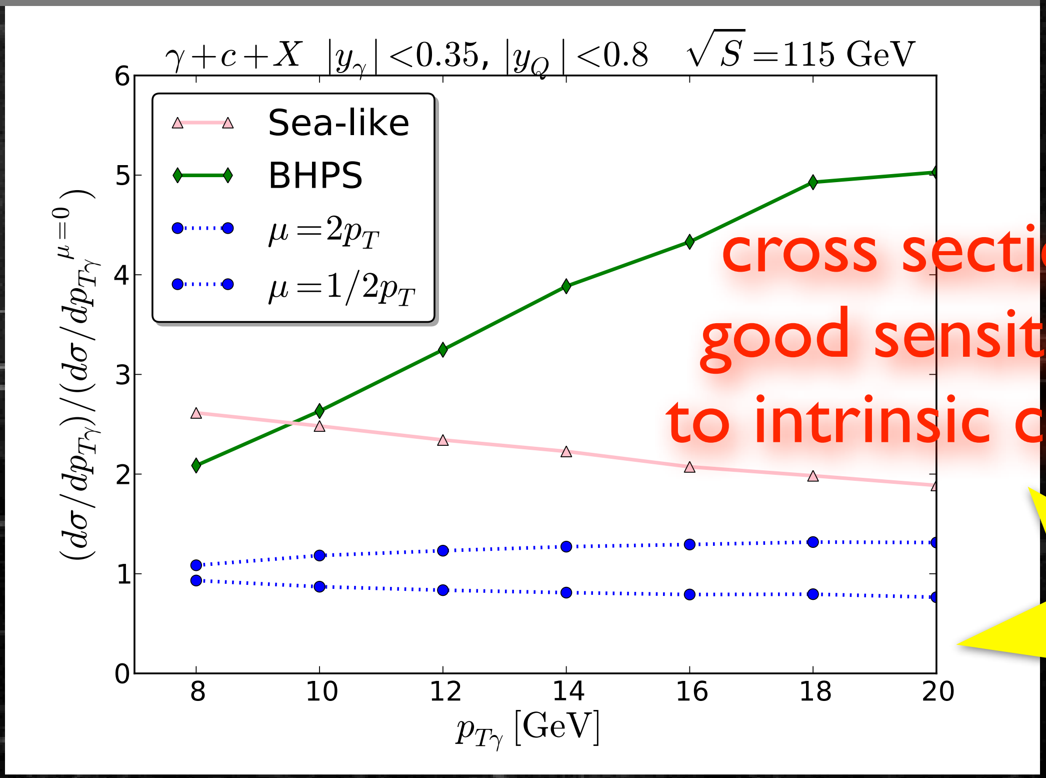
- γ + c , γ + b production



dominant diagram : photon couples to initial quarks

[T. Stavreva, Physics at AFTER using LHC beams, ECT Trento, Feb. 2013]*



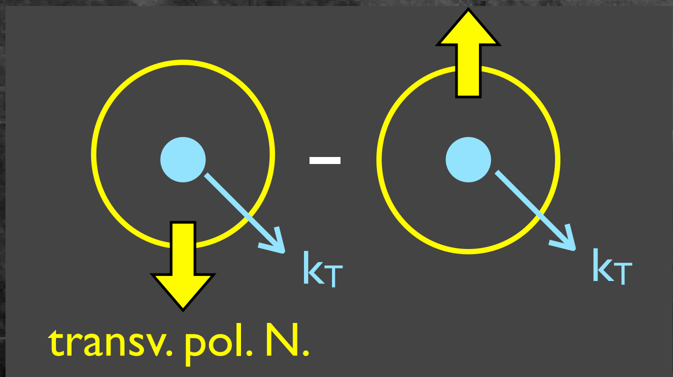


cross section : good sensitivity to intrinsic charm

ECT* Trento

Quark momentum tomography – Sivers Effect

p–p↑

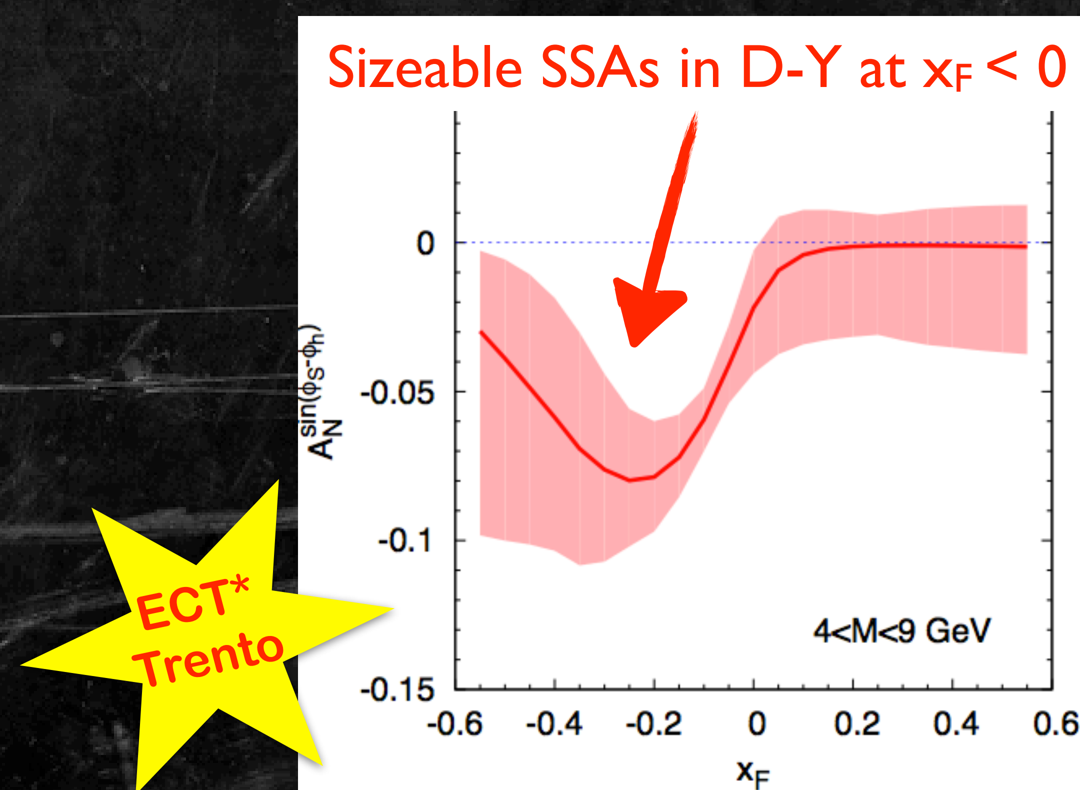


Sivers function :
Correlation between parton k_T and nucleon spin

- Sivers function from transverse Single Spin Asymmetries (SSAs)
- Access to quark TMDs in polarised Drell-Yan (excluding heavy flavors)
- Important test of QCD : test sign change between SIDIS and DY
  - Complementary with COMPASS

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

Sizeable SSAs in D-Y at $x_F < 0$



[M. Anselmino, Physics at AFTER using LHC beams, ECT* Trento, Feb. 2013]

Status and outlooks

M. Anselmino (Torino), R. Arnarldi (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) ...

AFTER @ LHC

- first paper on physics opportunities Phys. Rep. 522 (2013) 239
- webpage after.in2p3.fr
- workshops :
  - ✓ 10 days at Trento earlier in February 2013
  - ✓ 3 days, end November 2013, joint LUA9-AFTER meeting at IPN Orsay / LAL
  - ✓ next large workshop : 2014, January 12-17, at Les Houches
- Looking for partners !
- Target schedule : the installation of the extraction system should coincide with a LHC Long Shutdown.

Program & registration :

http://indico.in2p3.fr/event/AFTER@LesHouches

Program & registration :

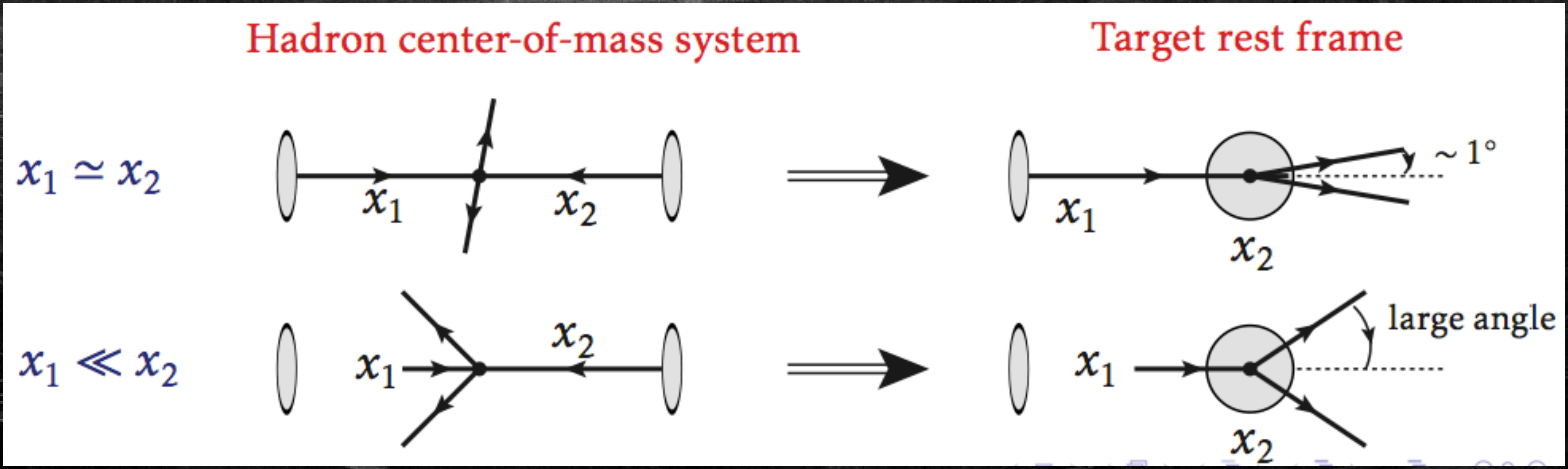
http://indico.in2p3.fr/event/AFTER@LesHouches

Program & registration :

http://indico.in2p3.fr/event/AFTER@LesHouches

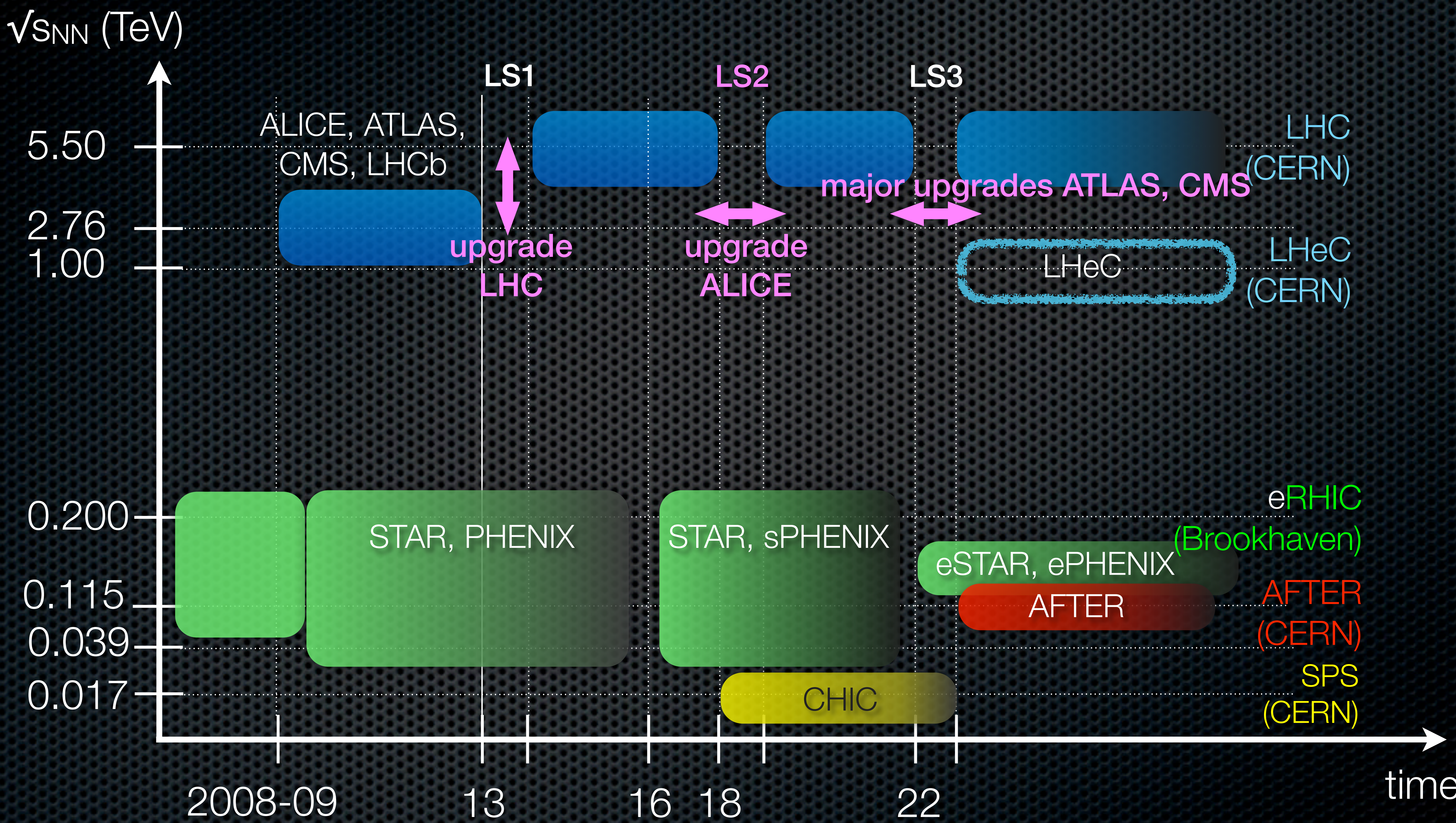
SPARE SLIDES

Backward physics



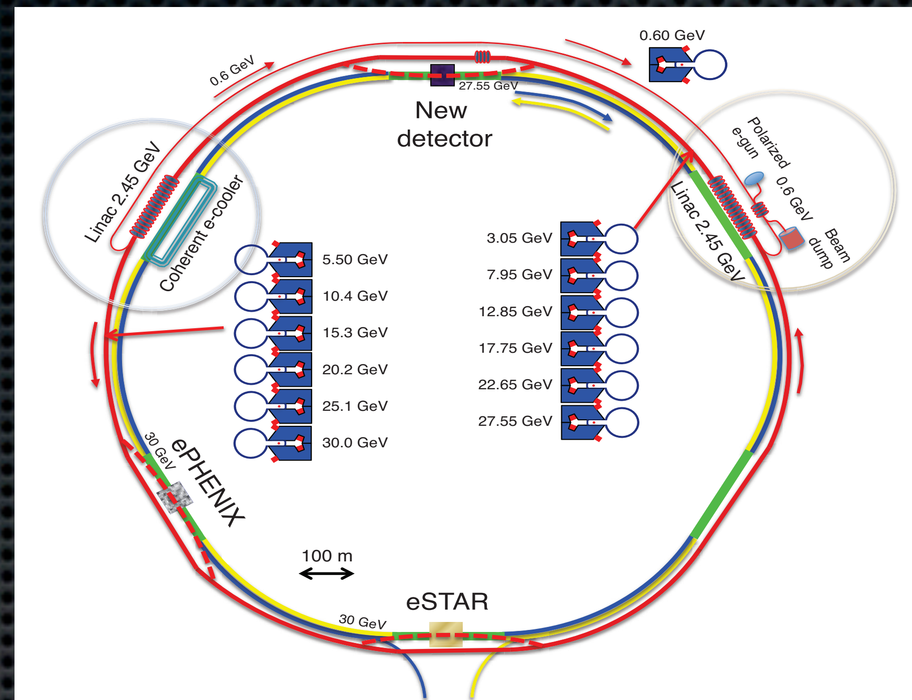
A rough timeline*

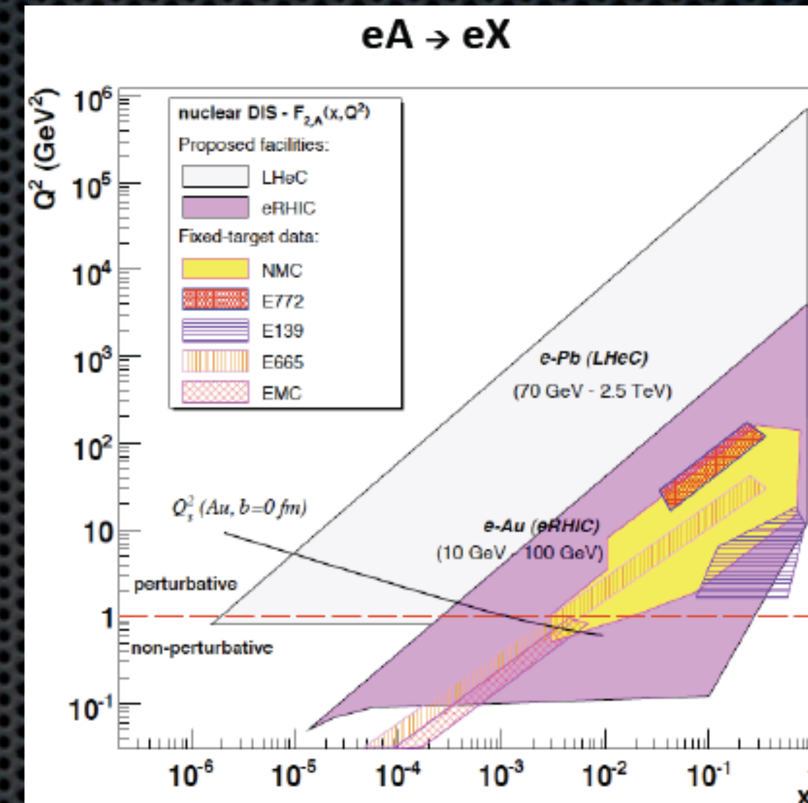
(*) focusing on AA, pA, eA, collisions only



LHeC / eRHIC : electron-ion colliders

[A. L. Deshpande, C. Marquet, A. Stasto, J.H. Lee, QM 2012]

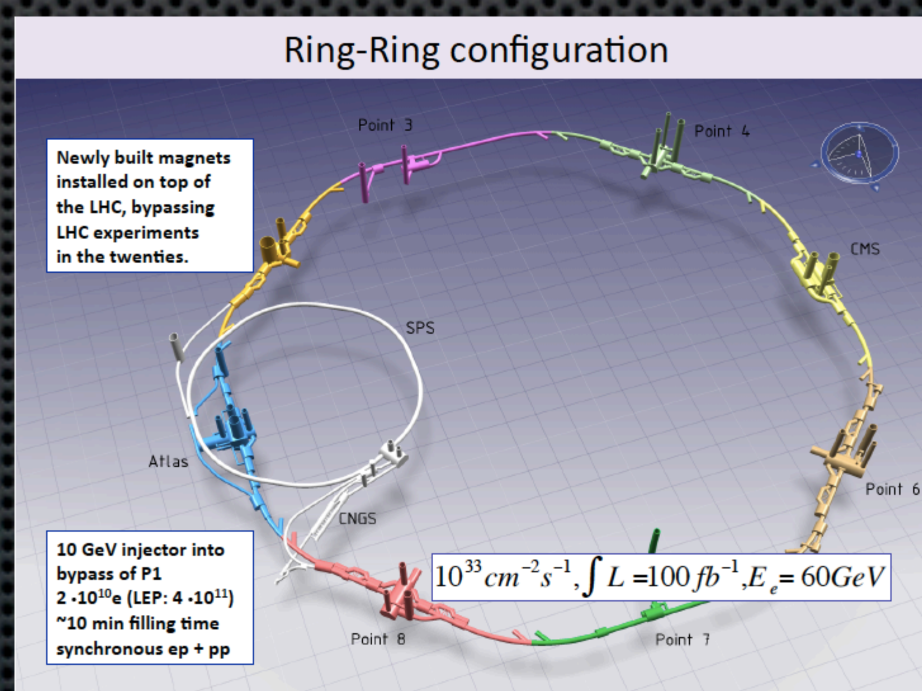


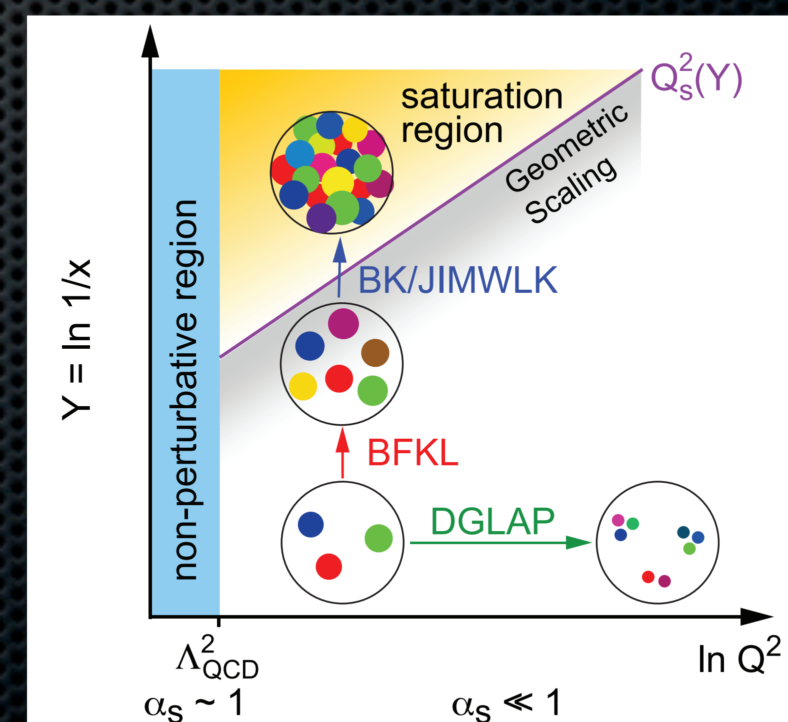


RHIC @ BNL

up to 140 (90) GeV ep (eA)

INT Report: arXiv:1108.1713v2





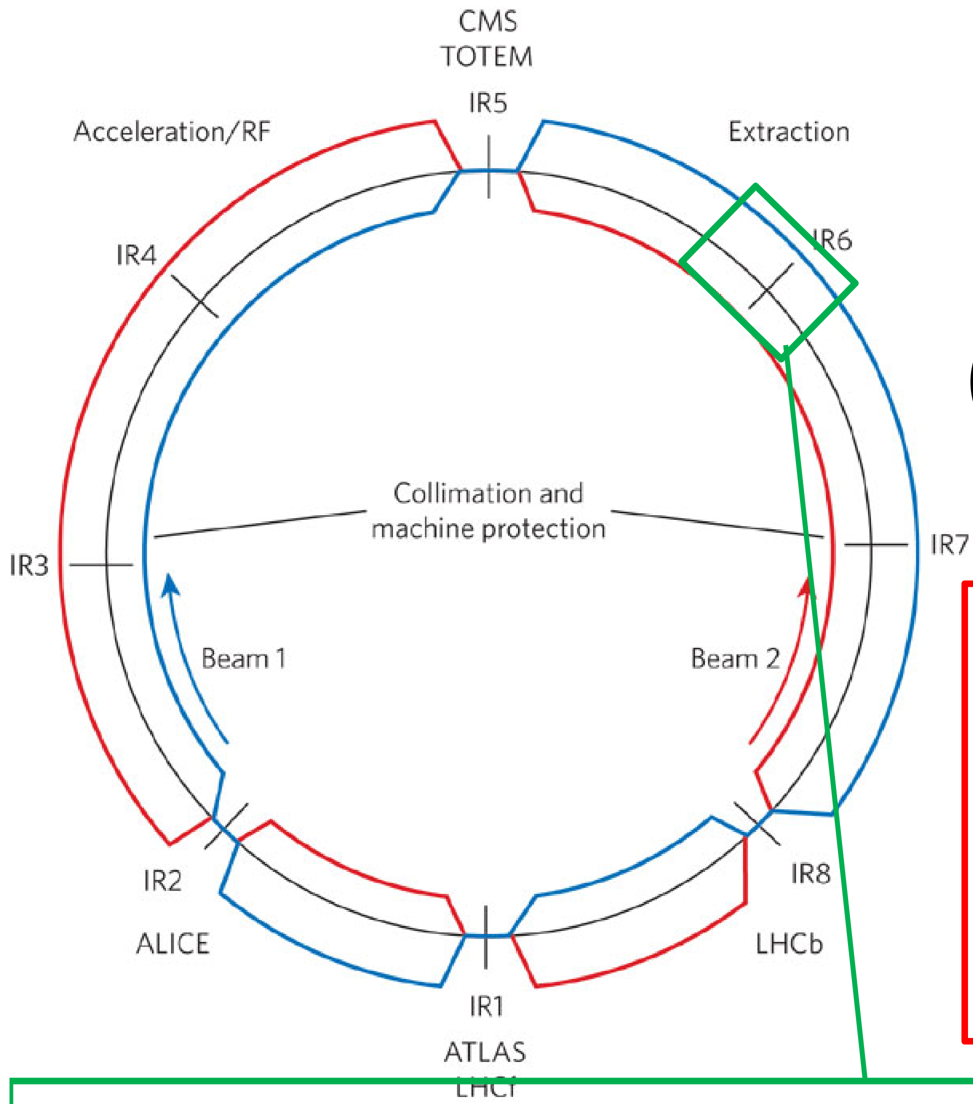
LHC @ CERN

up to 2 (1.2) TeV ep (eA)

CDR arXiv:1206.2913

One new possibility: LHC dump, IR6

(IR7 and IR3 to be investigated)

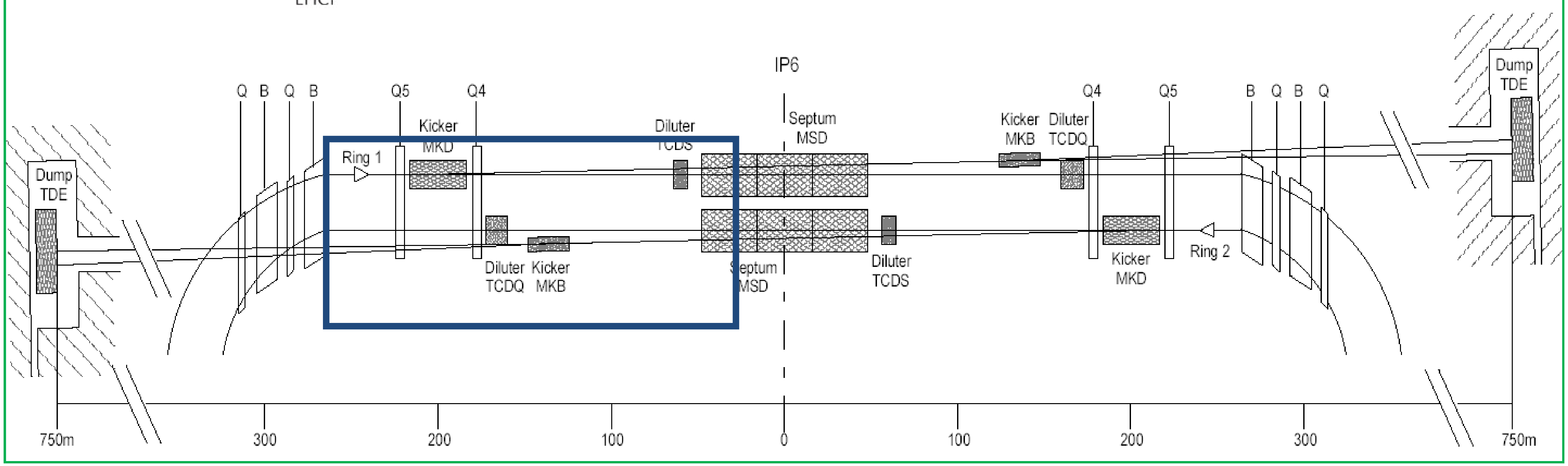


Nuclear Instruments and Methods in Physics Research B 234 (2005) 31–39

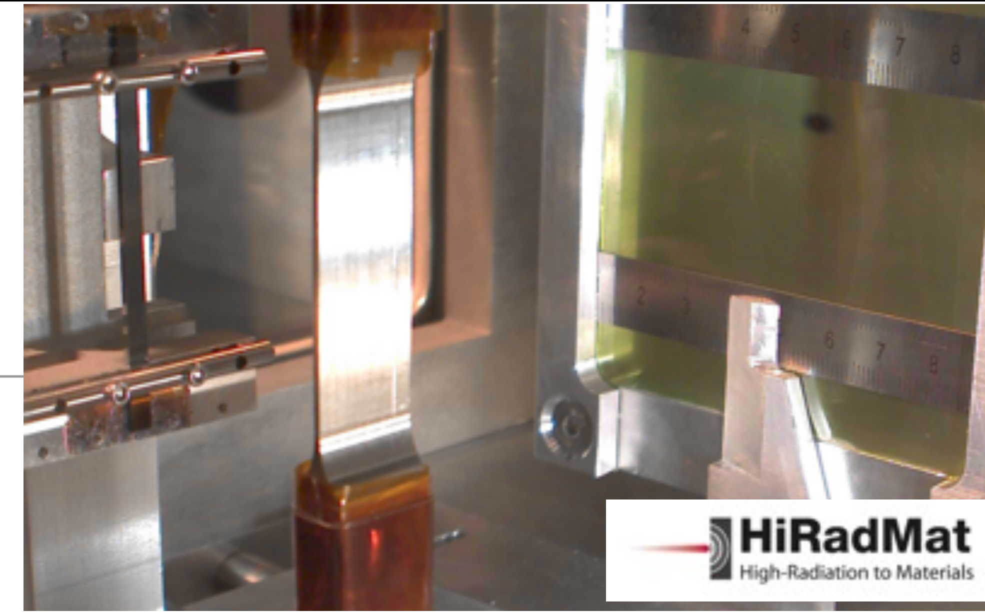
Strong crystalline fields – a possibility for extraction from the LHC

E. Uggerhøj, U.I. Uggerhøj *

Department of Physics and Astronomy, University of Aarhus,

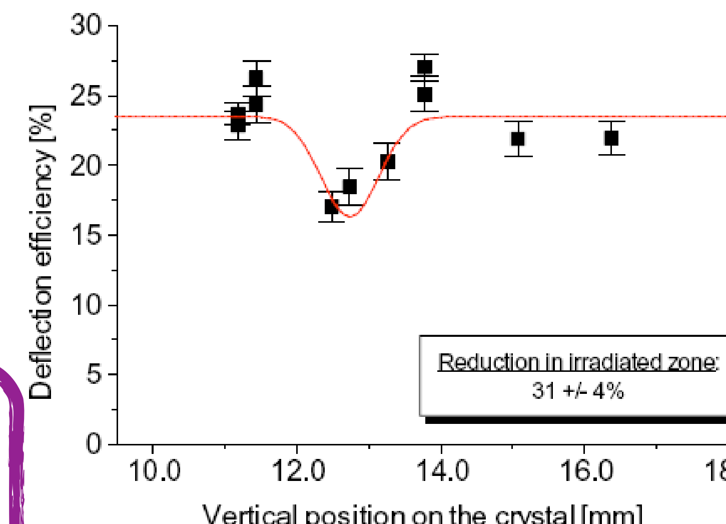


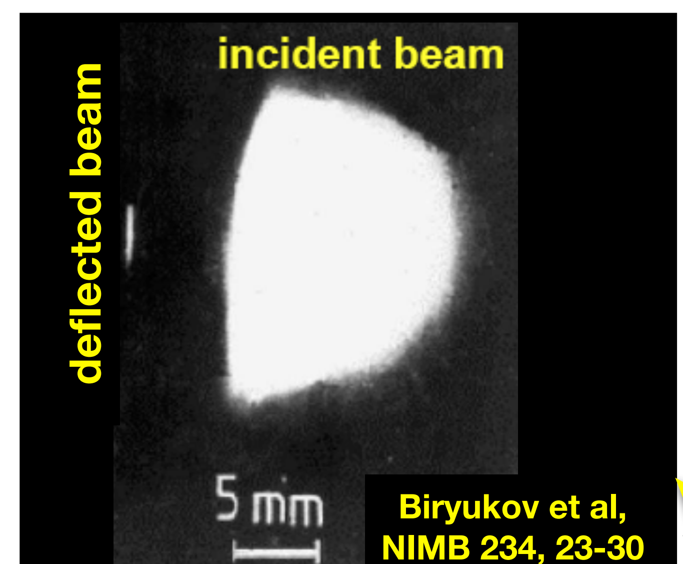
Crystal resistance to irradiation



- **IHEP U-70** (Biryukov et al, NIMB 234, 23-30):
  - 70 GeV protons, 50 ms spills of **10^{14} protons every 9.6 s**, several minutes irradiation
  - equivalent to 2 nominal LHC bunches for 500 turns every 10 s
  - 5 mm silicon crystal, **channeling efficiency unchanged**
- **SPS North Area - NA48** (Biino et al, CERN-SL-96-30-EA):
  - 450 GeV protons, 2.4 s spill of 5 x 10^{12} protons every 14.4 s, one year irradiation, **2.4 x 10^{20} protons/cm²** in total,
  - equivalent to several year of operation for a primary collimator in LHC
  - 10 x 50 x 0.9 mm³ silicon crystal, 0.8 x 0.3 mm² area irradiated, **channeling efficiency reduced by 30%**.
- **HRMT16-UA9CRY** (HiRadMat facility, November 2012):
  - 440 GeV protons, up to 288 bunches **in 7.2 μs**, 1.1 x 10^{11} protons per bunch (**3 x 10^{13} protons** in total)
  - energy deposition comparable to an asynchronous beam dump in LHC
  - 3 mm long silicon crystal, **no damage to the crystal after accurate visual inspection**, more tests planned to assess possible crystal lattice damage
    - **accurate FLUKA simulation of energy deposition** and residual dose

NA48 - Biino et al, CERN-SL-96-30-EA





ECT* Trento

Luminosities using :

7 TeV proton beam

pp, pd, pA $\sqrt{s}$ = 115 GeV

2.76 TeV lead beam

Pbp, Pbd, PbA $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239]

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

Table 1: Instantaneous and yearly luminosities obtained with an extracted beam of 5×10^8 p$^+$/s with a momentum of 7 TeV for various 1cm thick targets

extracted beam $N_{beam} = 5 .10^8$ p$^+$/s
9 months running / year ⇔ 10^7 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

Table 2: Instantaneous and yearly luminosities obtained with an extracted beam of 2×10^5 Pb/s with a momentum per nucleon of 2.76 TeV for various 1cm thick targets

extracted beam $N_{beam} = 2 .10^5$ Pb/s
1 month running / year ⇔ 10^6 s

Instantaneous luminosity :

$L = N_{beam} \times N_{target} = N_{beam} \times (\rho . e . N_A)$ with e = target thickness

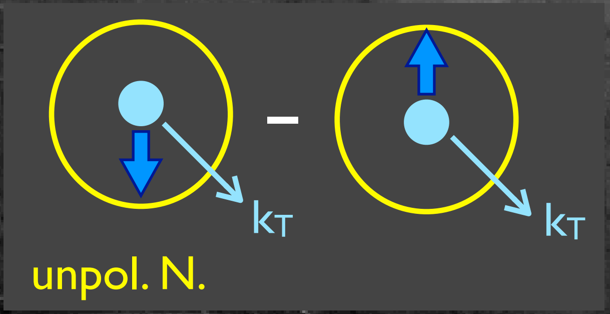
Planned luminosity for PHENIX :

- @ 200 GeV run14pp 12 pb^{-1}, run14dAu 0.15 pb^{-1}
- @ 200 GeV run15AuAu 2.8 pb^{-1} (0.13 nb^{-1} @ 62 GeV)

Nominal LHC luminosity PbPb 0.5 nb^{-1}

Gluon momentum tomography – Boer-Mulders

p–p

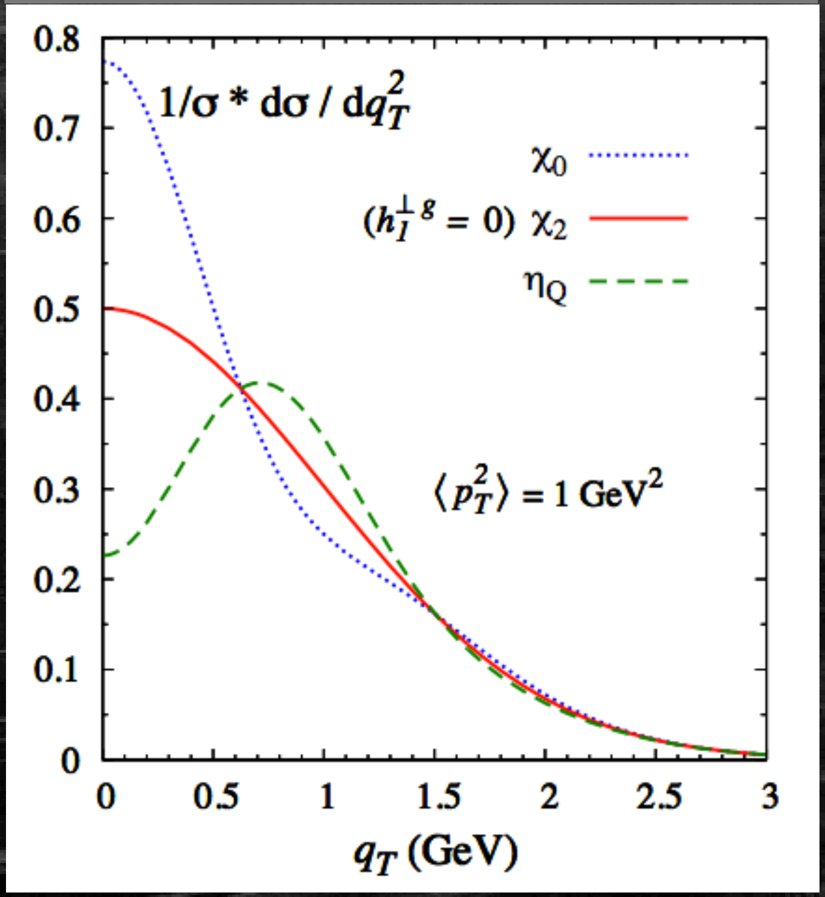


Boer-Mulders function :
Correlation between gluon k_T and gluon transverse spin

- unknown distribution of linearly polarised gluons in unpolarised N
- tool to determine if Higgs is a scalar or pseudo-scalar boson [Boer et al, PRL 108 (2012) 032002]
- can be accessed by modulations of the transverse-momentum distribution of $J^{PC} = 0^{\pm+}$ quarkonia (η_c , η_b , χ_{c0} , χ_{b0})

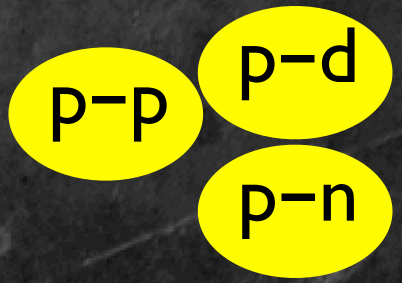
AFTER : large quarkonium yields + modern calorimetry (χ_Q detection)

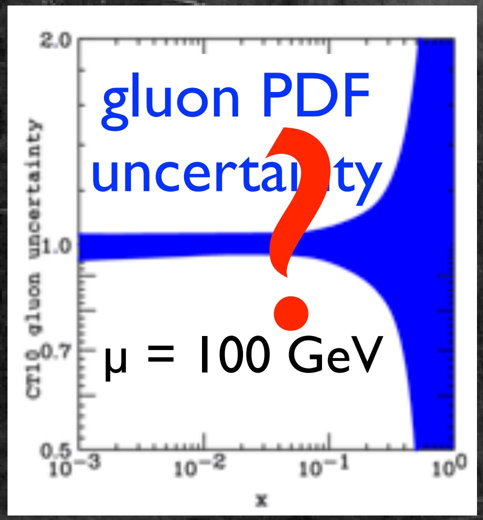
[Boer, Pisano, PRD 86 (2012) 094007]



double-node structure (unknown magnitude) and sign difference between scalar and pseudo-scalar

Gluon : proton vs neutron ?



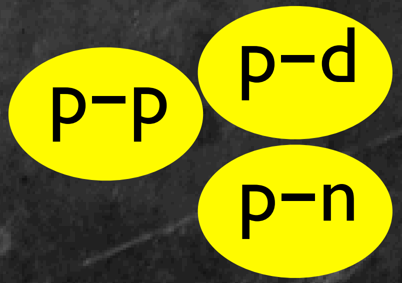


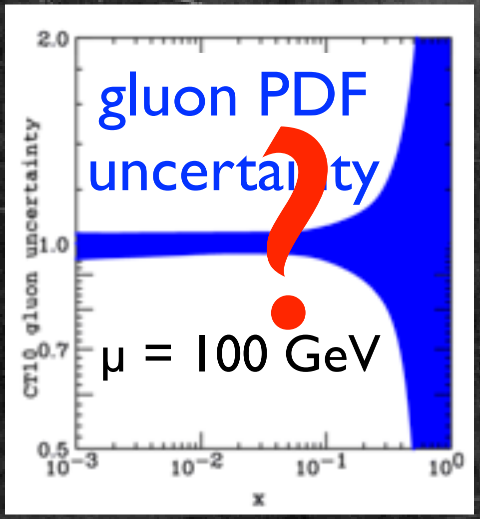
gluon PDF experimentally unknown for neutron

exp. probes :

- heavy quarkonia
- isolated photons
- high p_T jets

Gluon : proton vs neutron ?





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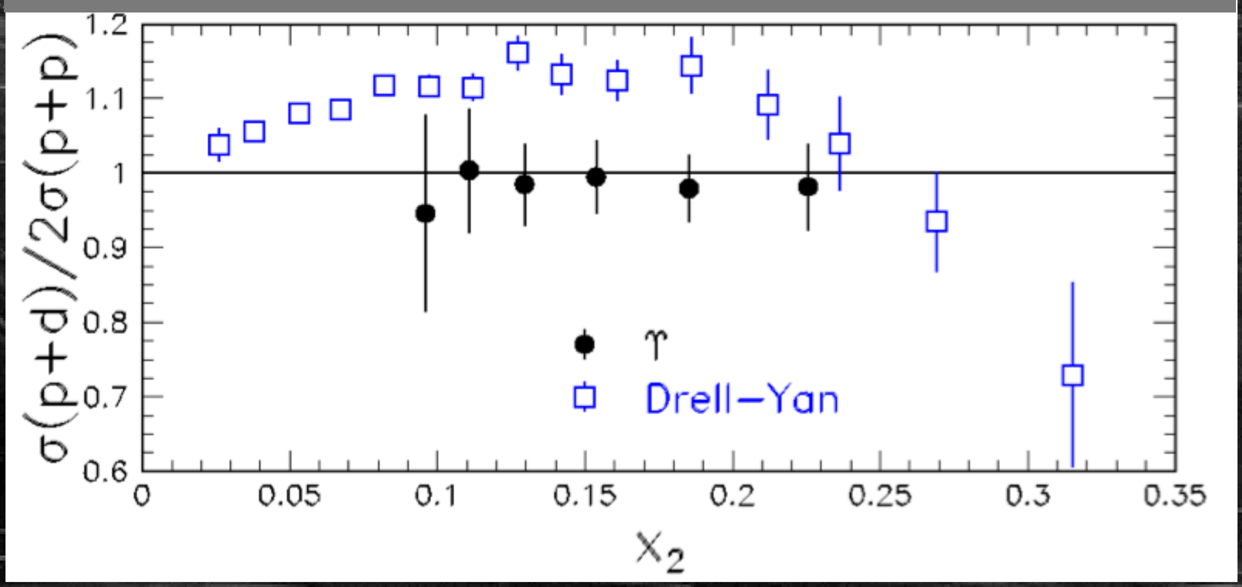
[E866, PRL 100 (2008) 062301]



Pioneering measurement by E866 @ Fermilab :

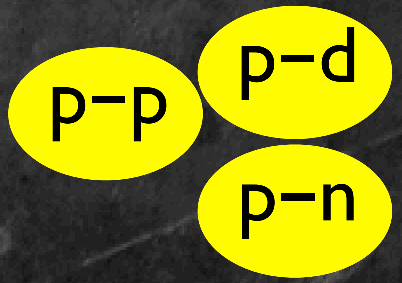
- using ϒ
- at $Q^2 \sim 100$ GeV^2 similar gluon distribution in proton and neutron

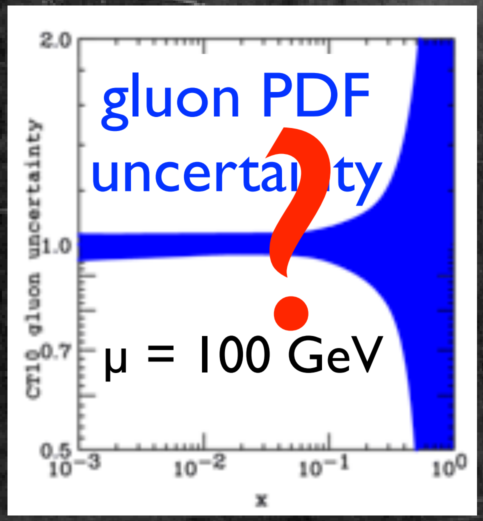
could be extended using J/ψ :

- to (~10x) lower x
- to lower Q^2

Need high luminosity.

Gluon : proton vs neutron ?





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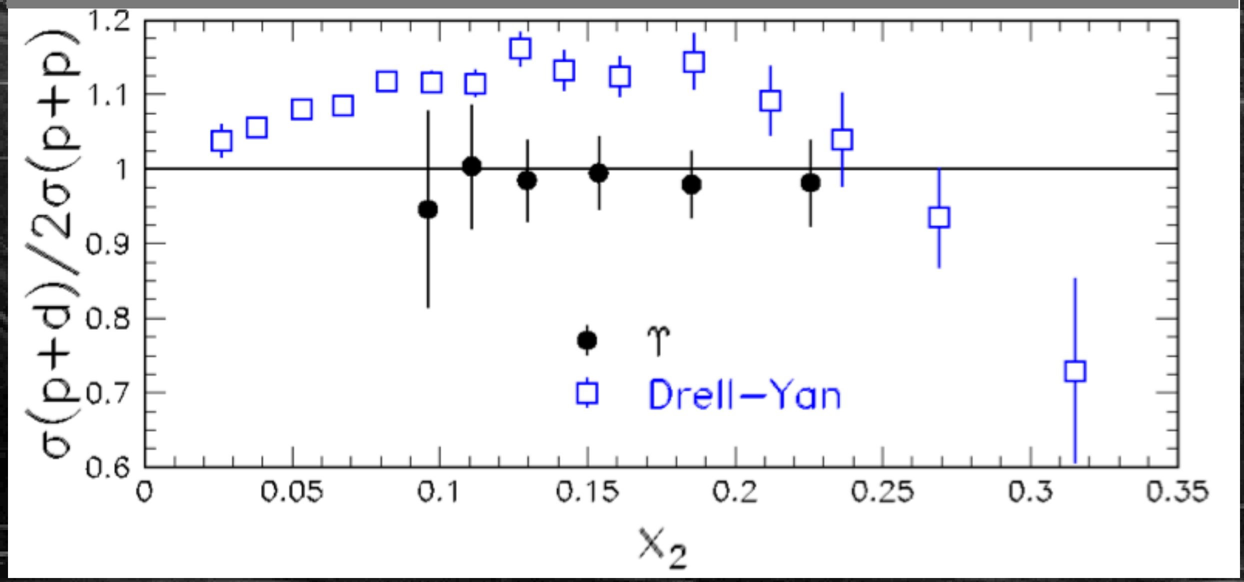


Pioneering measurement by E866 @ Fermilab :

- using ϒ
- at Q^2 ~ 100 GeV^2 similar gluon distribution in proton and neutron

could be extended using J/ψ :

- to (~10x) lower x
- to lower Q^2

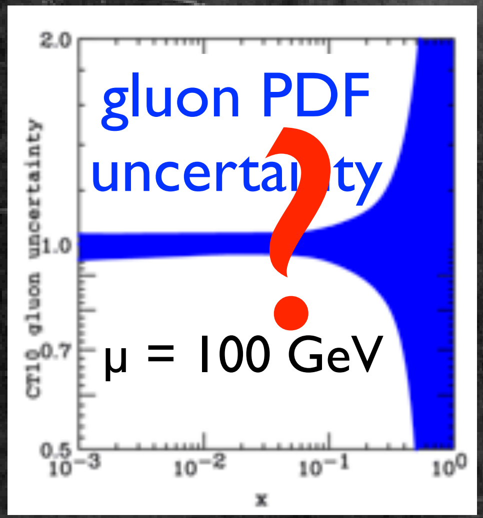
Need high luminosity.

[Lansberg et al., FBS 53 (2012) 11]

target	yearly lumi(fb^{-1})	$B_{ll} \frac{dN_{J/\psi}}{dy}\Big\vert_{y=0}$	$B_{ll} \frac{dN_{\Upsilon}}{dy}\Big\vert_{y=0}$
1 m Liq. H_2	20	$4.0\ 10^8$	$8.0\ 10^5$
1 m Lid. D_2	24	$9.6\ 10^8$	$1.9\ 10^6$

Gluon : proton vs neutron ?

p-p
p-d
p-n



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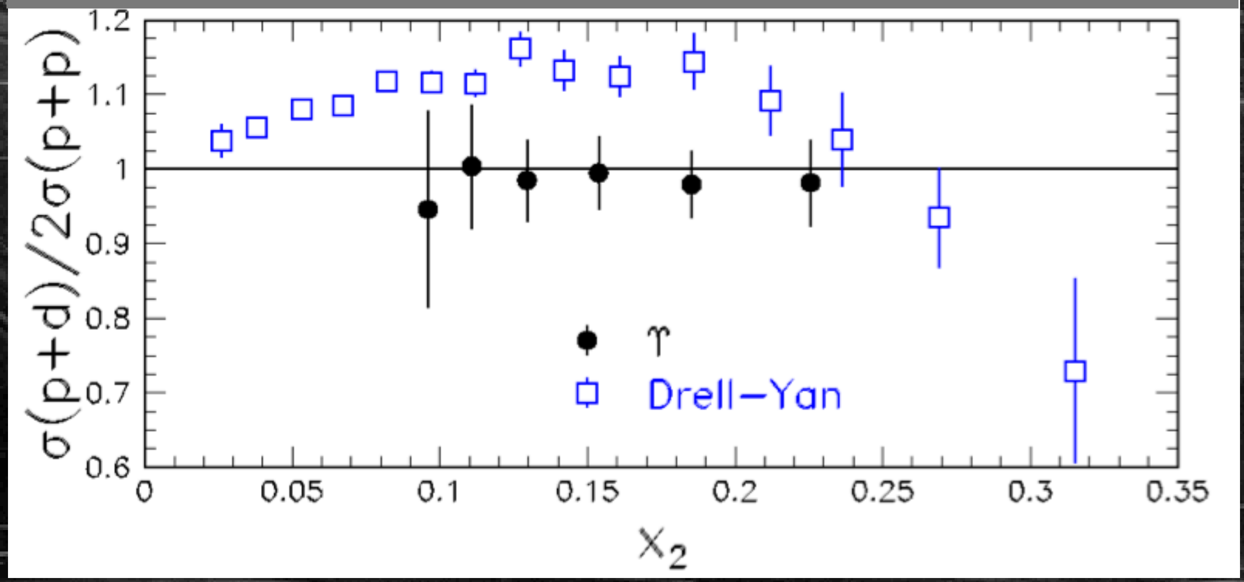

Pioneering measurement by E866 @ Fermilab :

- using Υ
- at Q^2 ~ 100 GeV^2 similar gluon distribution in proton and neutron

could be extended using J/ψ :

- to (~10x) lower x
- to lower Q^2

Need high luminosity.

High energy + deuteron target : rare opportunity, feasible in AFTER

[Lansberg et al., FBS 53 (2012) 11]

target	yearly lumi(fb^{-1})	$B_{ll} \frac{dN_{J/\psi}}{dy}\Big\|_{y=0}$	$B_{ll} \frac{dN_{\Upsilon}}{dy}\Big\|_{y=0}$
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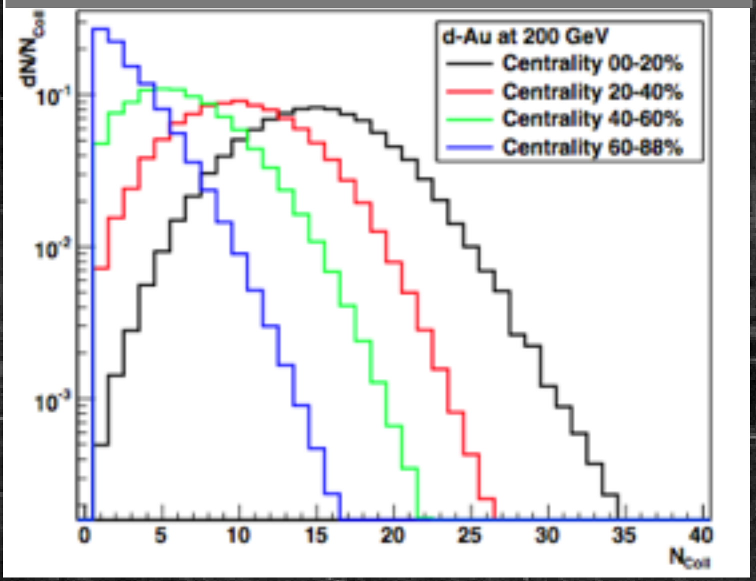
Gluon nPDF

p–A

Pb–p

- A dependence thanks to target versatility

[PHENIX, arXiv:1204.0777]



$\langle N_{coll} \rangle$ dependence ⇛ A dependence (à la NA50, NA60)

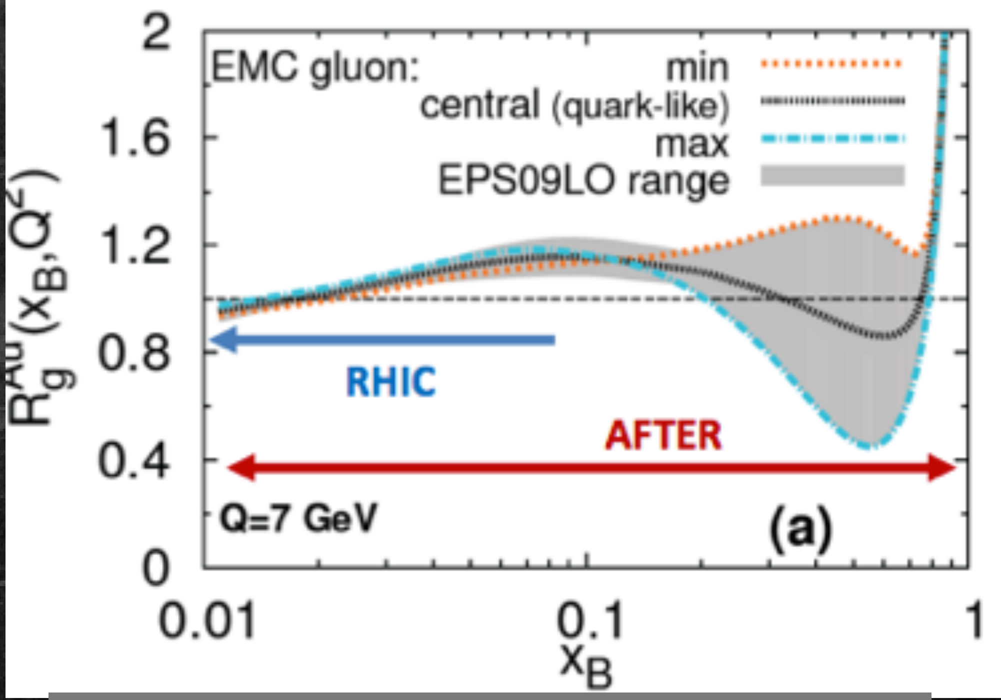
Gluon nPDF

p–A

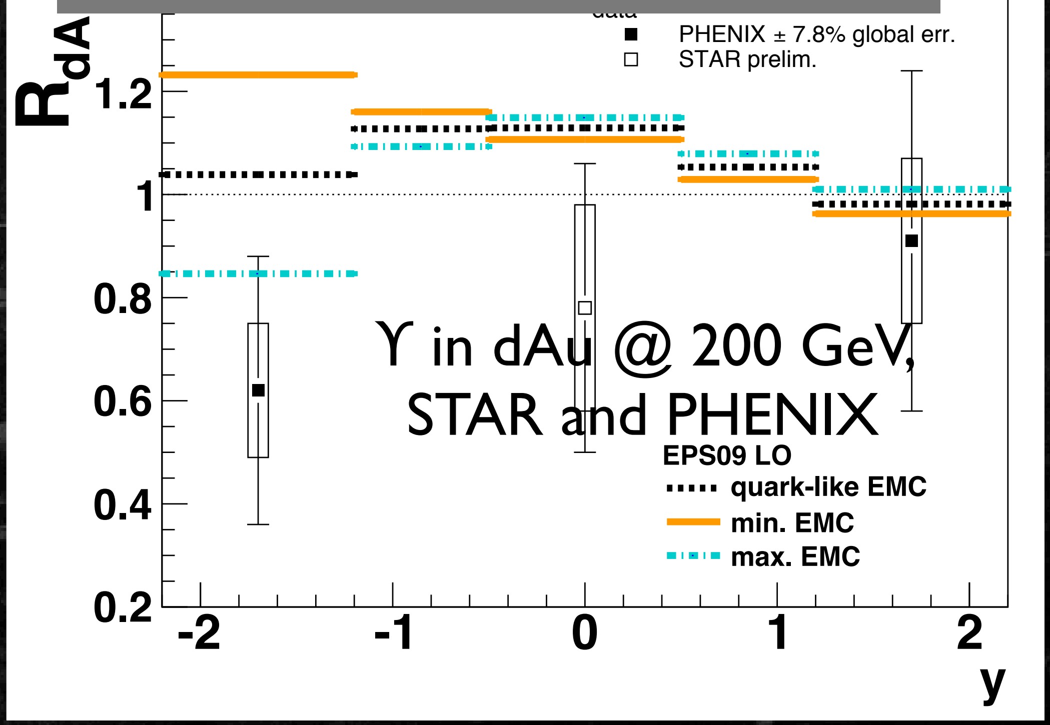
Pb–p

- A dependence thanks to target versatility
- nuclear PDF from intermediate to high x : antishadowing , EMC region , Fermi motion
- extraction using quarkonia, isolated photons, photon-jet correlation

nuclear modification of g PDF in Au



[E.G. Ferreiro et al., arXiv:1110.5047]



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p–A

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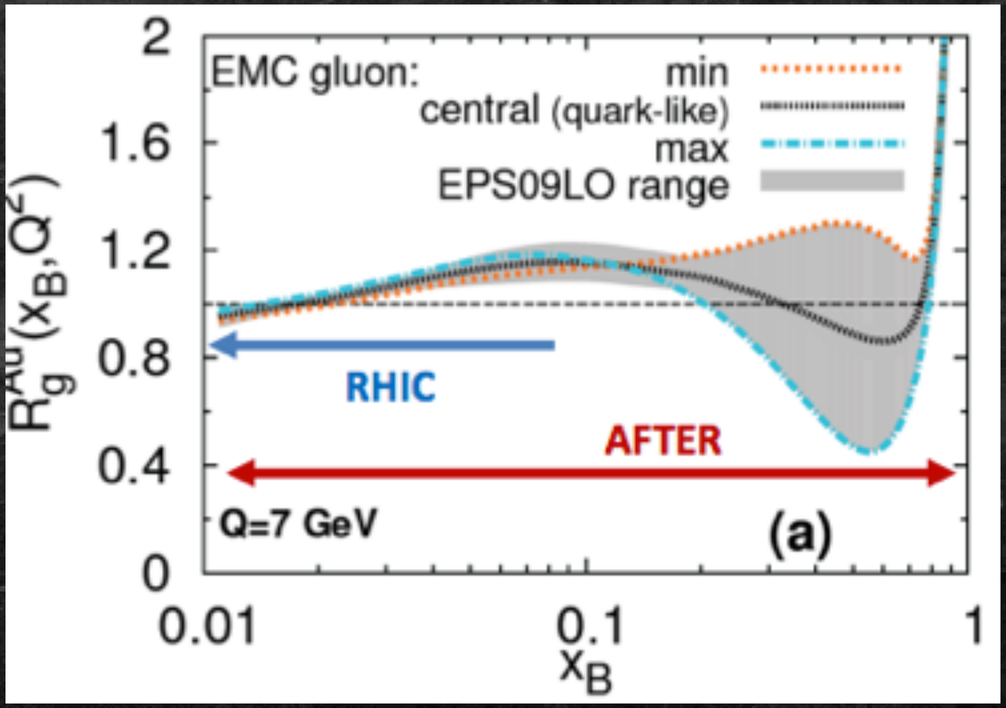
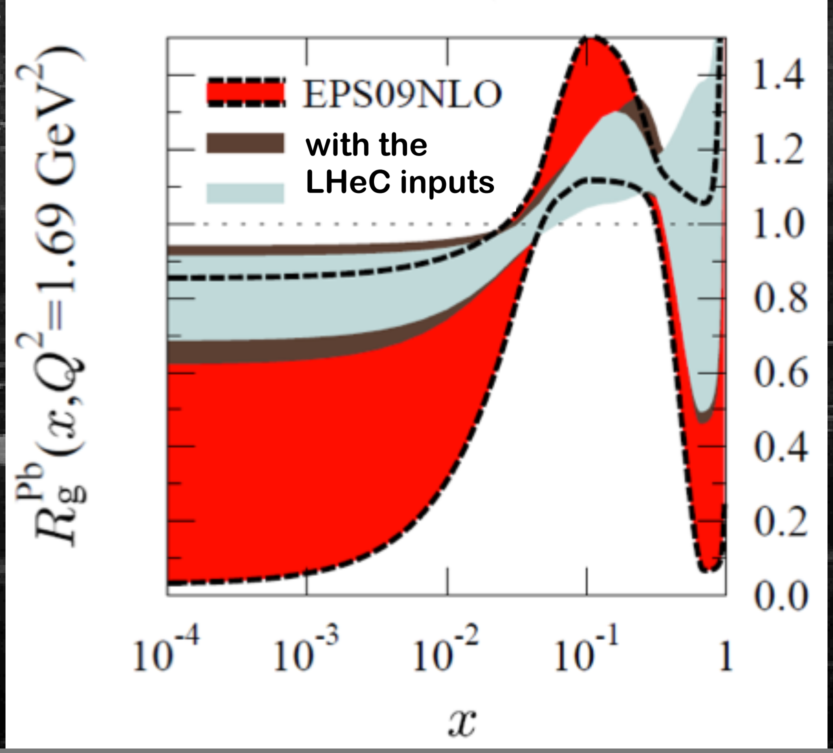
nuclear modification of g PDF in Au



nuclear modification of g PDF in Pb



[LHeC CDR, J. Phys. G 39 (2012) 075001]

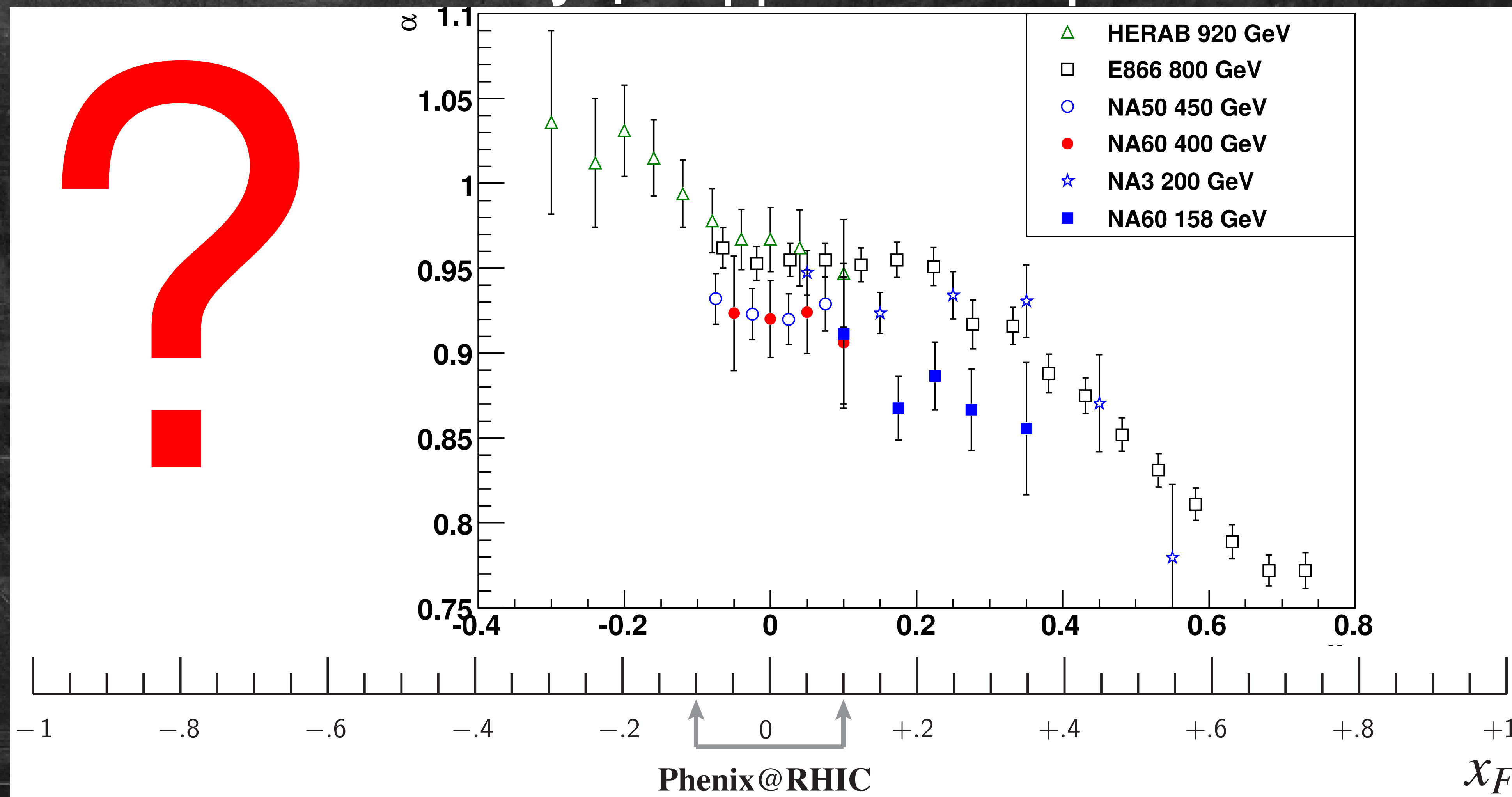
complementary with LHeC (focus at low x) and EIC (intermediate x)

The uncharted negative x_F region

p-A

- HeraB down to $x_F = -0.3$
- PHENIX @ RHIC : $|x_F| < 0.1$ (could be wider with Υ, but low stat.)
- CMS/ATLAS : $|x_F| < 5.10^{-3}$
- LHCb : $5.10^{-3} < x_F < 4.10^{-2}$

J/ψ suppression in pA



Precision studies of the nuclear matter :

First systematic access to the target-rapidity region, down to $x_F \rightarrow -1$

Questions

- Is the extraction of half the beam loss realistic ?
- Is the extracted flux constant over a (10h) fill ?
- Political problems aside, could we extract more than half the beam loss ?
- Are there any difficulties to extract Pb ions ?
- Would a better collimation of the LHC beam, by reducing the halo, decrease the flux of extracted particles ?
- Is it possible to extract during the beam-energy ramp ?

  for Pb, from $\sqrt{s_{NN}} = 19$ GeV up to 72 GeV.

Joint meeting

J.P. Lansberg @ Joint LUA9-AFTER meeting, Nov. 2013