The future in H.I.

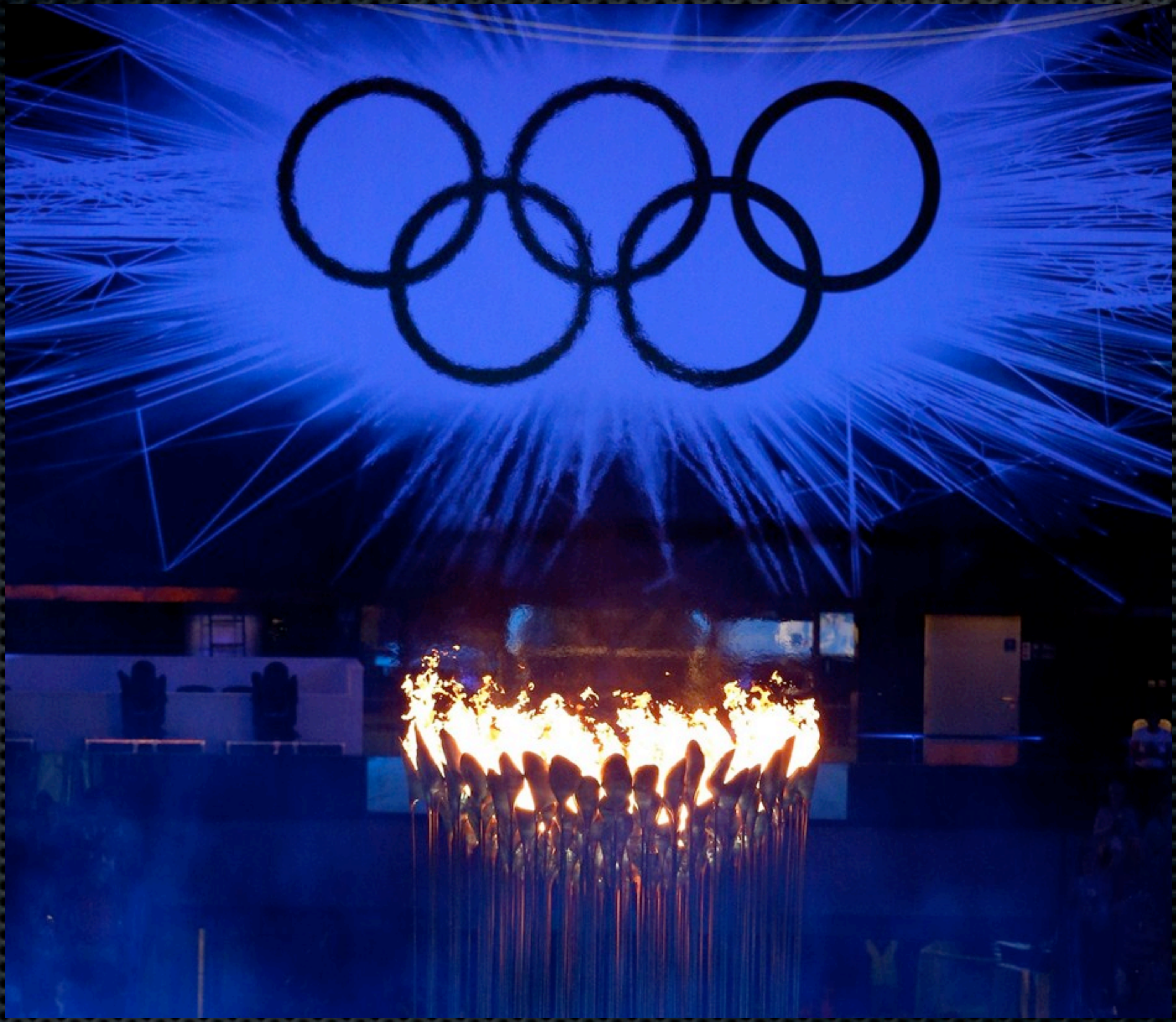
QM2012 + ESPG Cracow + personal biases

Andry Rakotozafindrabe

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

Physics at a Fixed Target ExpeRiment (AFTER) using the LHC beams
ECT Trento, Feb. 2013*

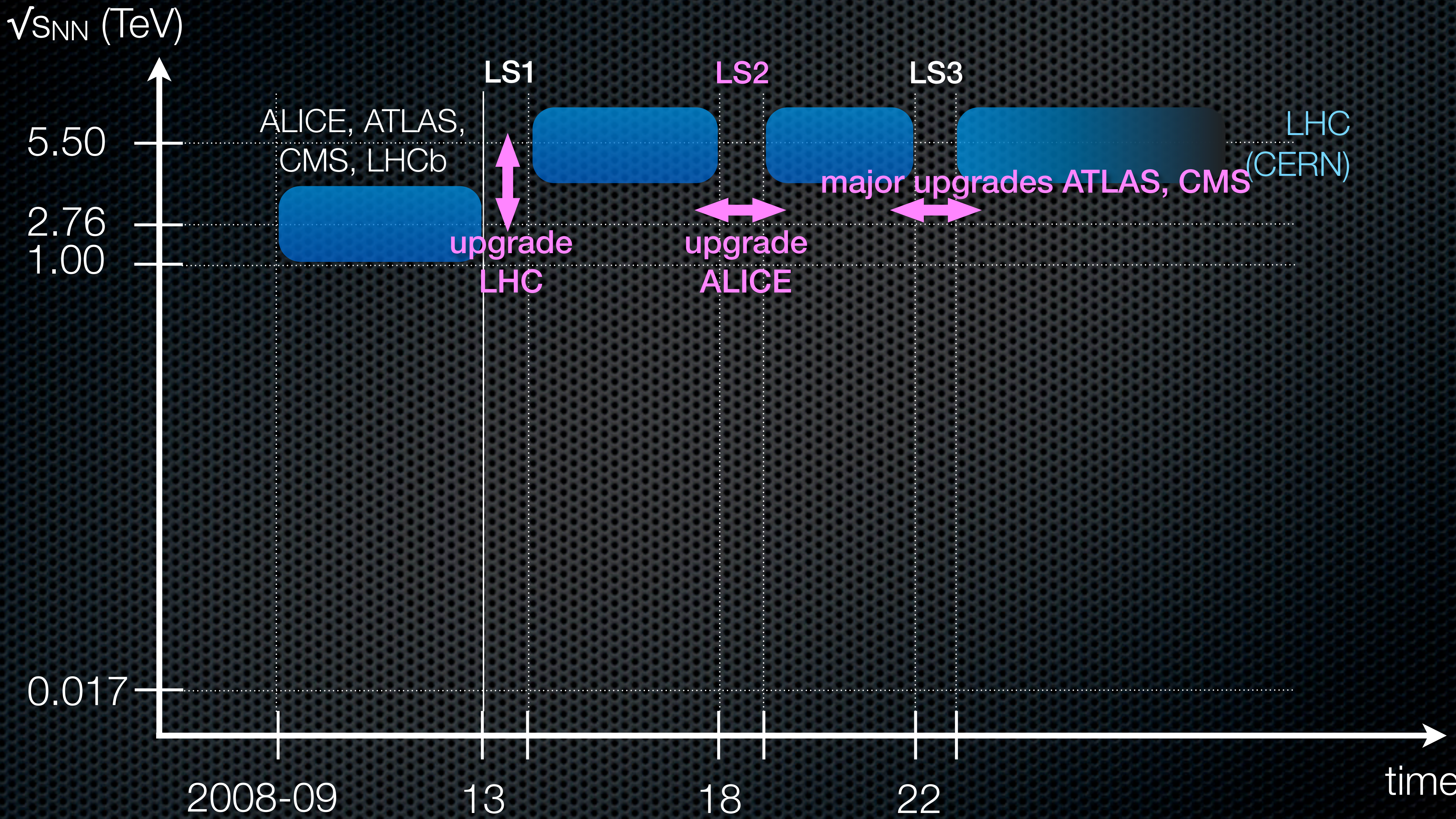
« Faster, Higher, Stronger »



Olympic games, London, 2012

A rough timeline*

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



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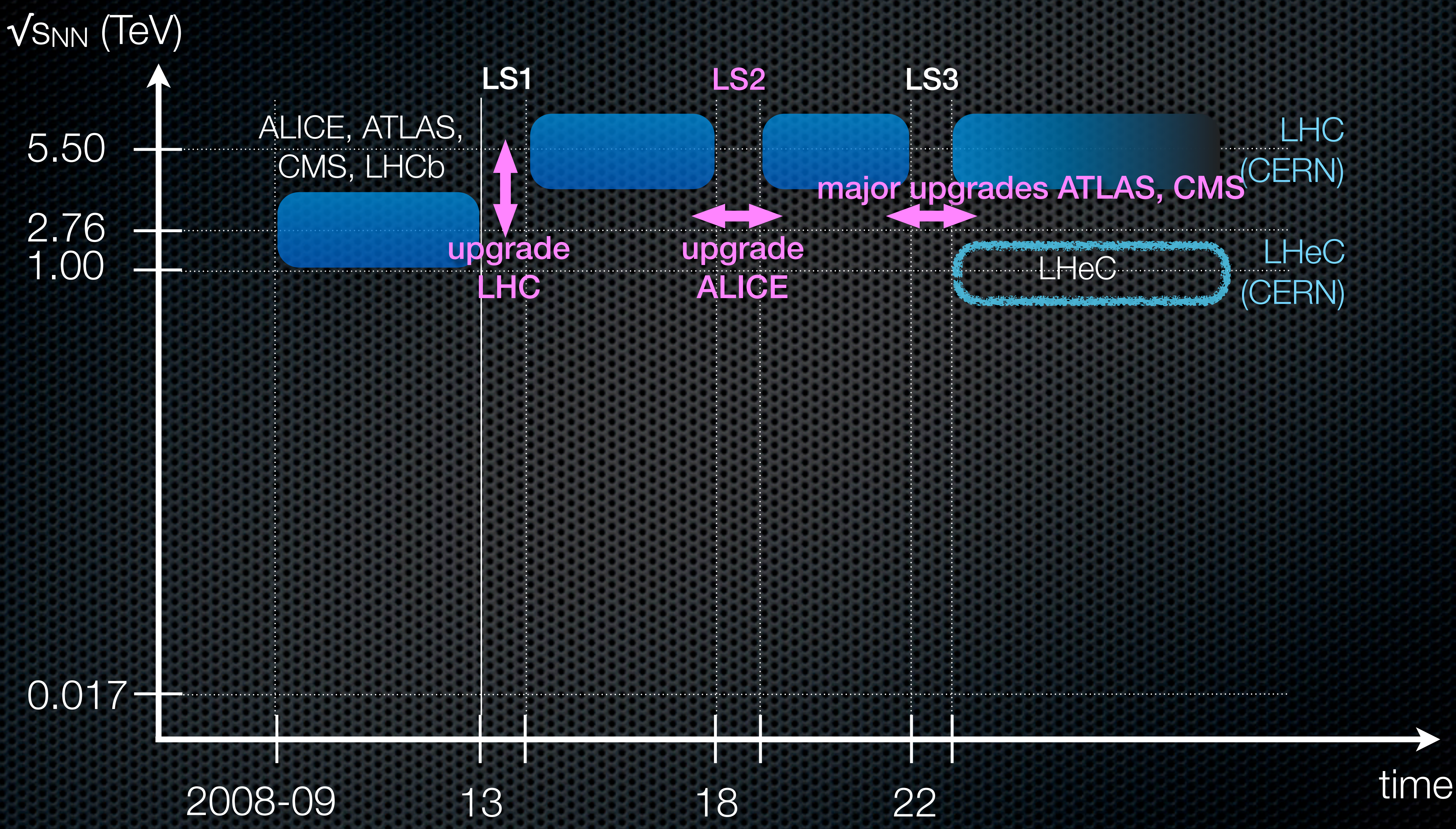

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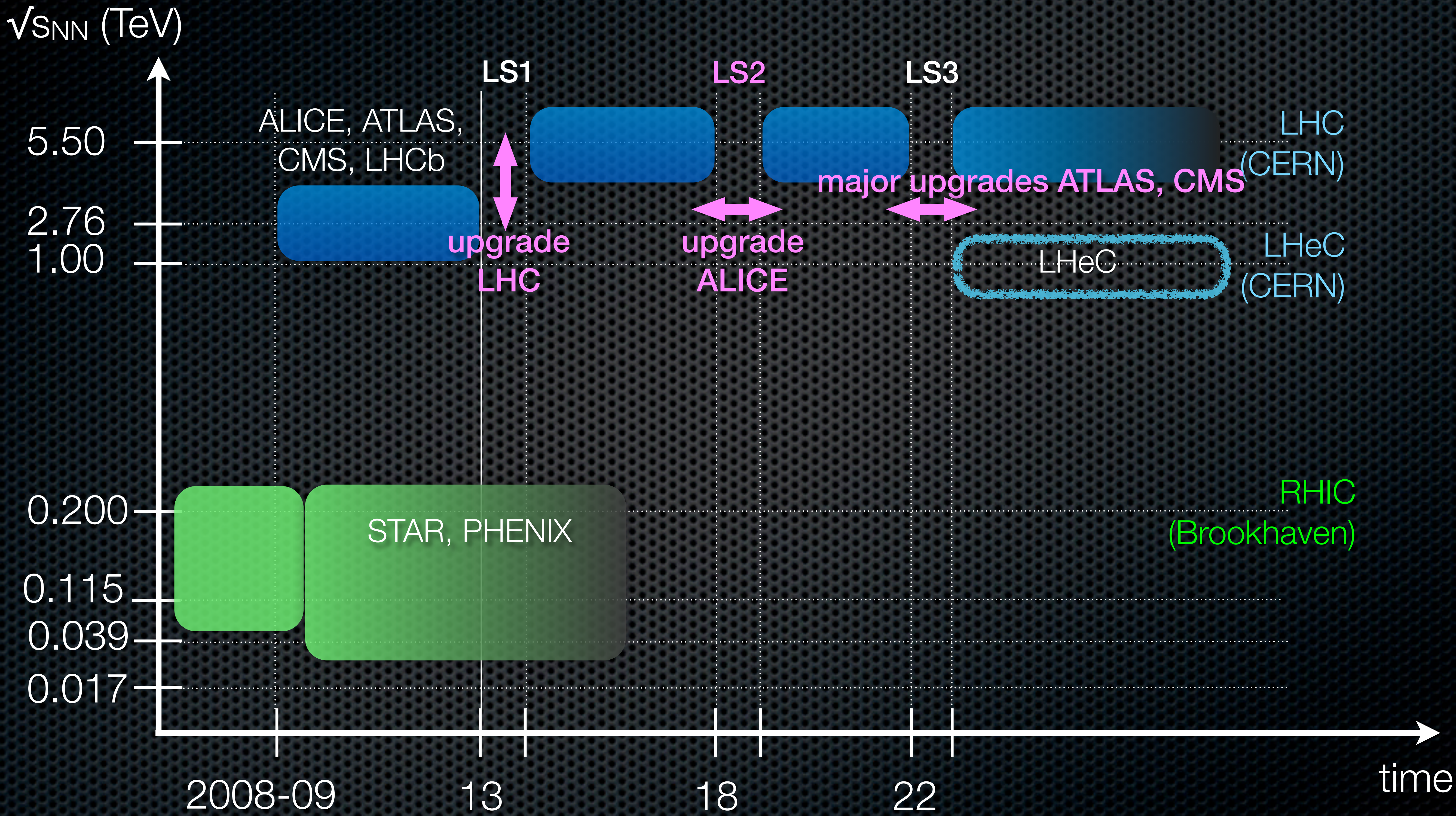

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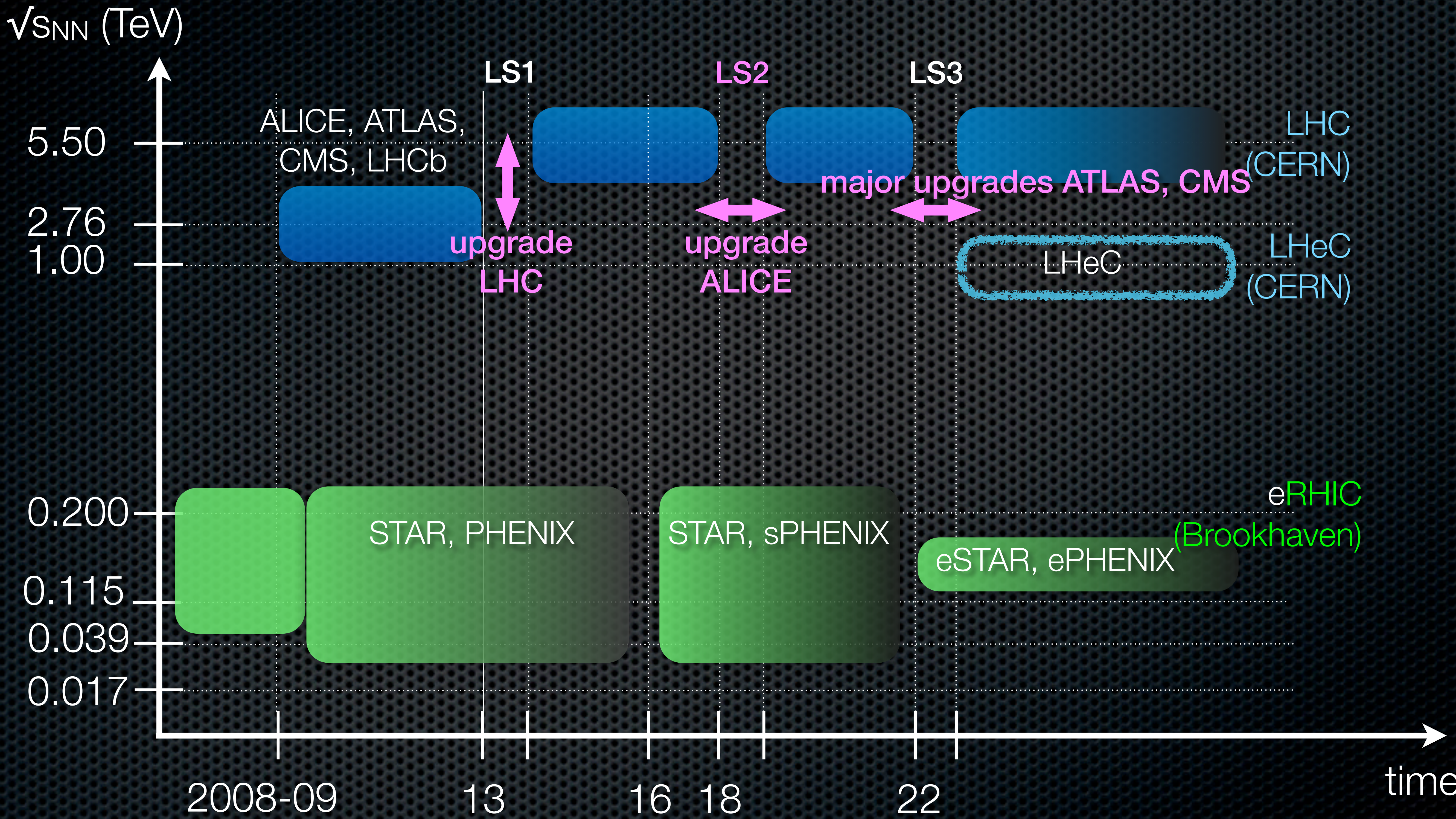

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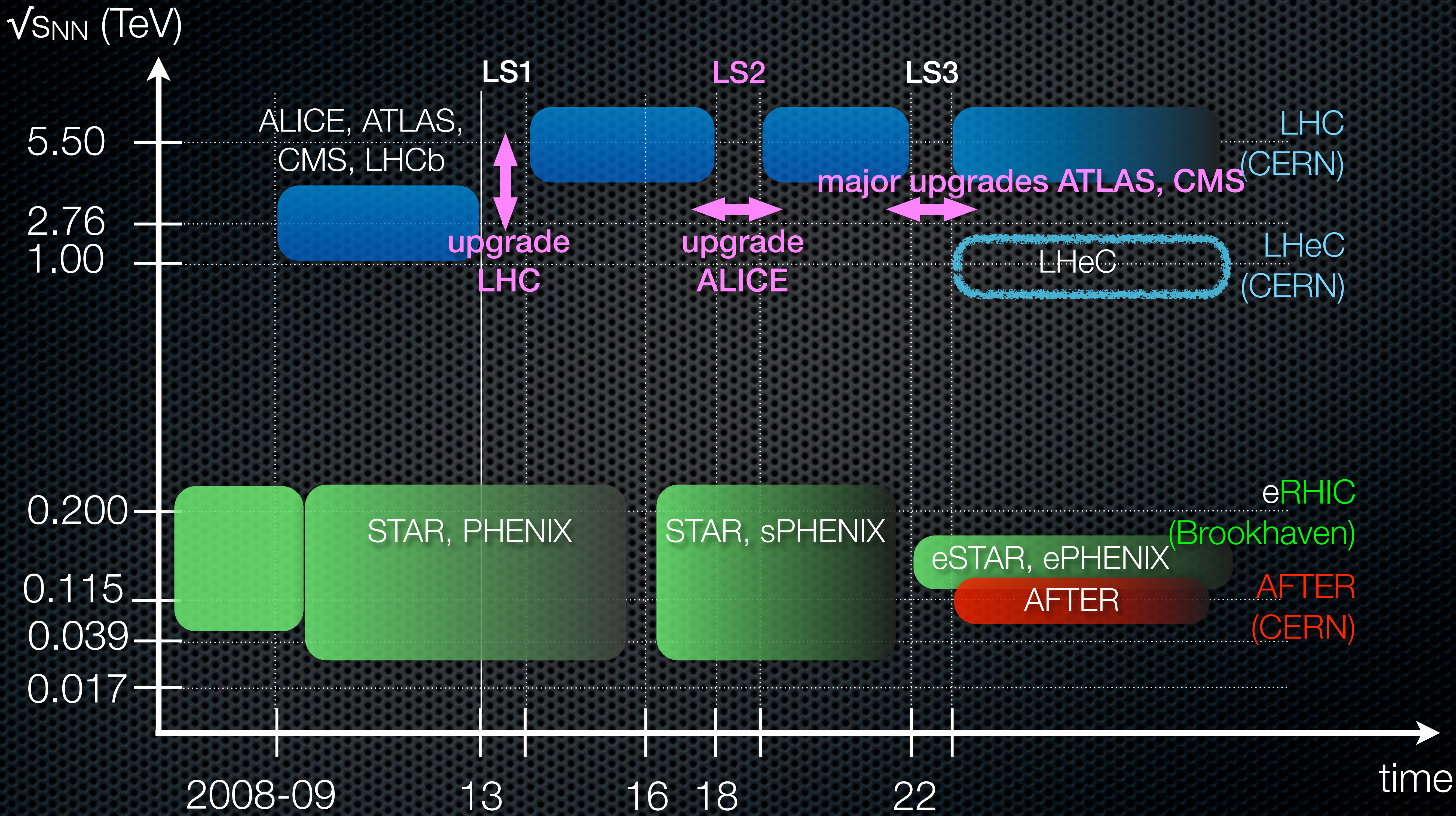

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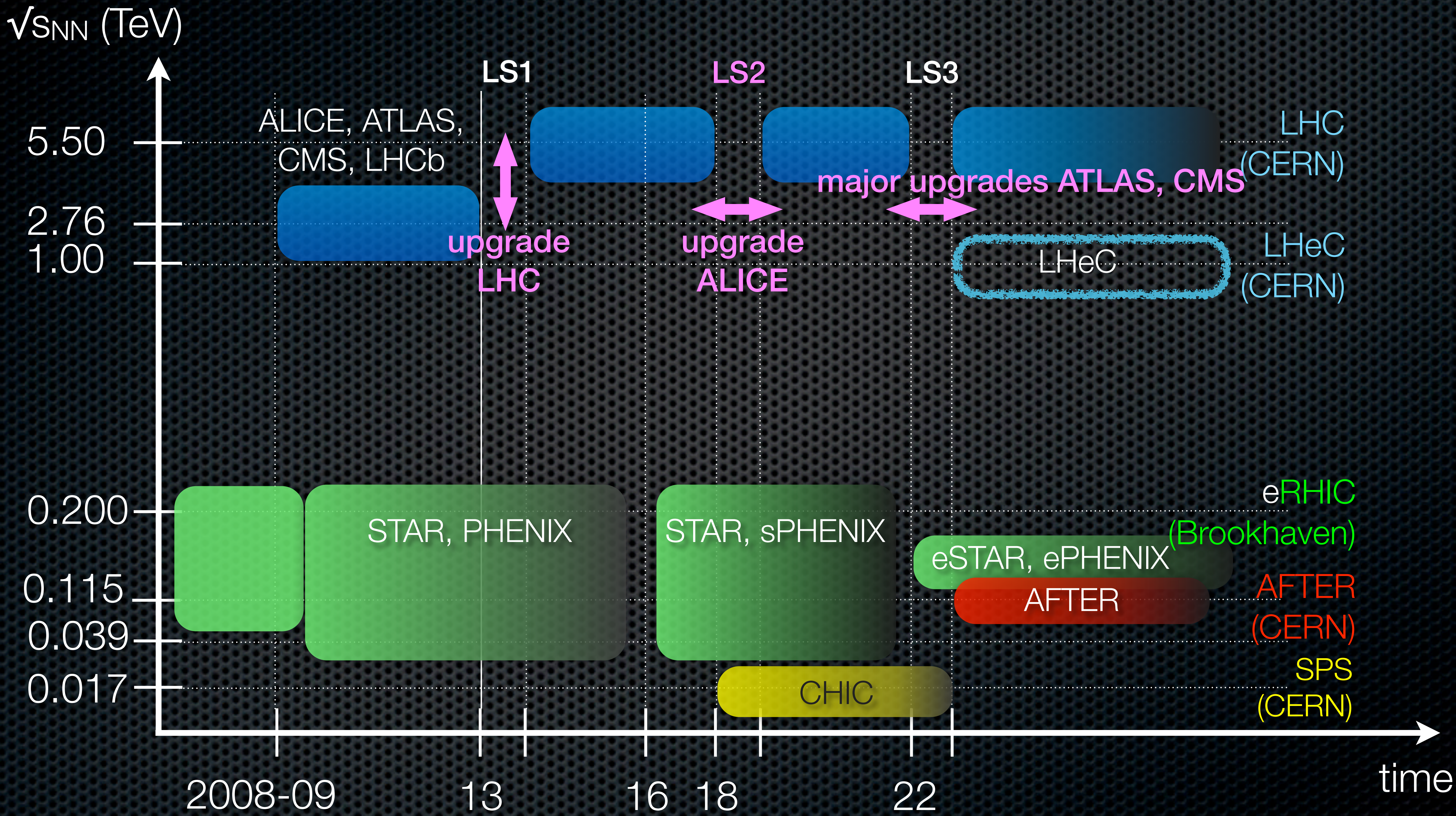
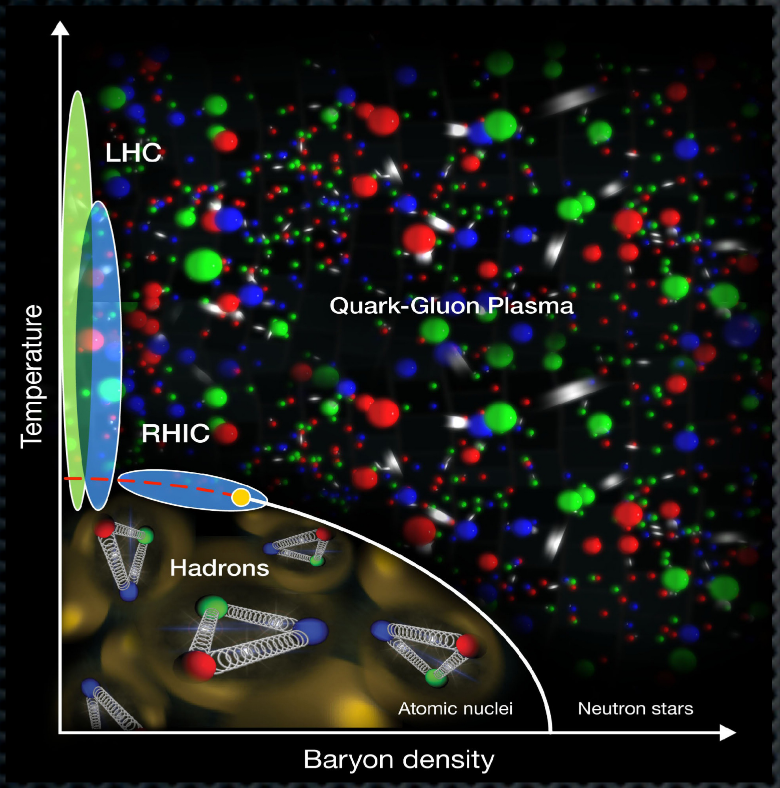


H.I. collisions @ LHC

[H. Appelshäuser, ESPG Symposium, Cracow, Sept. 2012]

- unique opportunities to study QCD at $\mu_B \sim 0$ in H.I. collisions via hard and electroweak probes
- initial T and energy density : the highest achievable in the lab
- large $\sqrt{s_{NN}}$ ➠ abundant production of hard probes
- first principle methods (pQCD, Lattice Gauge Theory) most applicable



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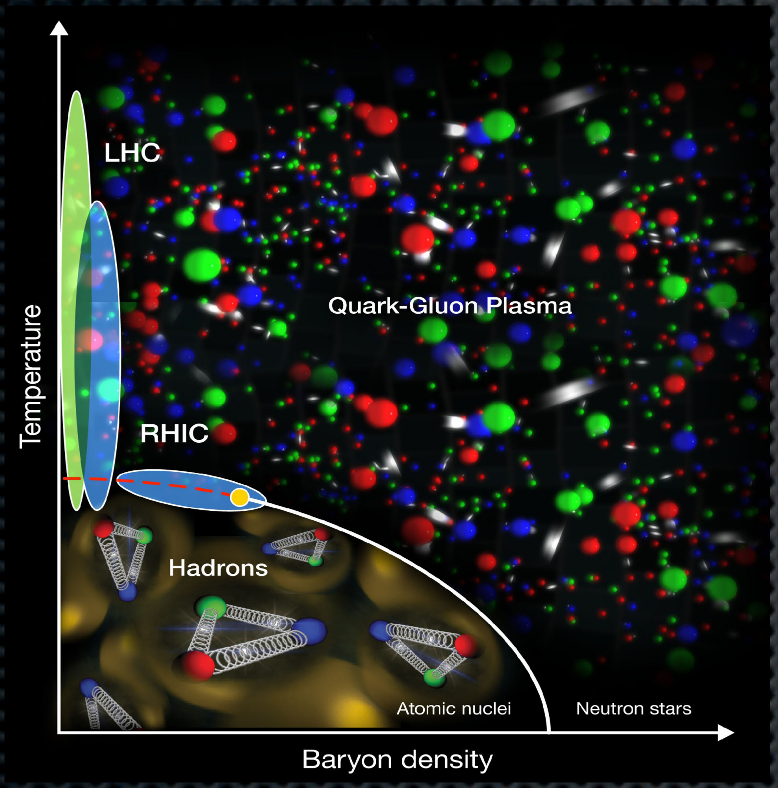

« The top priority for future quark matter research in Europe is the full exploitation of the physics potential of colliding heavy ions in the LHC »

Conclusions of the Heavy-Ion Town meeting (June 2012, CERN), in the preparation of the European Strategy Preparatory Group for Particle Physics (ESPG)

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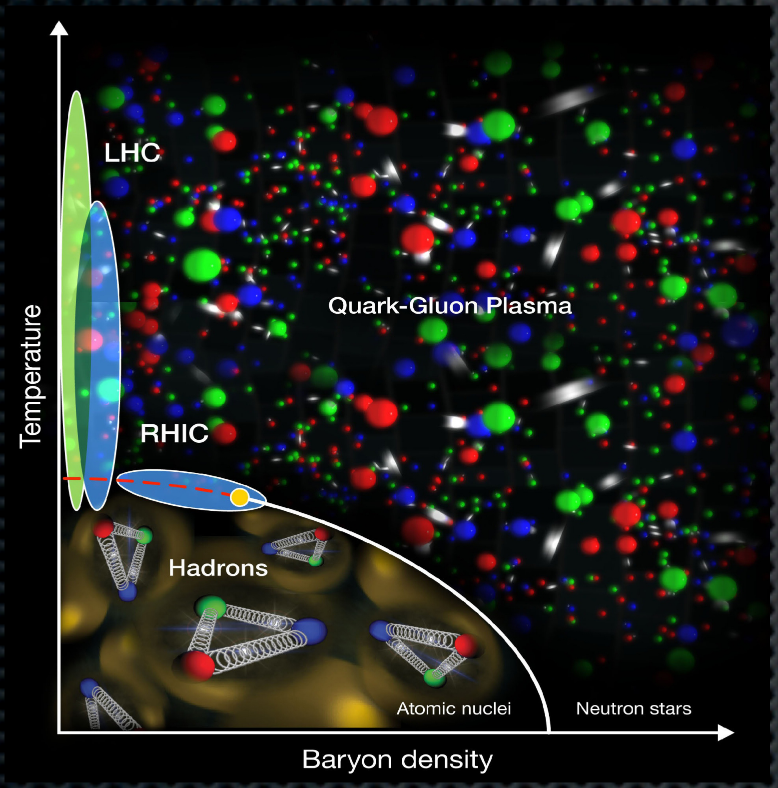

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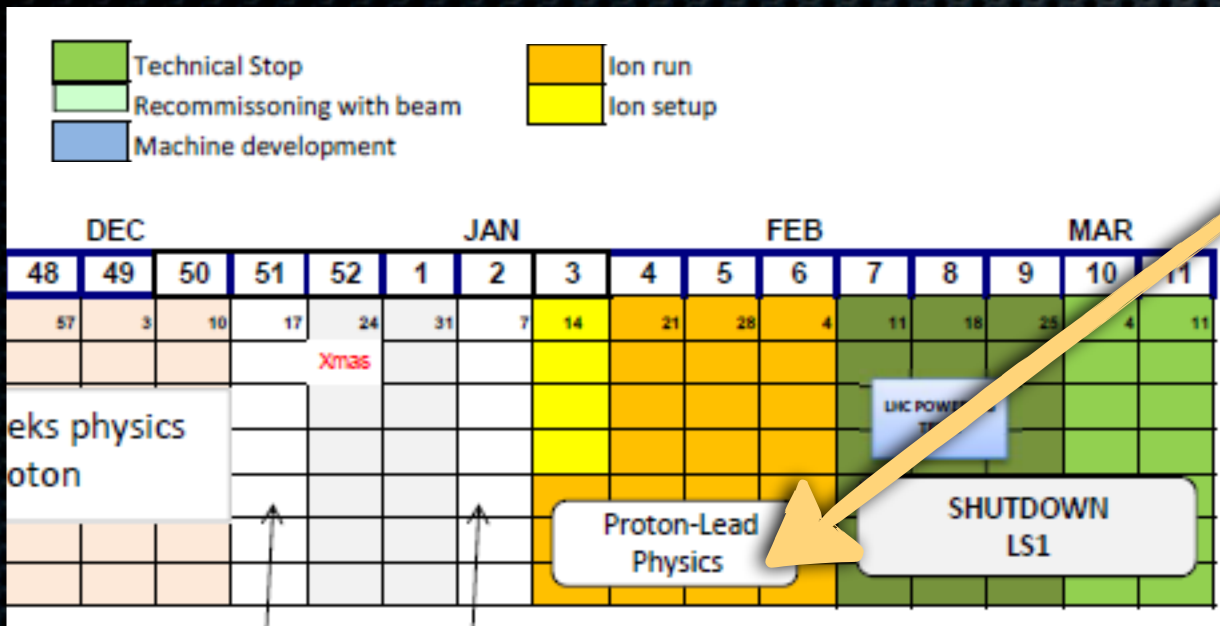
Conclusions of the Heavy-Ion Town meeting (June 2012, CERN), in the preparation of the European Strategy Preparatory Group for Particle Physics (ESPG)

- currently approved program (1 nb^{-1}) : essential step towards an era of precision measurements
- extension to 10 nb^{-1} : full exploitation of LHC physics potential + experiments complementarity

➡ H.I. beyond LS3

LHC - short term (2013 - 2014)



p-Pb + Pb-p (Jan. 2013) : CNM effects

- $\sqrt{s}$ = 5 TeV, target luminosity 30 nb^{-1}
- 22 days of stable beams

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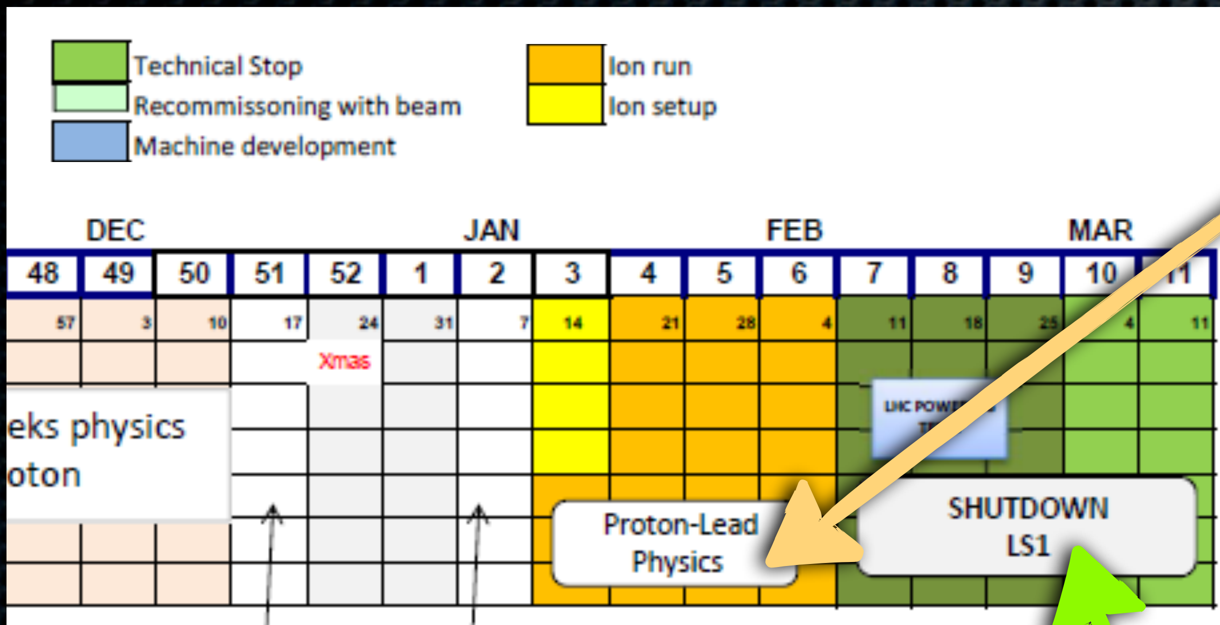

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- 1 year ½ ⇒ LHC design energy (p+p 14 TeV, Pb+Pb 5.5 TeV)
- detector maintenance, completion and (small) upgrades (e.g. ALICE-TRD, -CAL, ATLAS additional pixel layer, ...)

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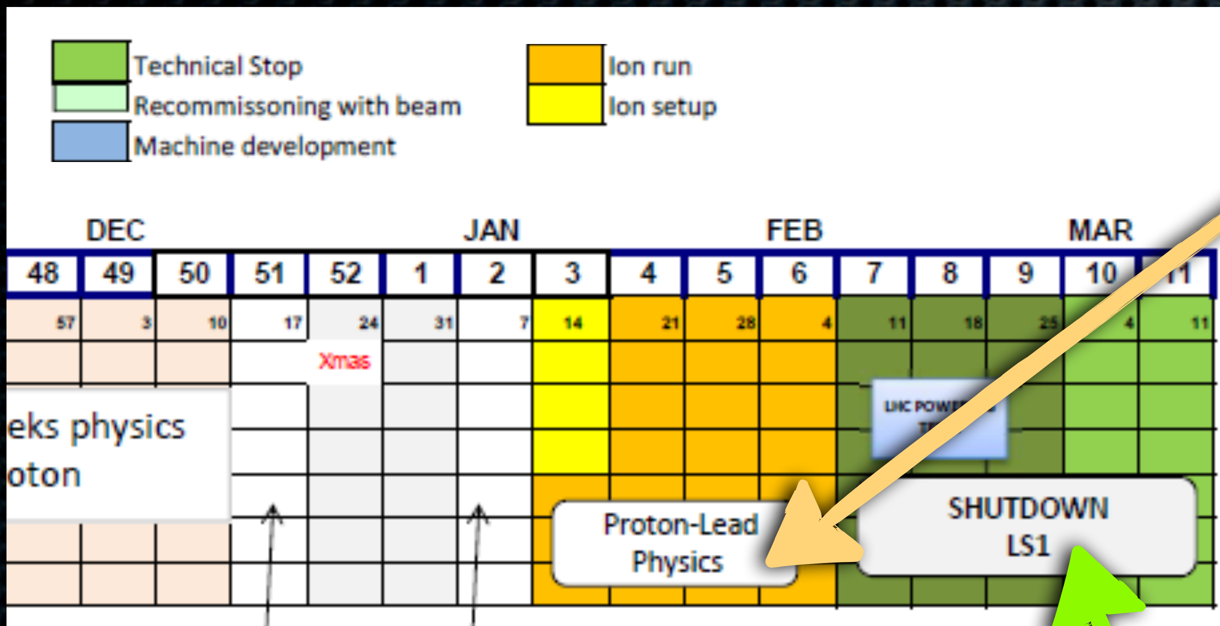

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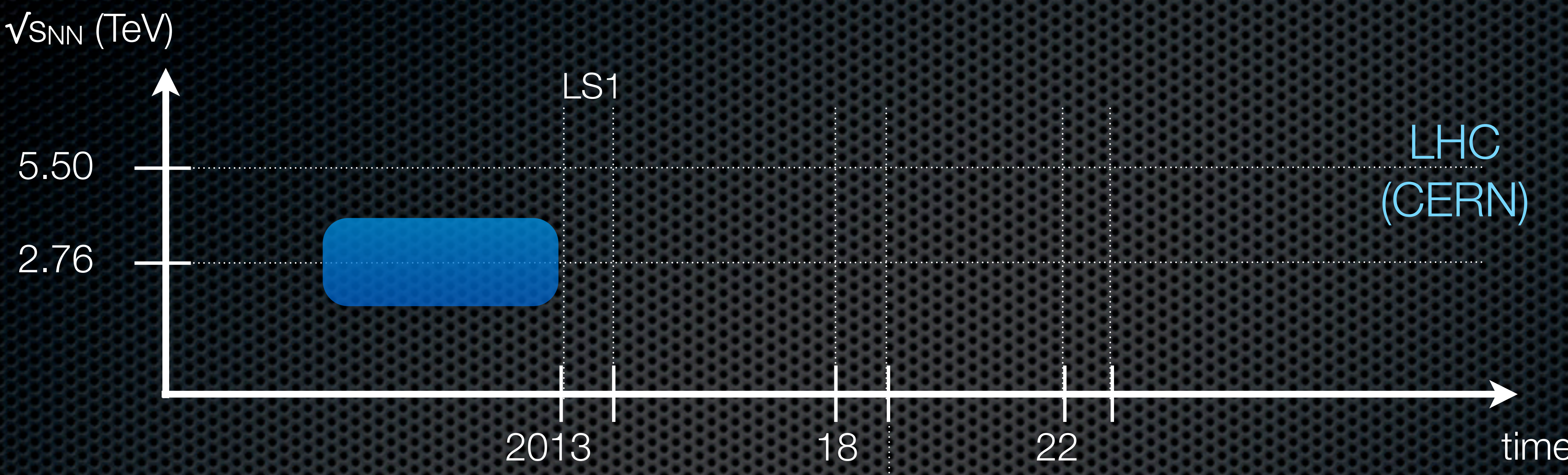
Followed by 3 years of data taking at the LHC *design energy*

LHC - mid/long term



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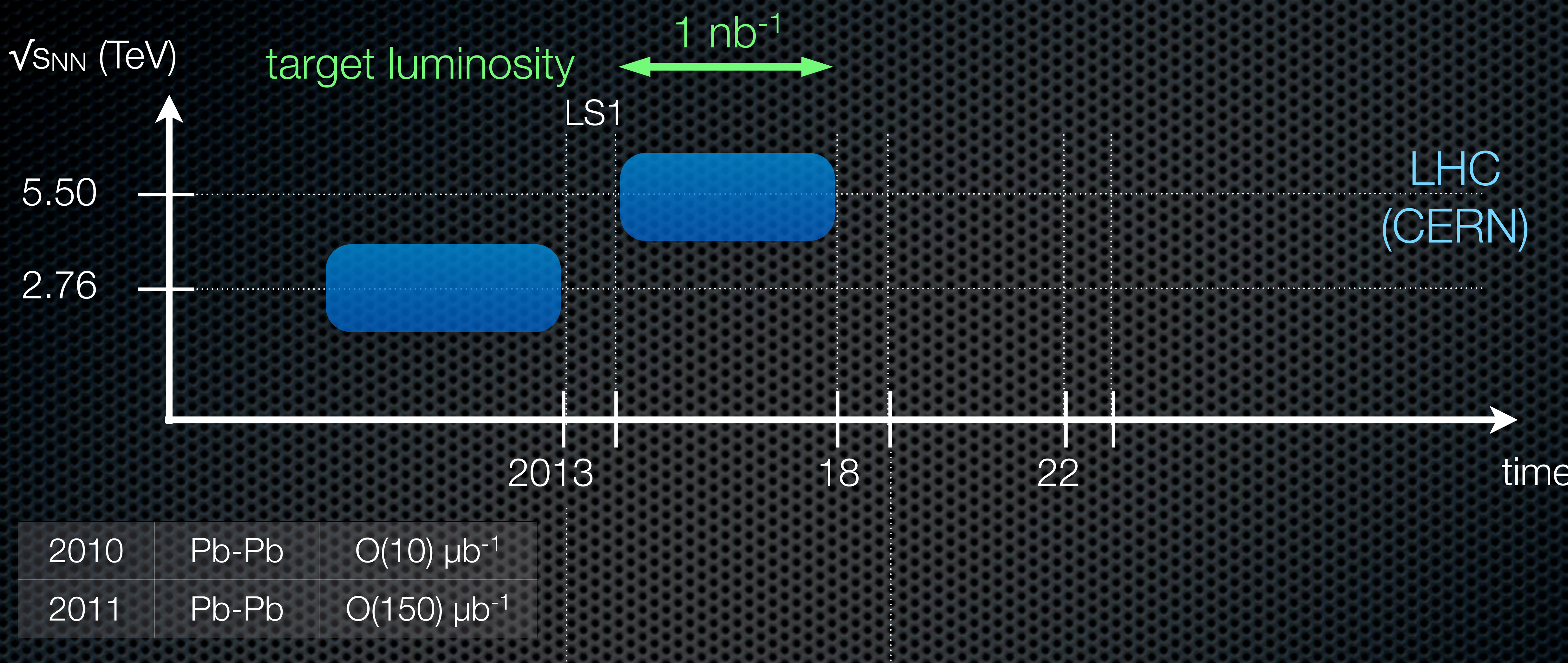

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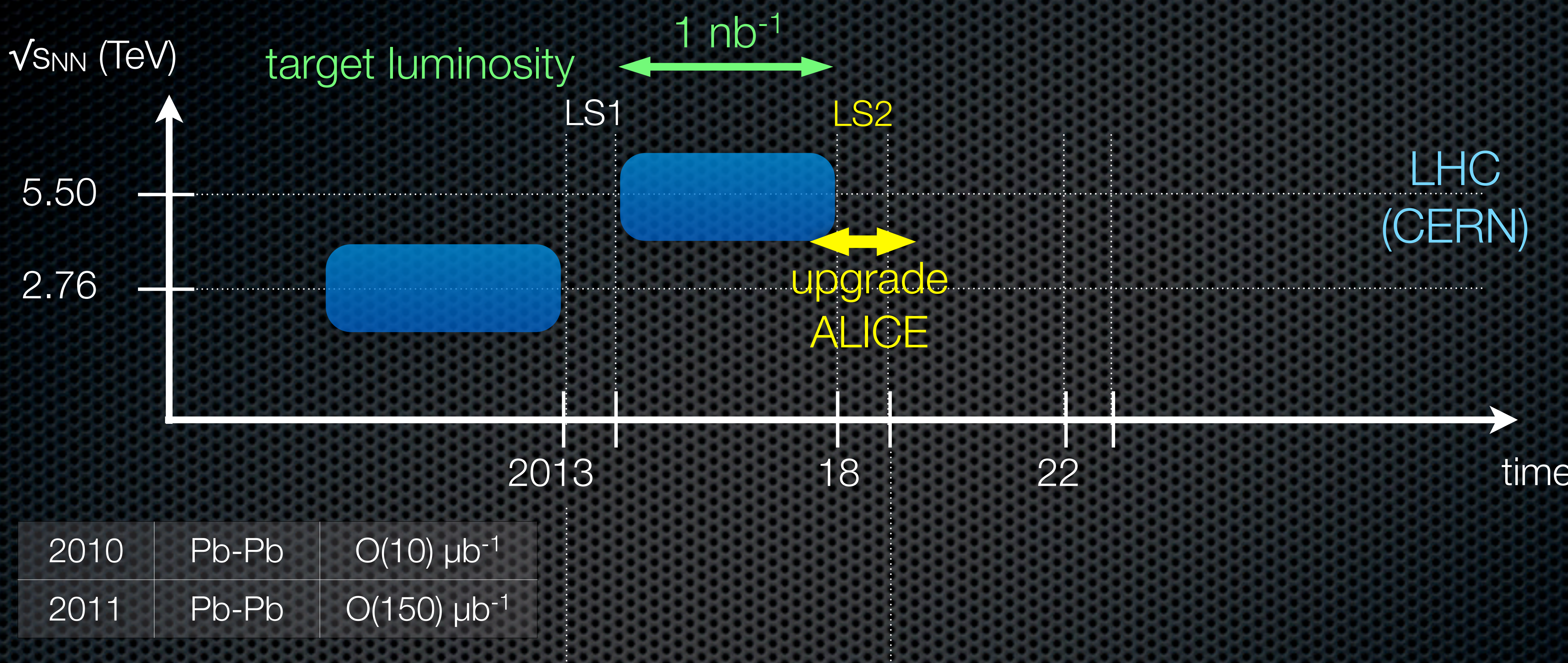

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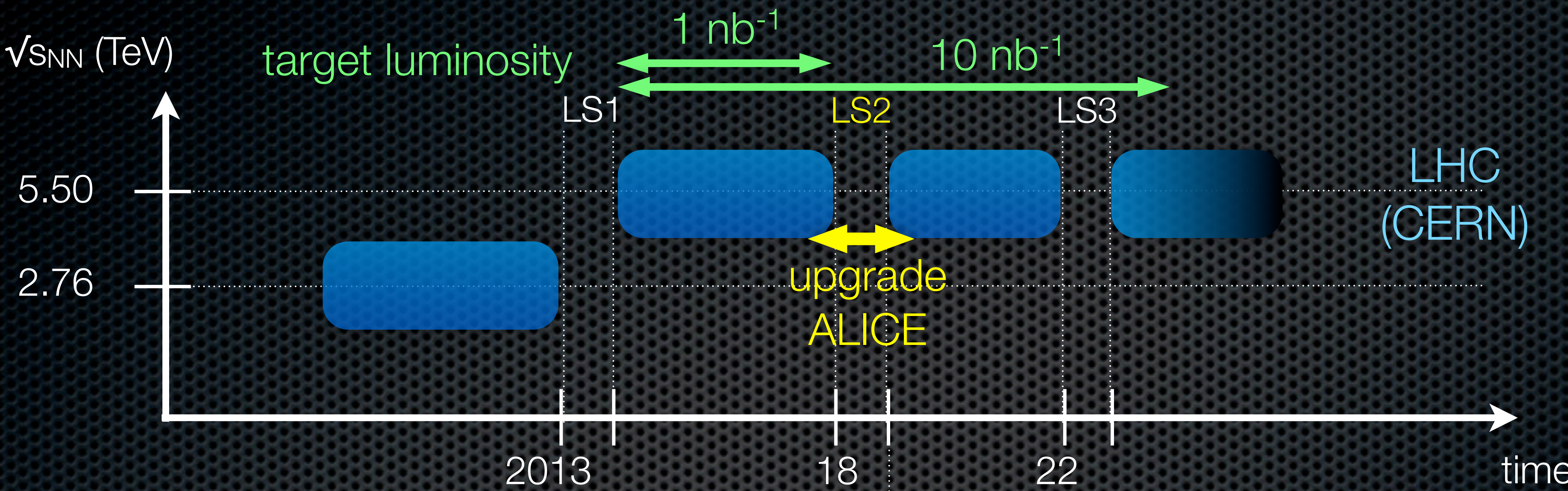

High lumi. Pb-Pb runs :
50 kHz collision rate
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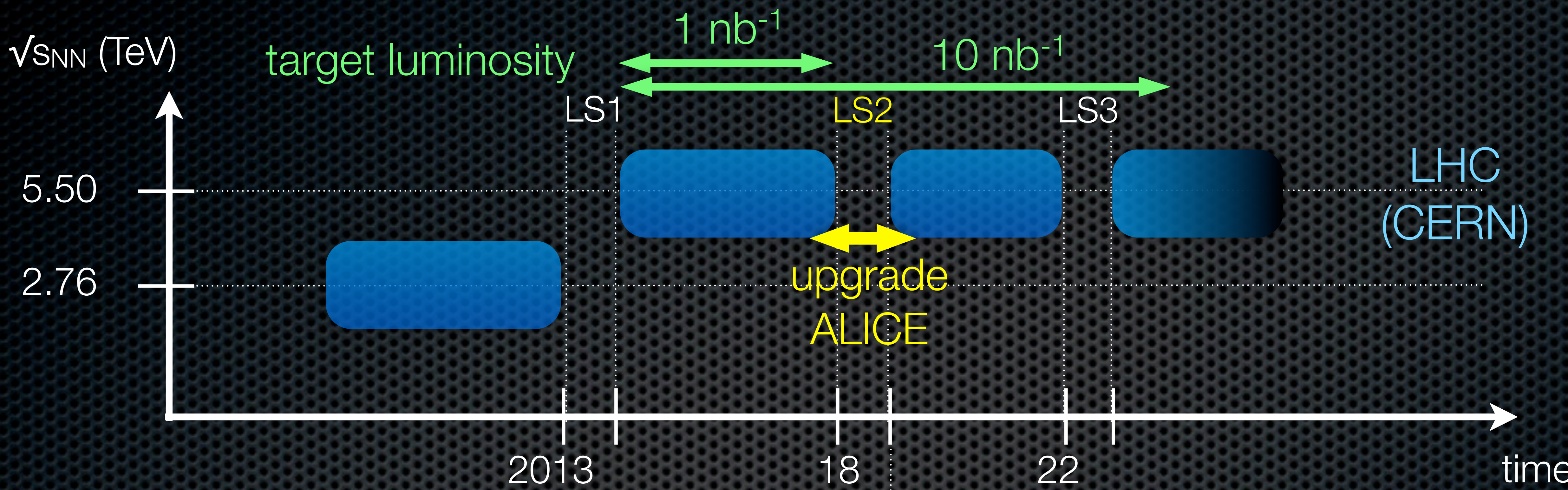

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- ALICE LoI (Sept. 2012) : upgrade ITS, TPC, Muon Arm, ...
  - ✓ improve low p_T tracking, vertexing, PID capabilities, reduce material budget
  - ✓ many key observables do not allow low-level triggering ➠ high rate capability of detectors and readout system
- ALICE LoI addendum : Muon Forward Tracker (MFT), VHMPID, FoCal

ALICE ITS upgrade

new ALICE Inner Tracking System:

→ 7 Si-layers (7 pixel or 3 pixel + 4 strip)
→ low material budget X/X_0= 0.3% per layer (currently 1.14%)
→ improve vertex resolution by factor 3
→ improve low p_T tracking efficiency
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CERN-LHCC-2012-05 / LHCC-G-159

Parallel 6C: R. Lemmon
Poster: G. Contin

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

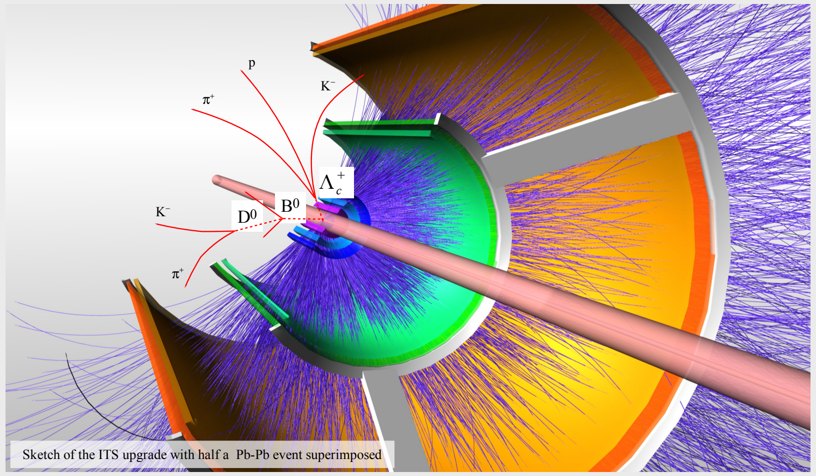
ALICE

CERN-LHCC-2012-05 / LHCC-G-159
March 6, 2012

Conceptual Design Report for the Upgrade of the ALICE ITS

The ALICE Collaboration*

Version: CDR-0



Sketch of the ITS upgrade with half a Pb-Pb event superimposed

*See Appendix A for the list of collaboration members

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L. Massacrier
(ALICE upgrades)

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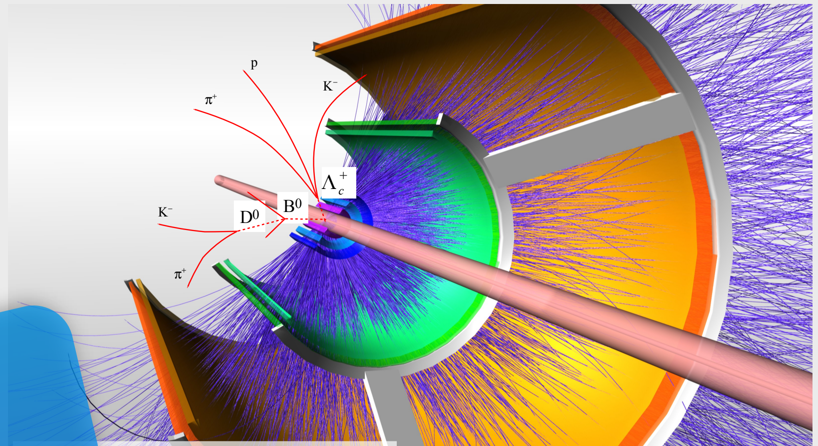

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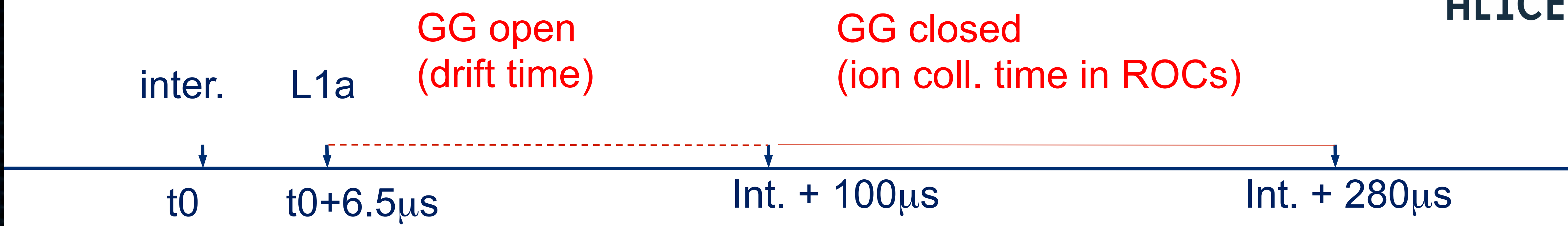
ALICE TPC upgrade



Parallel 6C: T. Peitzmann

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Limitation of the present system:

Readout rate limited to 3.5 kHz due to Gating Grid closing time

- Needed to prevent ions from drifting back into the drift volume

→ drift distortions from space charge

Solution:

Replace present MWPC-based readout chambers by GEMs

- GEMs have intrinsic property to block back-drifting ions

→ allows continuous operation at 50 kHz

→ preserves the present momentum and d*E*/d*x* resolution

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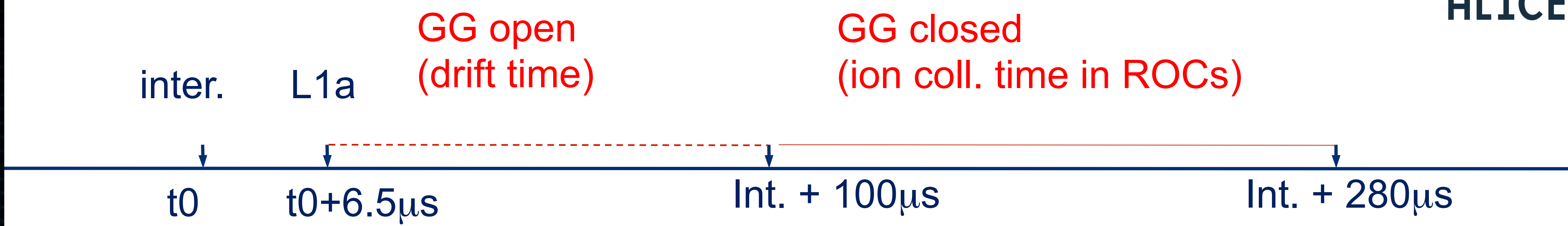

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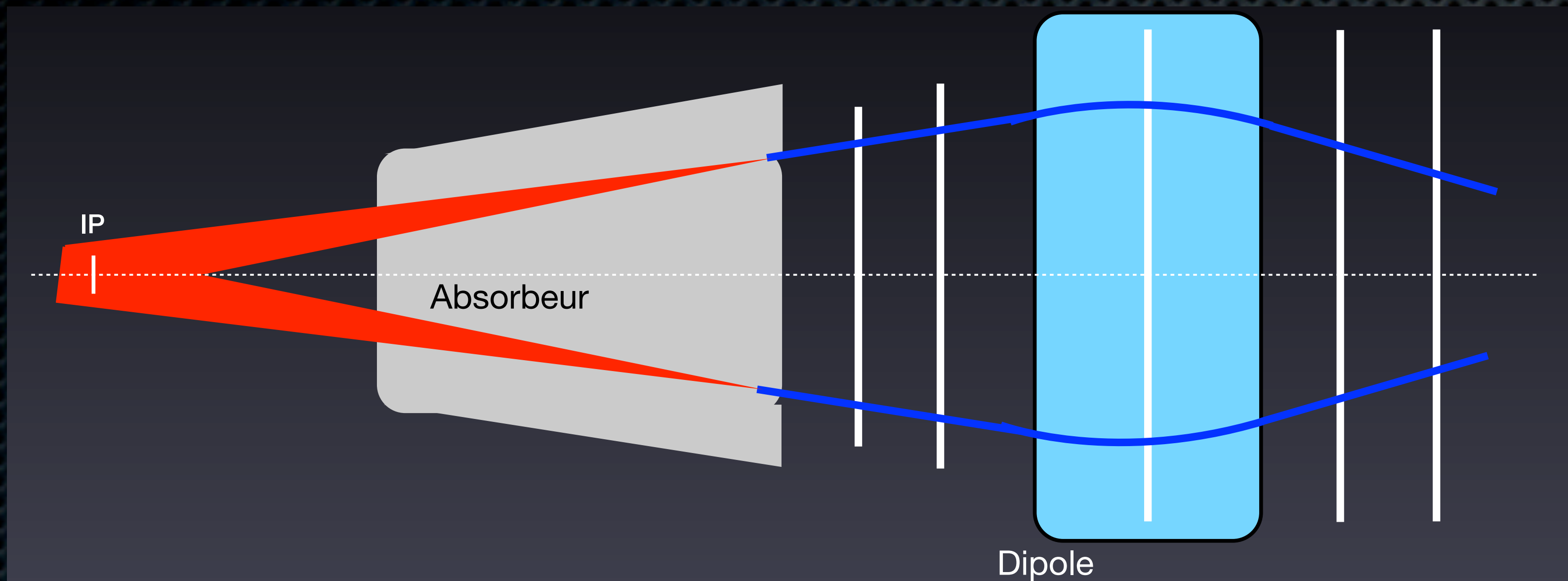
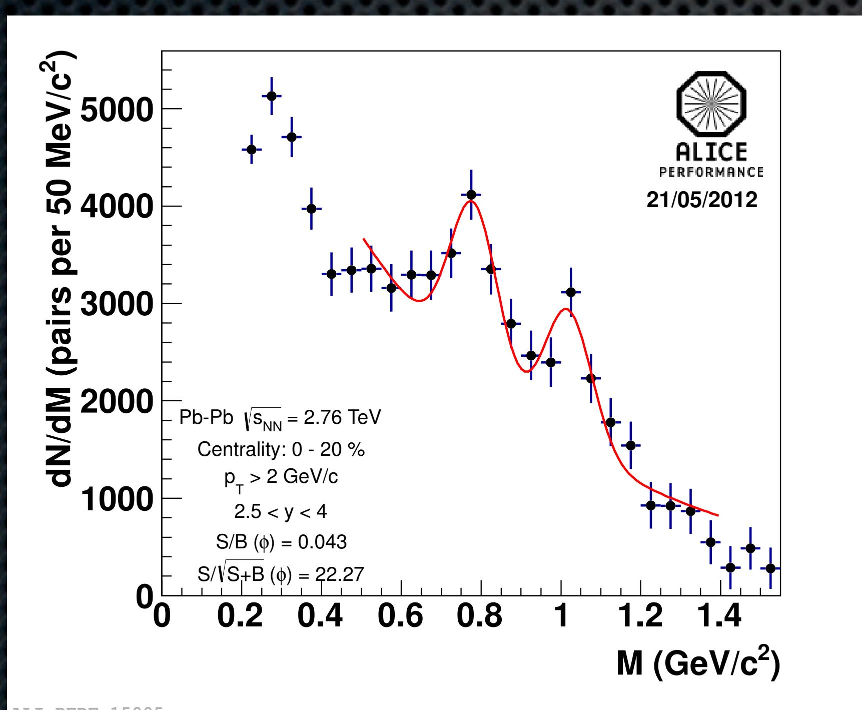
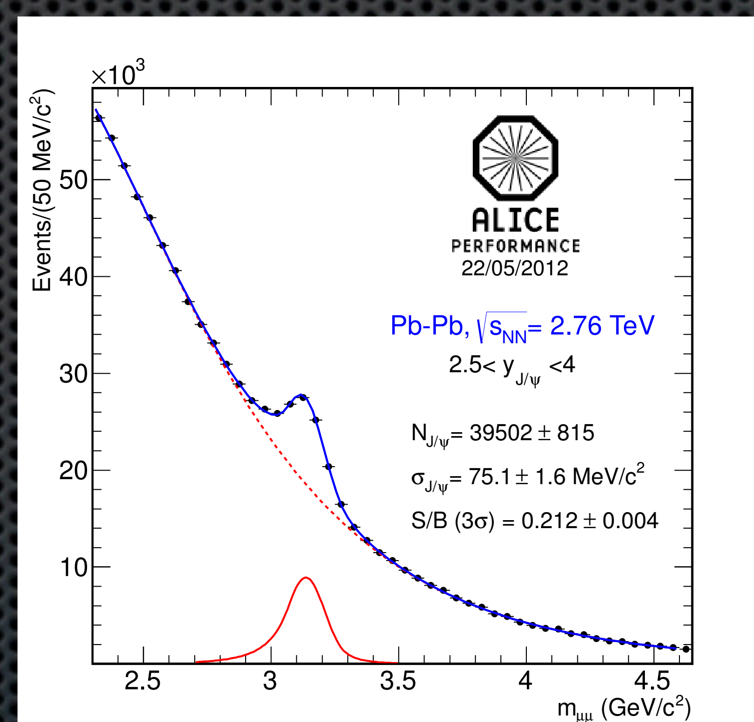


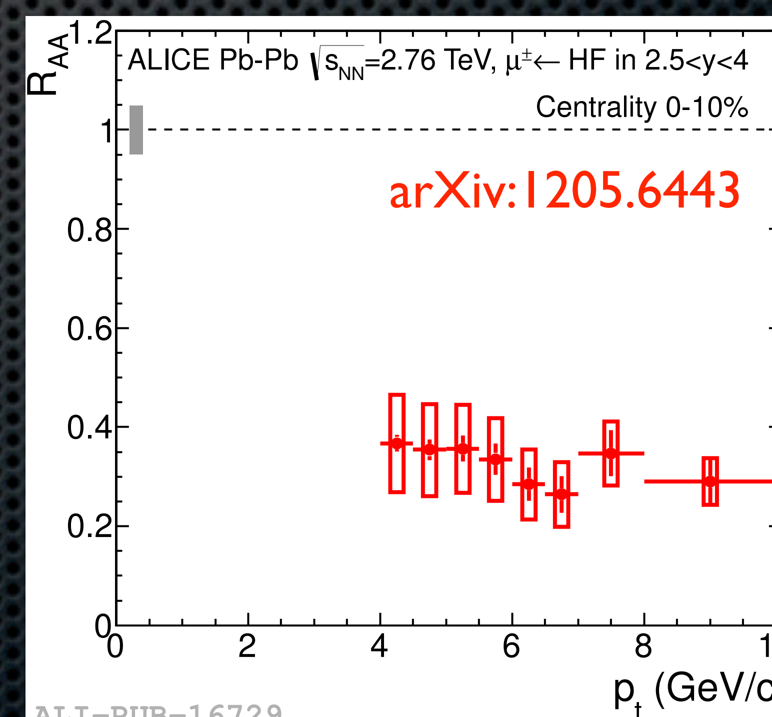
Multiple scatterings in the absorbeur ~$60X_0$
⇛ blur track extrapolation to vertex



low mass vector mesons

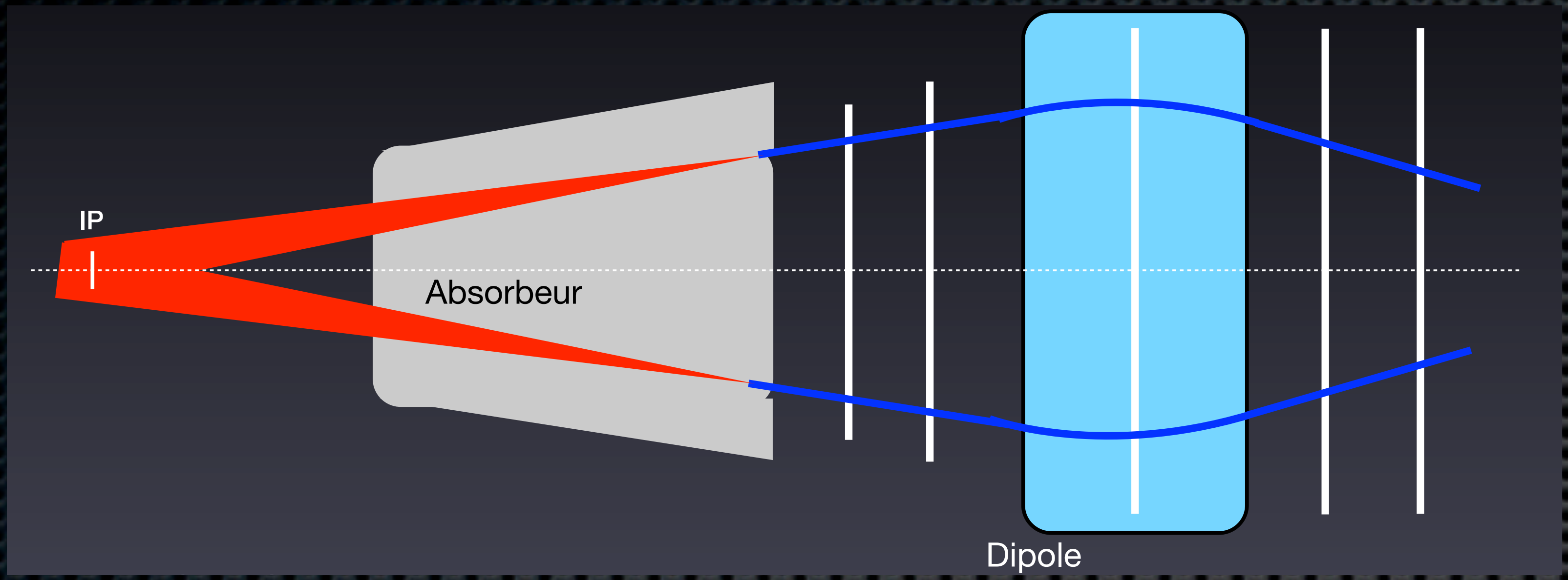


inclusive J/ψ



open heavy flavor (D+B) from single μ

MFT (Muon Forward Tracker)



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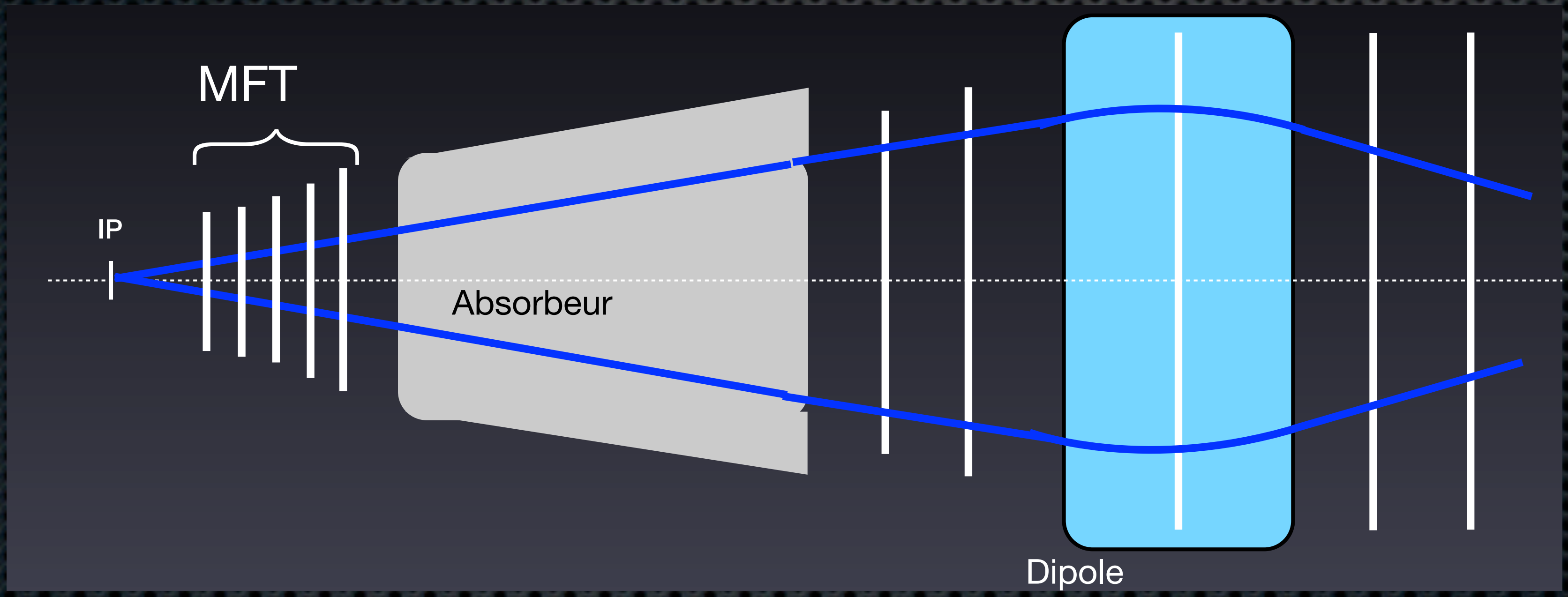

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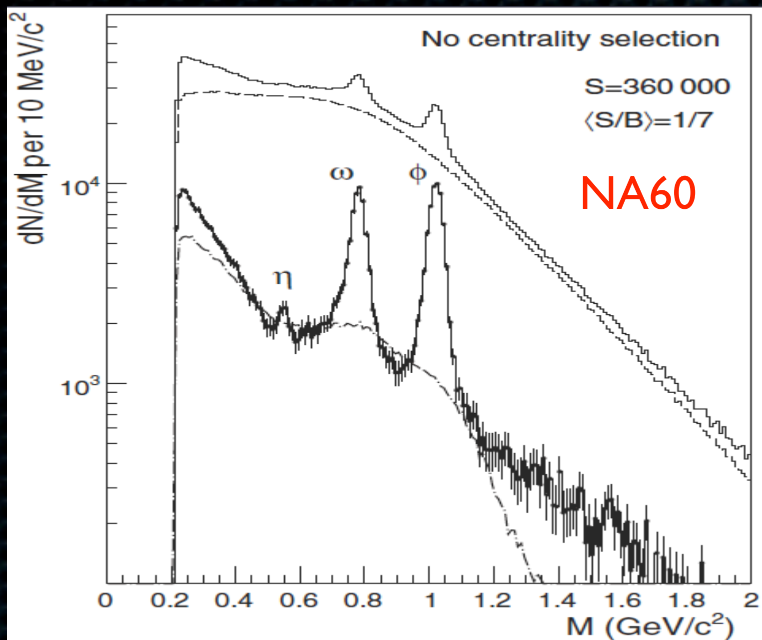

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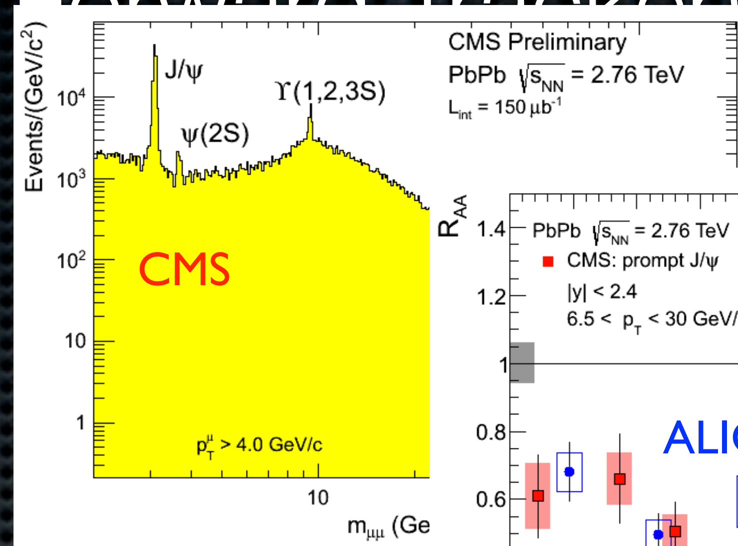
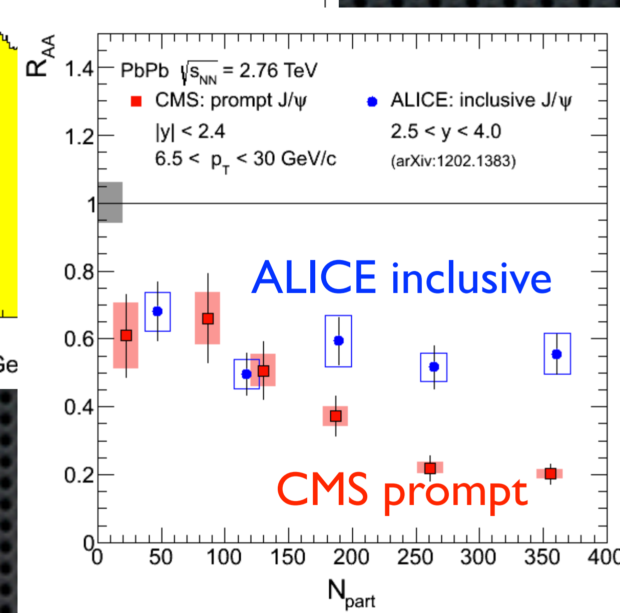
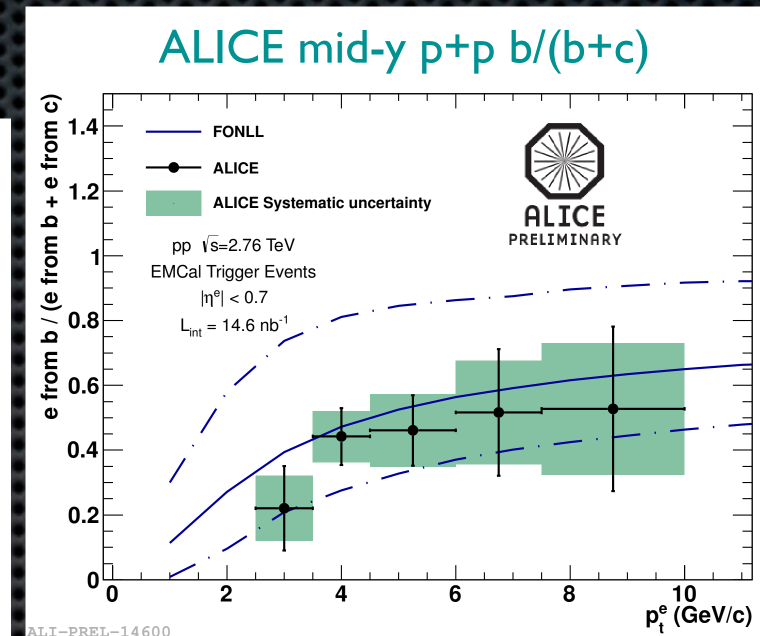
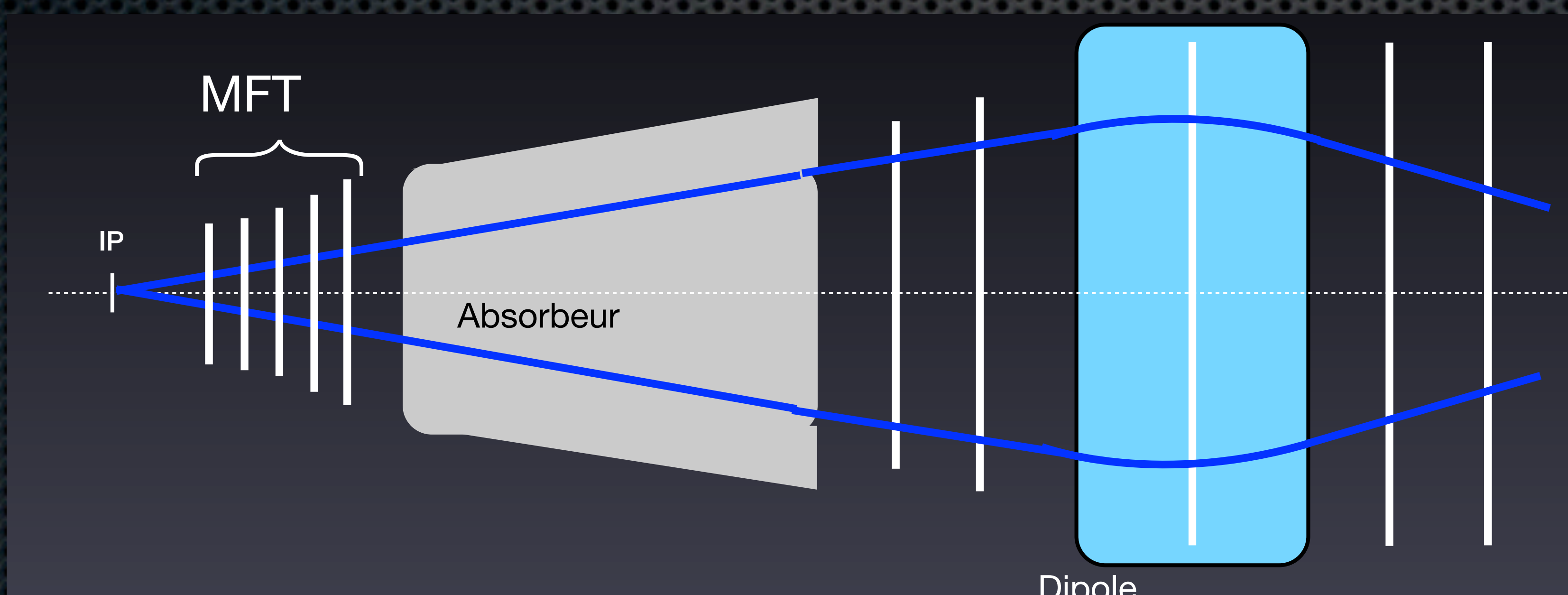


prompt J/ψ
+ ψ(2S)





open heavy flavor
with D/B separation



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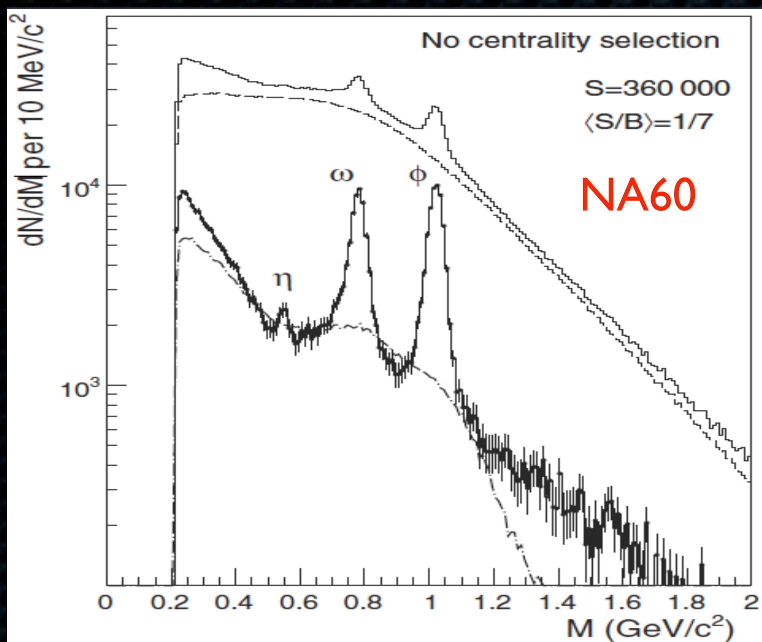

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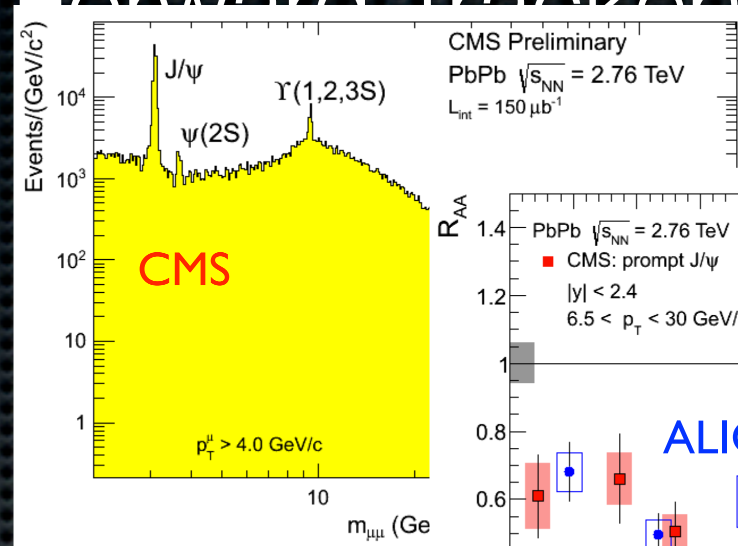

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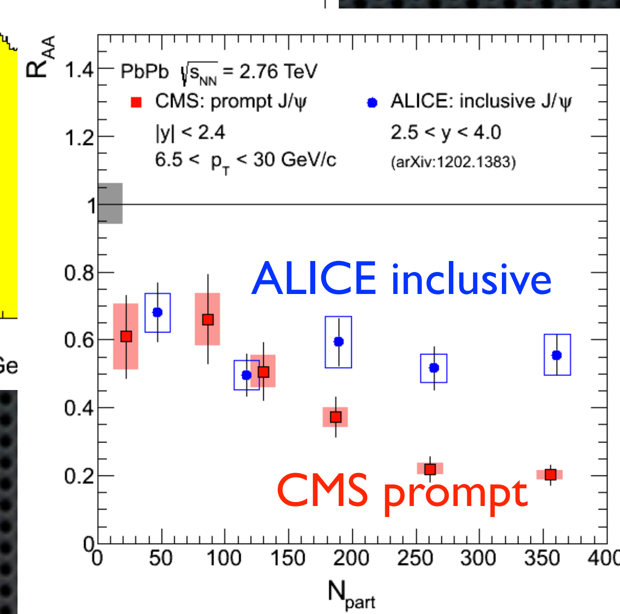

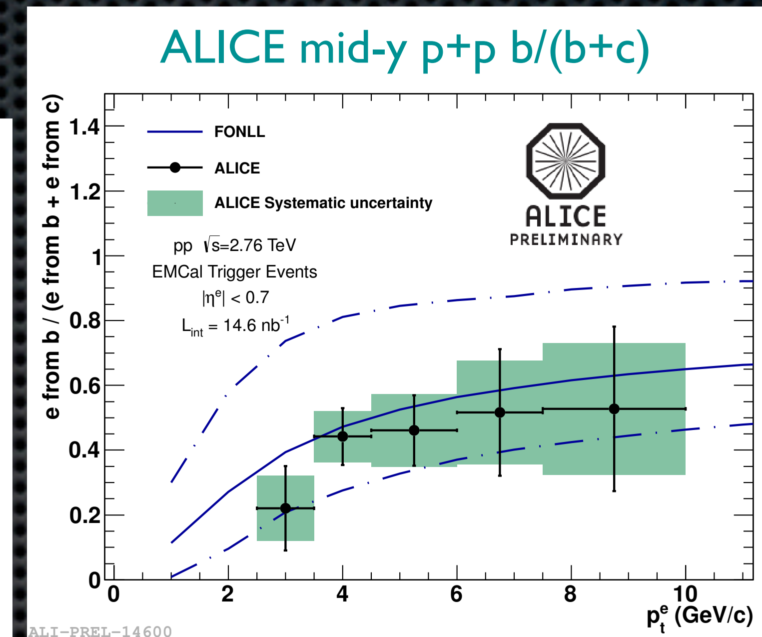

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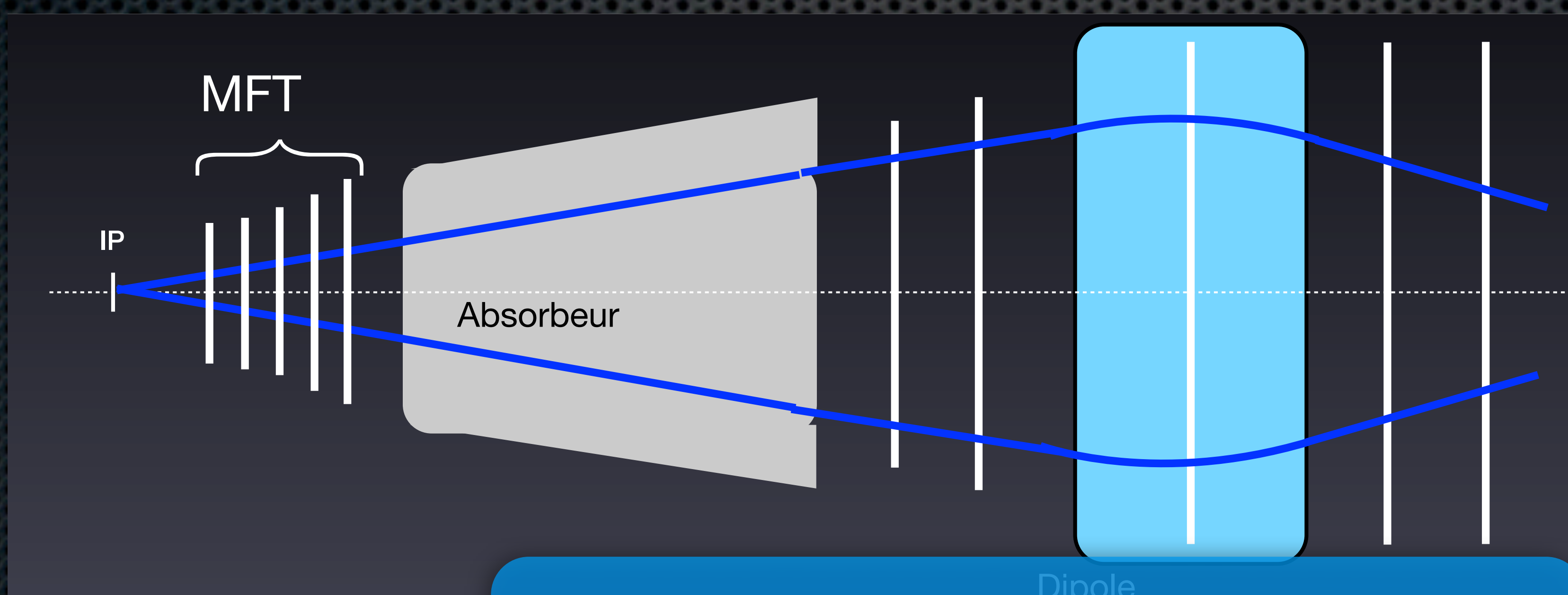

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Future opportunities @ LHC

[H. Appelshäuser, ESPG Symposium, Cracow, Sept. 2012]

Jets - precision measurements:
γ-Jet, b-Jet, Z-Jet, multi-Jet,
PID fragmentation functions,
TeV-scale jet quenching

ϒ spectroscopy - 1s, 2s, 3s states, onset-behaviour

Charmonia - low p_T J/ψ over wide rapidity range, ψ', X_c

Heavy Flavors - comprehensive measurement of D, D^*, D_s, Λ_c, B, Λ_b:
Baryon/Meson ratios down to low p_T, R_{AA}, v_2
accurate normalization for quarkonia

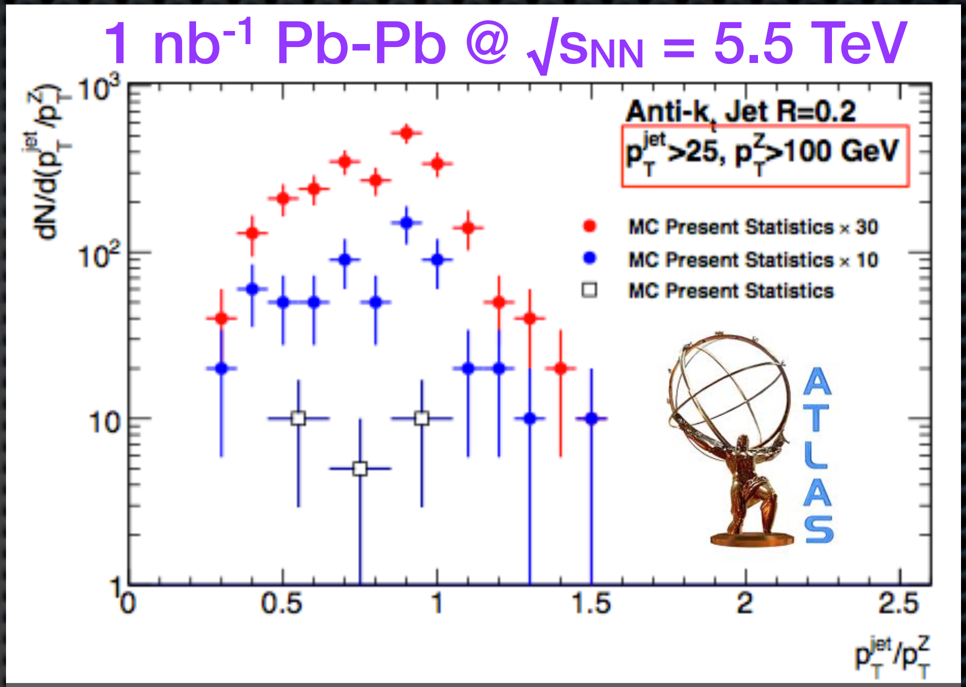
EM radiation - low mass dileptons

Exotica - anti- and hypernuclei

→ enter 10 nb^{-1} regime

Future opportunities @ LHC

First measurement of Z-jet correlations



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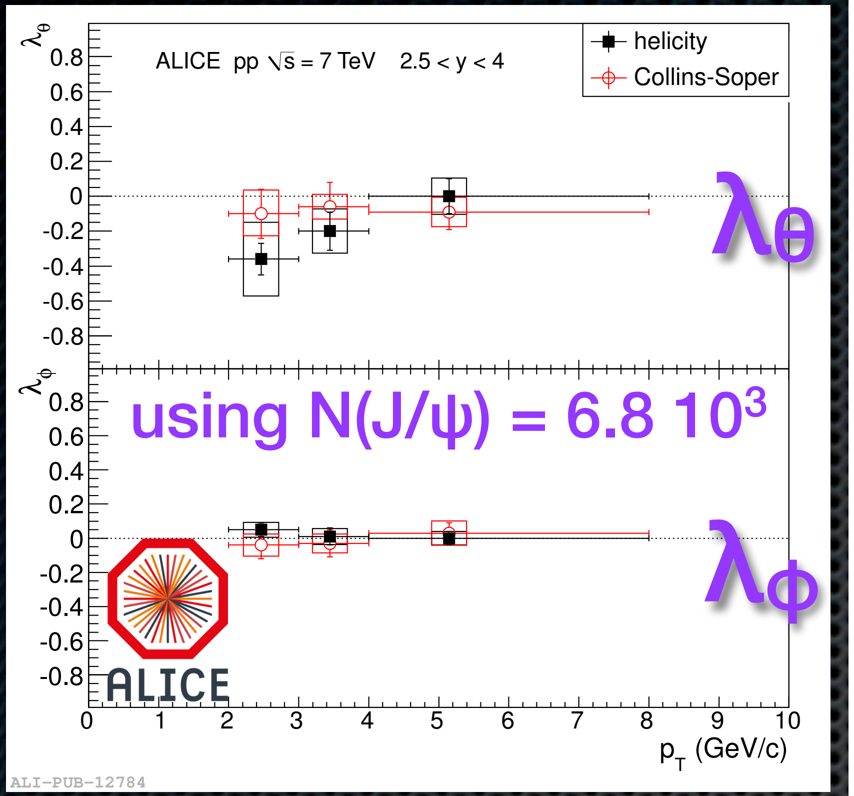
Future opportunities @ LHC

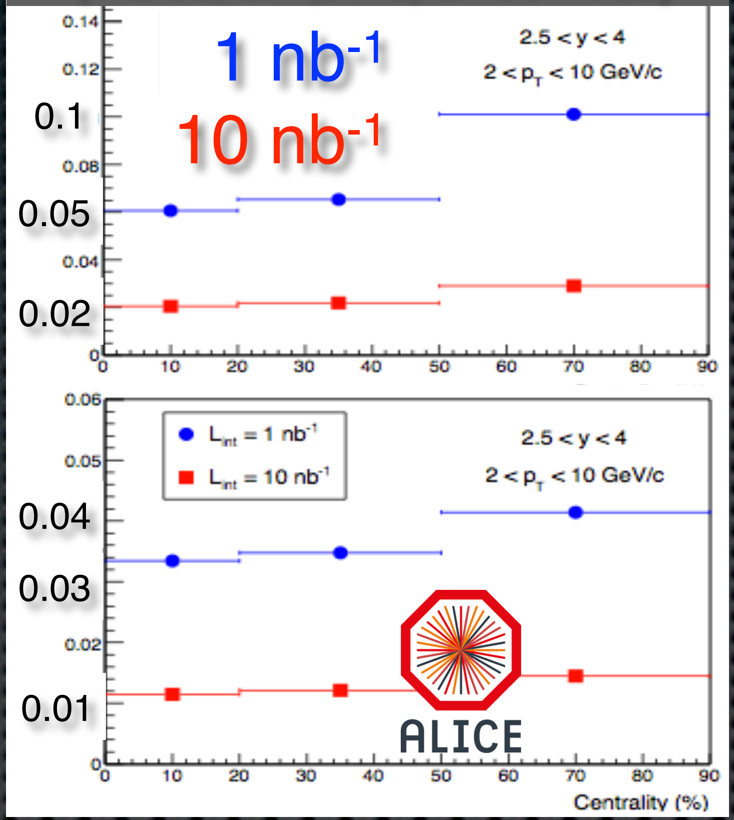
J/ψ polarisation p-p @ 7 TeV

[ALICE, PRL 108 (2012) 082001]



absolute error in Pb-Pb

[ALICE, LoI (2012) LHCC-I-022]



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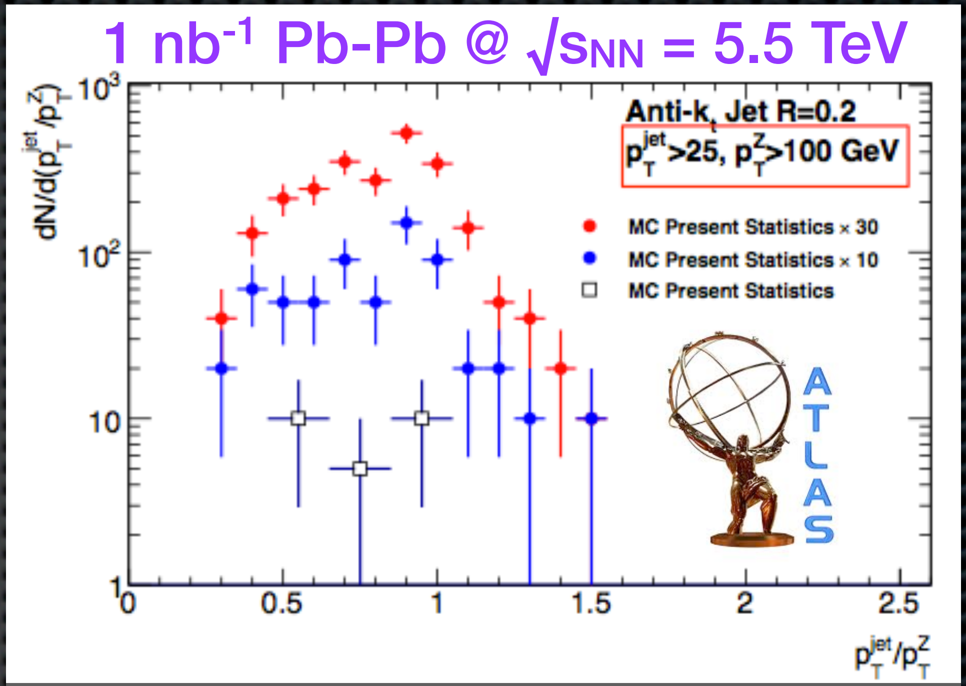

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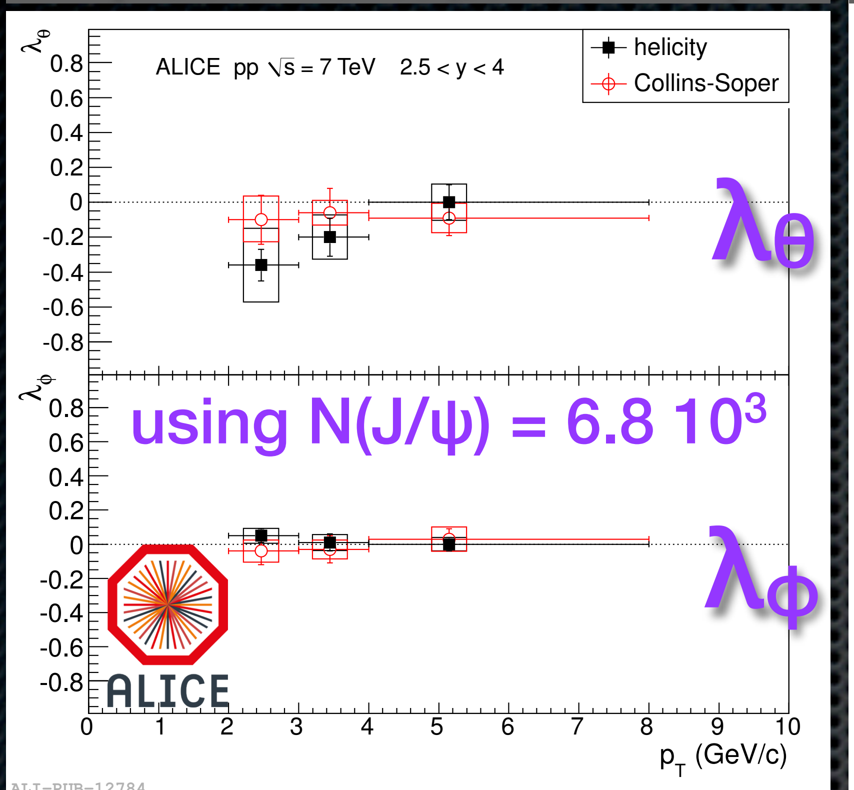

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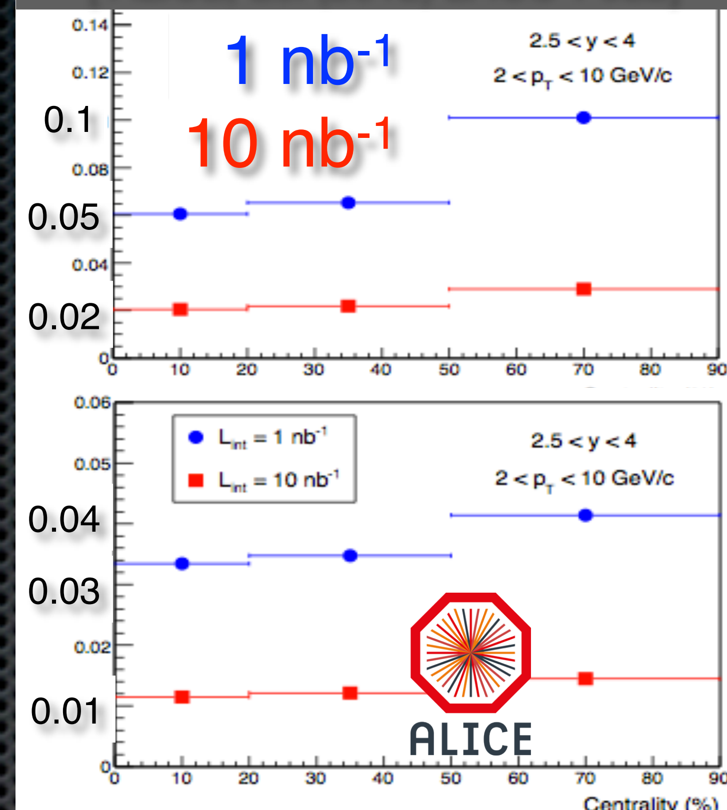

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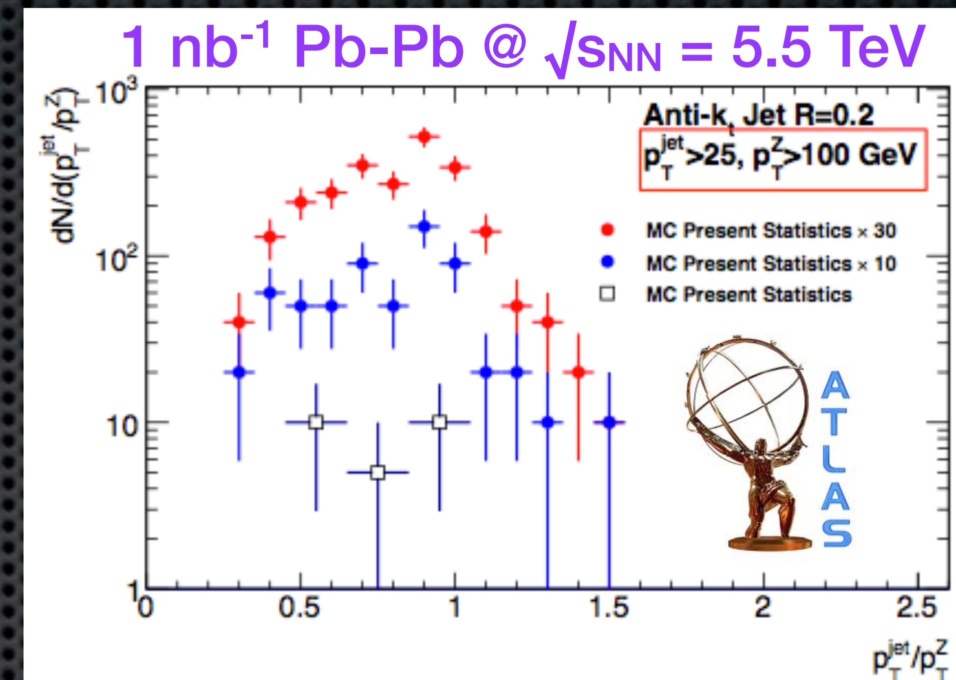

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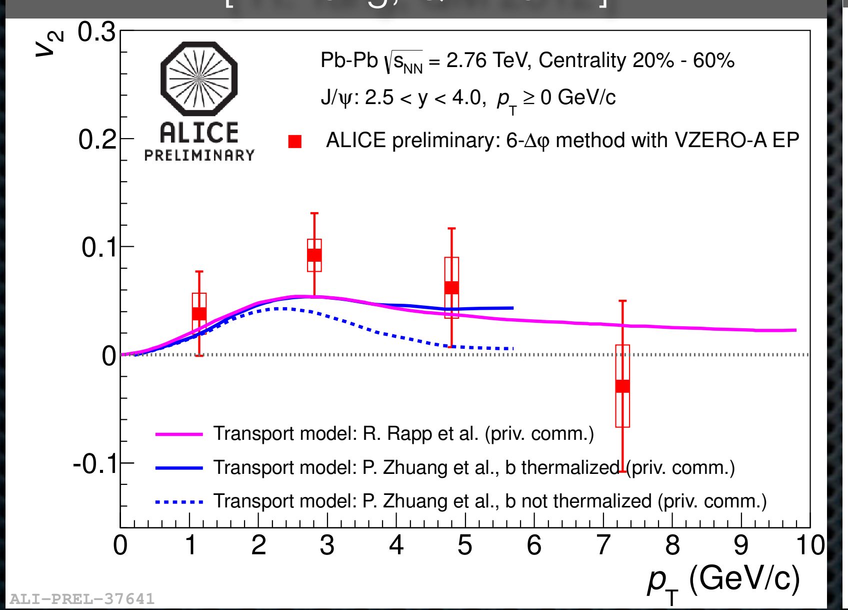
J/ψ v2 in Pb-Pb @ 2.76 TeV

[H. Yang, QM 2012]



absolute error @ 5.5 TeV

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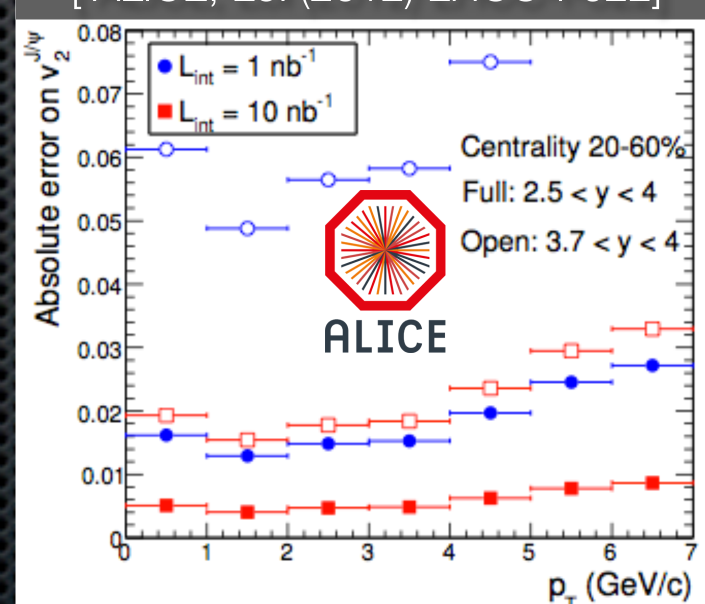

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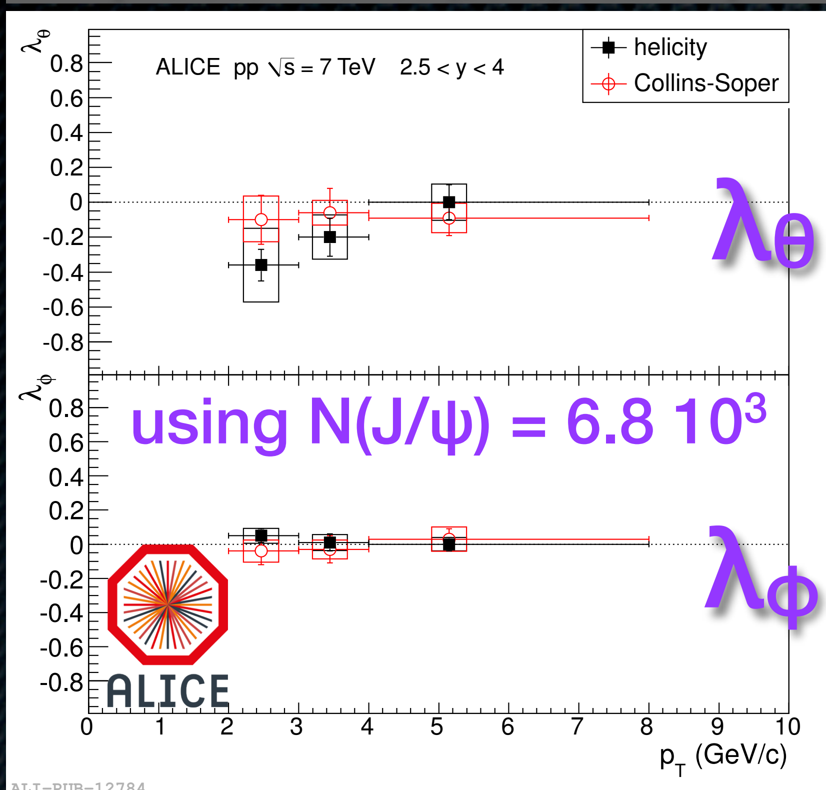
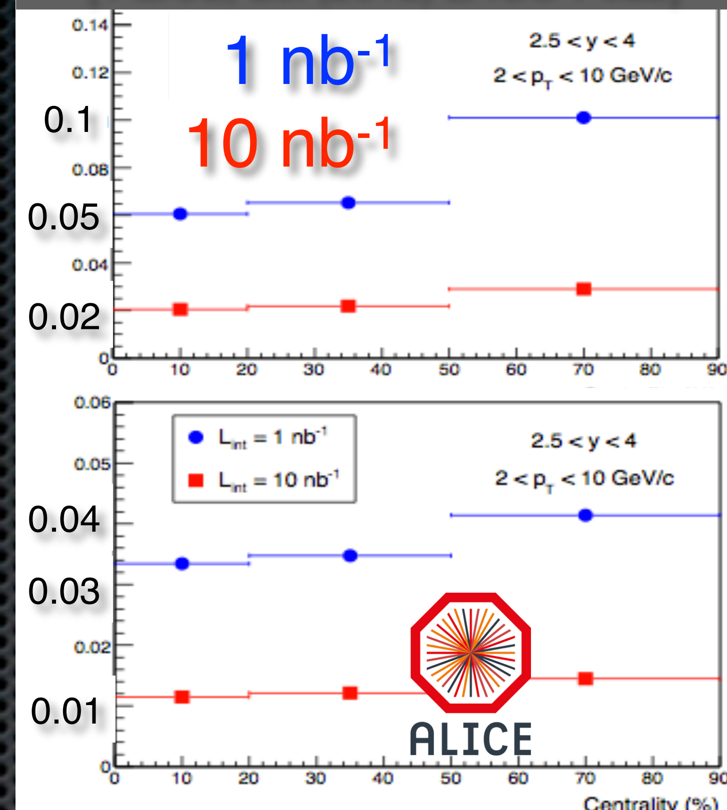
J/ψ polarisation p-p @ 7 TeV

[ALICE, PRL 108 (2012) 082001]

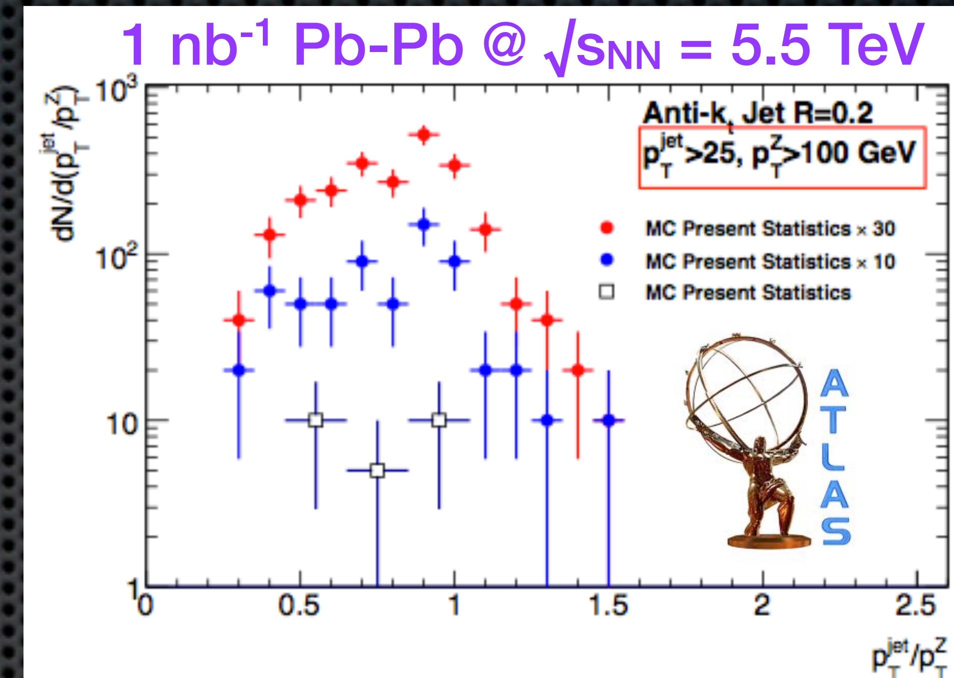


absolute error in Pb-Pb

[ALICE, LoI (2012) LHCC-I-022]



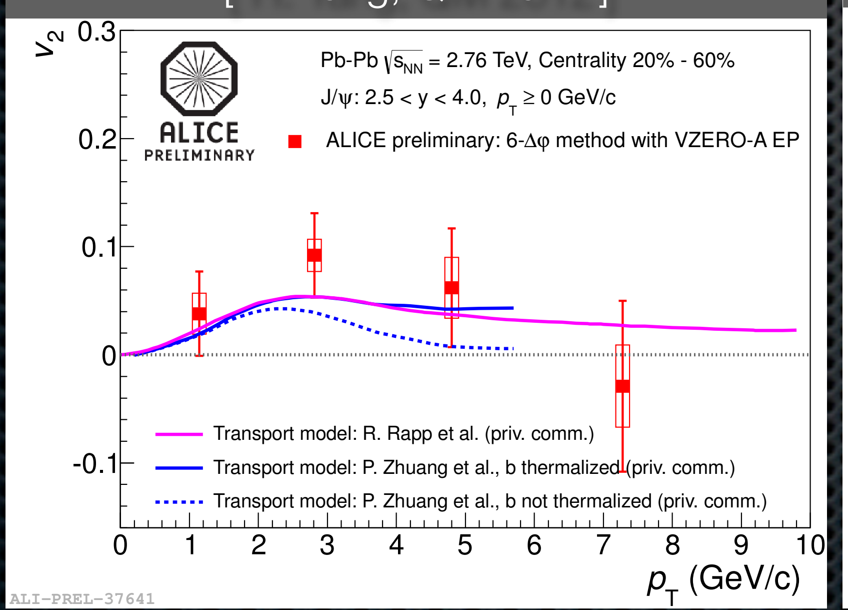
First measurement of Z-jet correlations



[H. Appelshäuser, ESPP Symposium, Cracow, Sept. 2012]

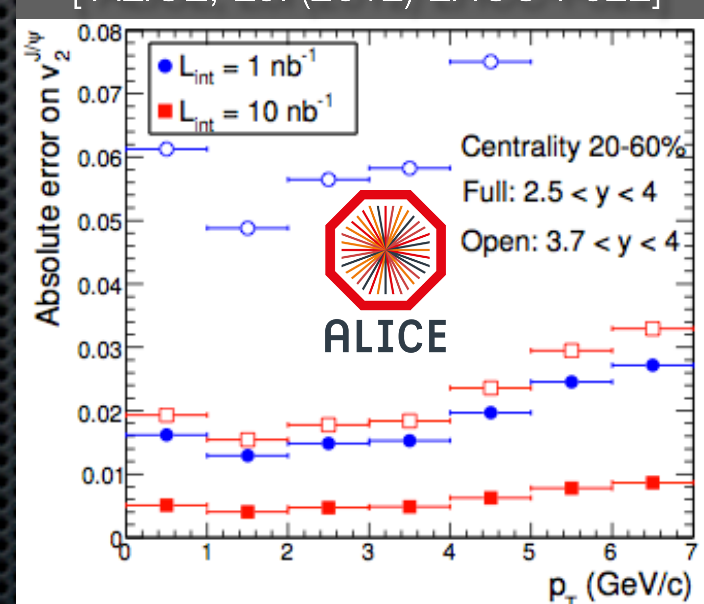
J/ψ v2 in Pb-Pb @ 2.76 TeV

[H. Yang, QM 2012]



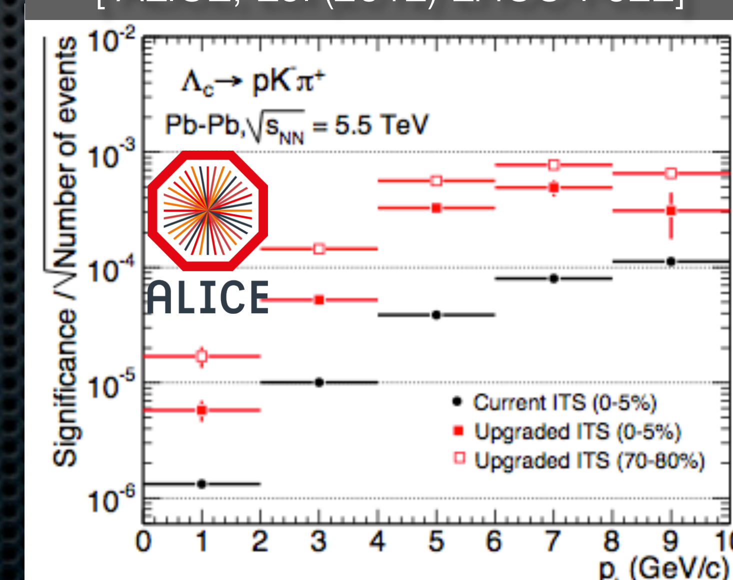
absolute error @ 5.5 TeV

[ALICE, LoI (2012) LHCC-I-022]



open charm Λ_c @ 5.5 TeV

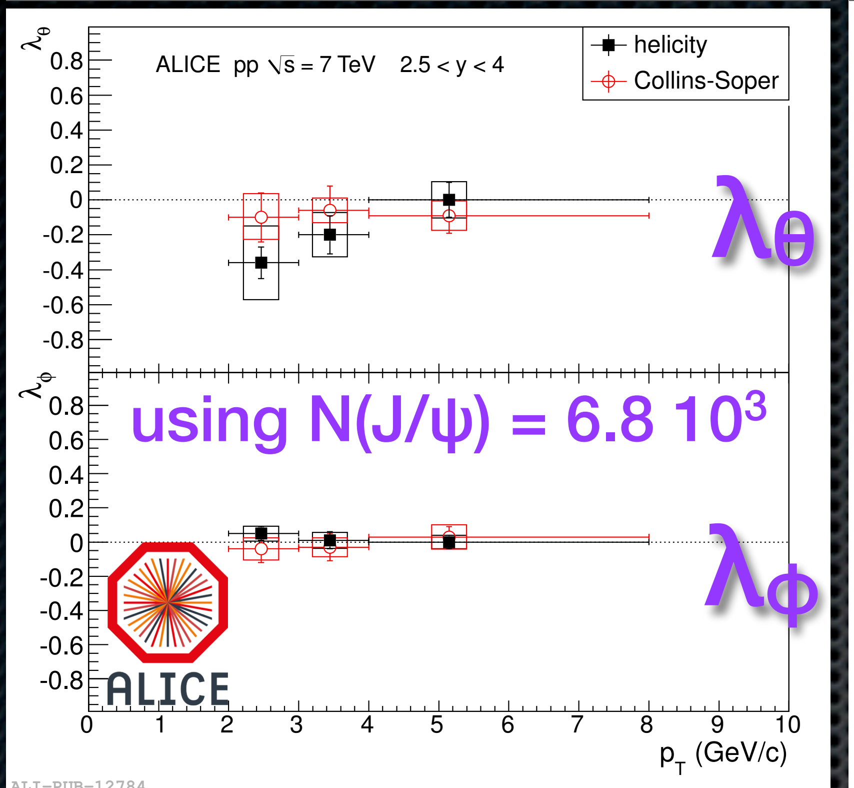
[ALICE, LoI (2012) LHCC-I-022]



Future opportunities @ LHC

J/ψ polarisation p-p @ 7 TeV

[ALICE, PRL 108 (2012) 082001]



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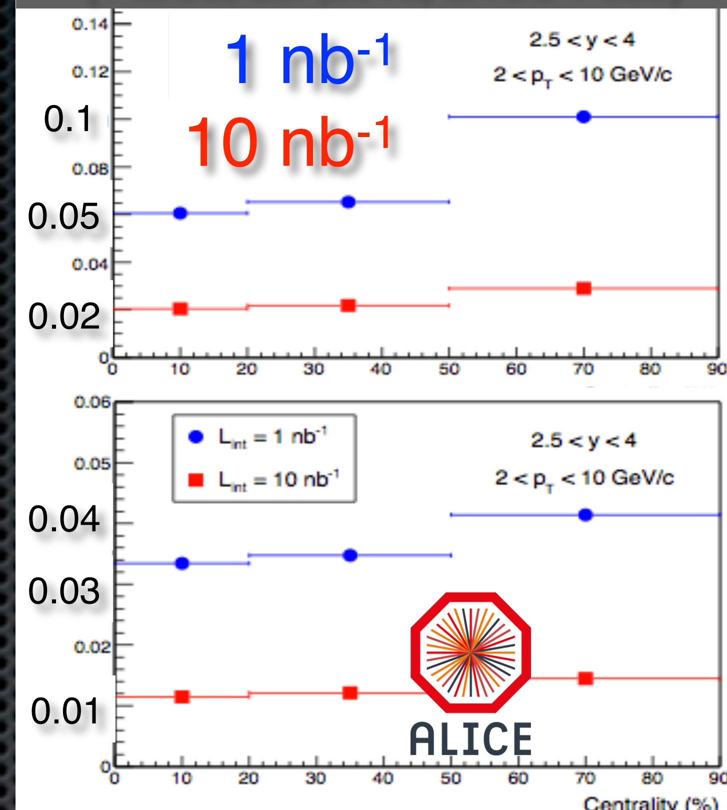

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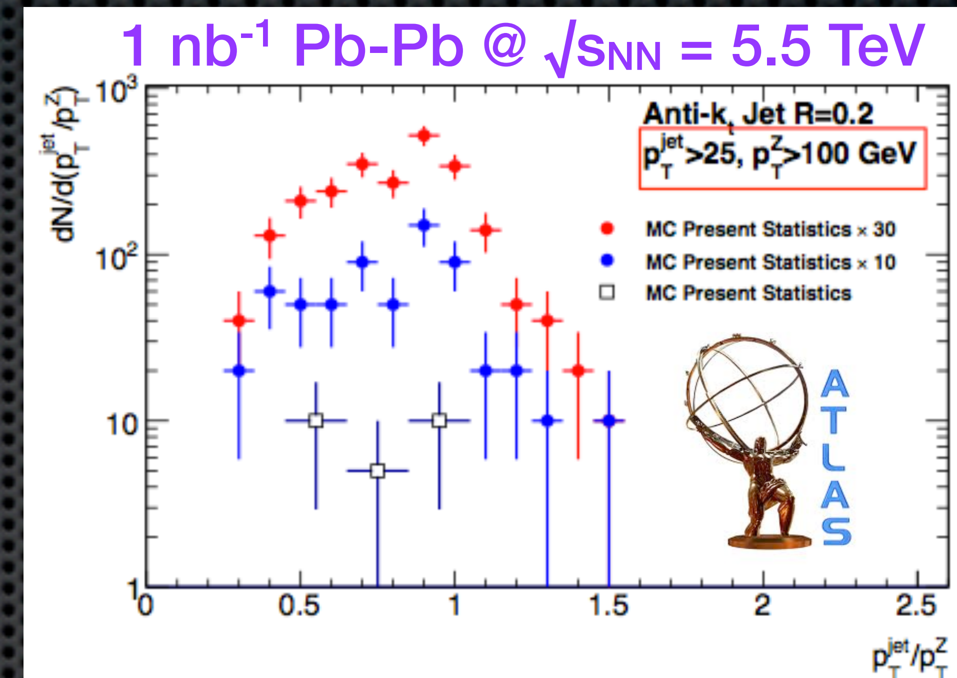

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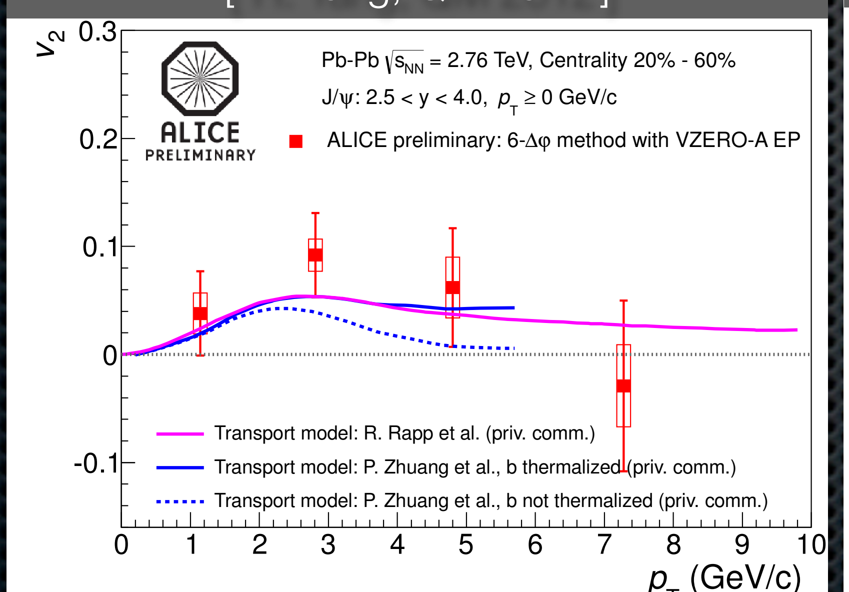

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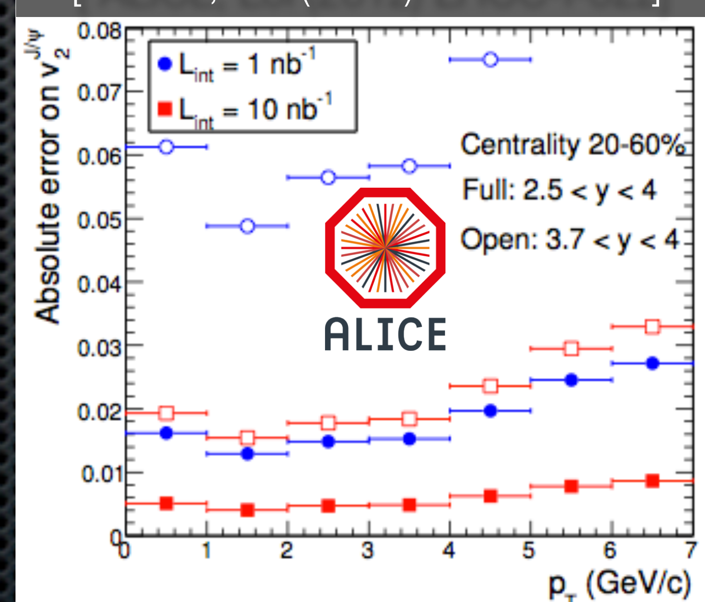
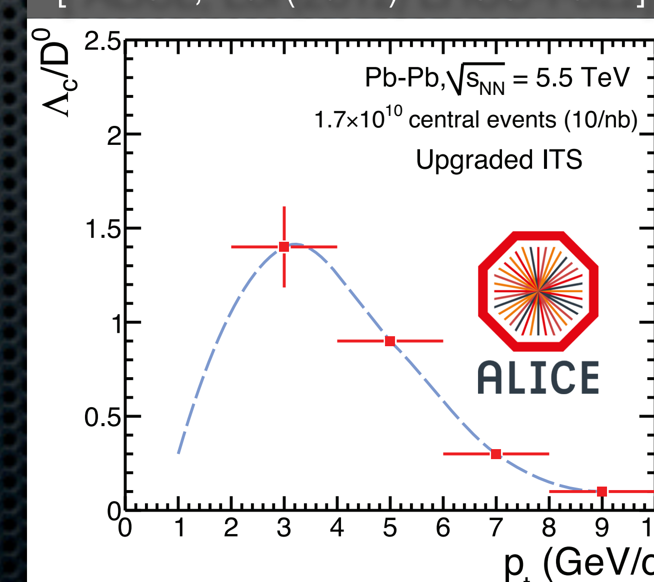
[ALICE, LoI (2012) LHCC-I-022]



charm baryon/meson @ 5.5 TeV

[ALICE, LoI (2012) LHCC-I-022]



A rough timeline*

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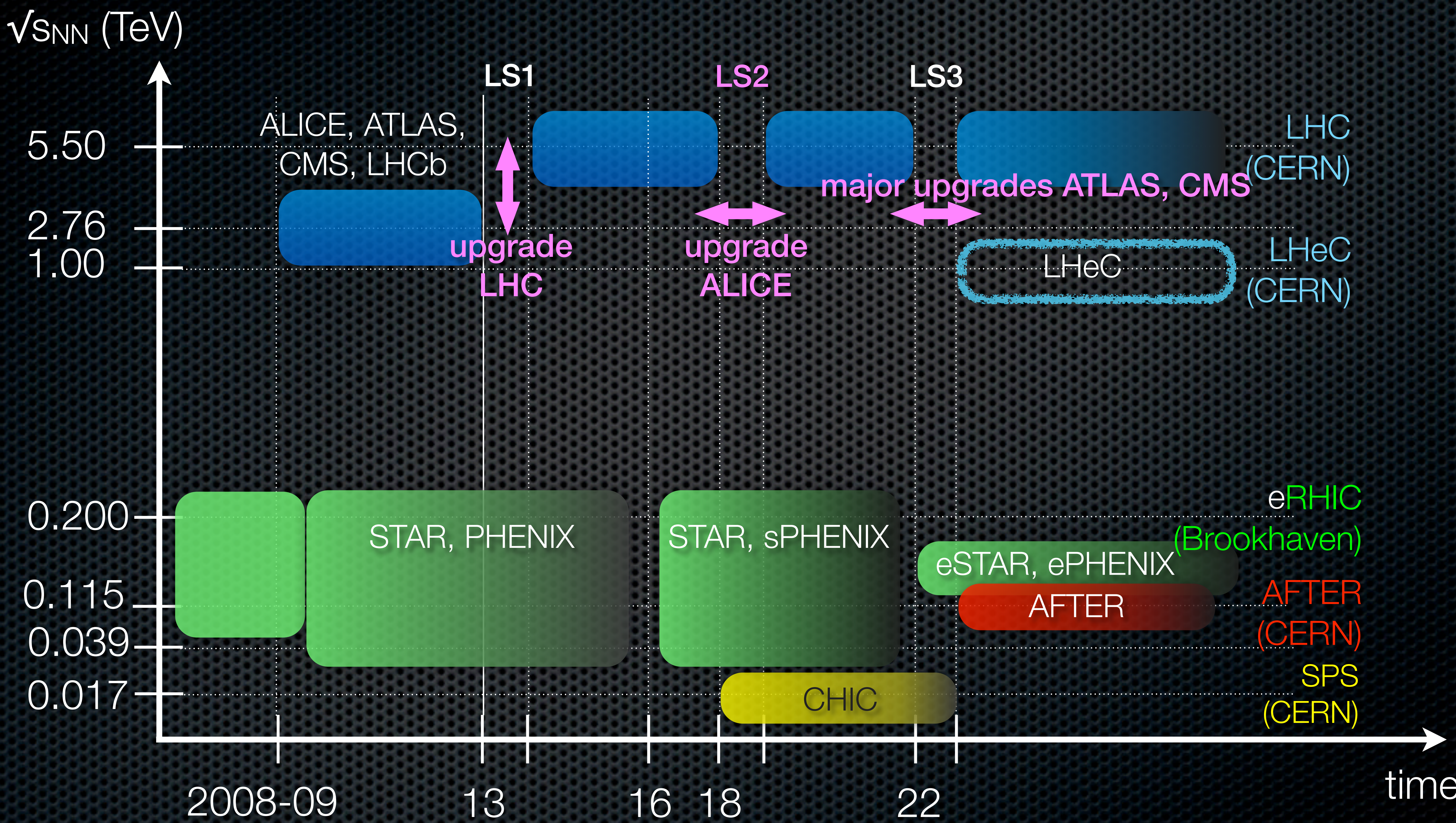
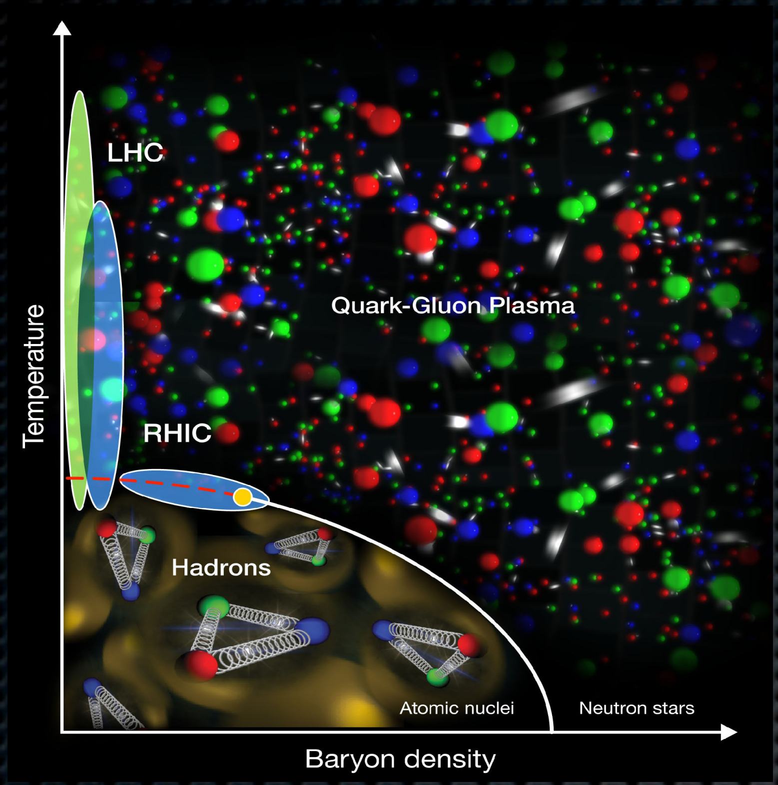


H.I. collisions @ RHIC



« The complementarity of LHC and RHIC is an essential resource in efforts to quantify properties of the Quark-Guon plasma. »

Conclusions of the Heavy-Ion Town meeting (June 2012, CERN), in the preparation of the European Strategy Preparatory Group for Particle Physics (ESPG)

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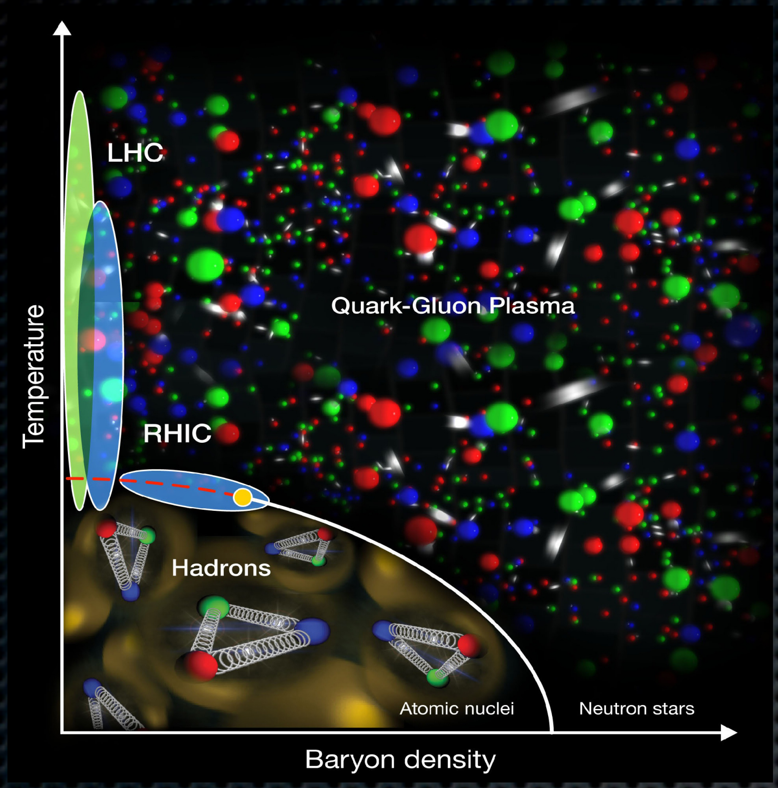

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what is the nature of the QGP at $\mu_B > 0$?

- can we map the transition from plasma to hadron gas ?
- is there a critical point in the phase diagram ?
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QGP transition from strong (RHIC) to weak coupling (LHC?)

- do QGP properties change from T=170 to 400 MeV ?
- quasi-particles ?
- heavy flavor jet quenching, flow

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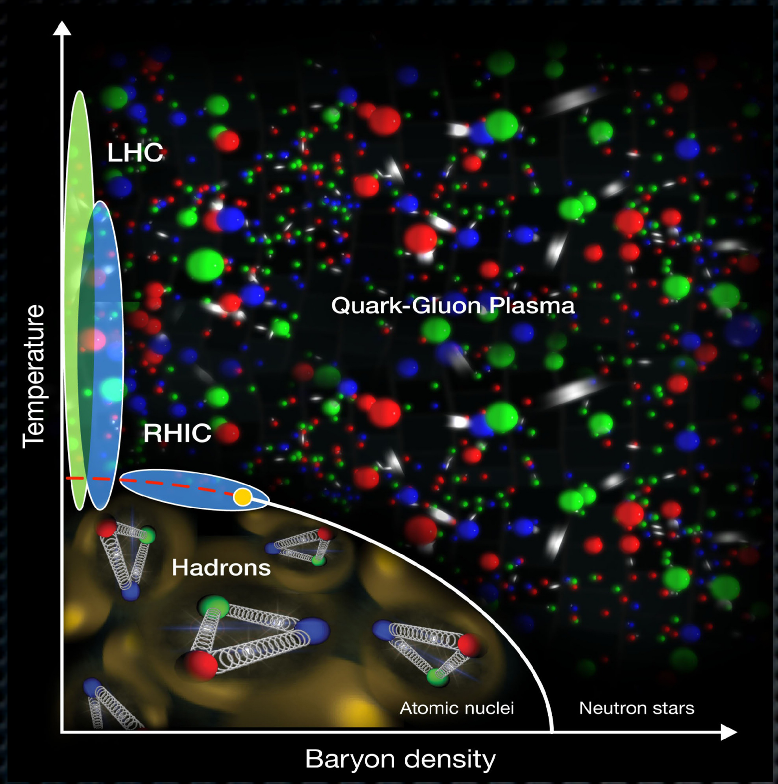

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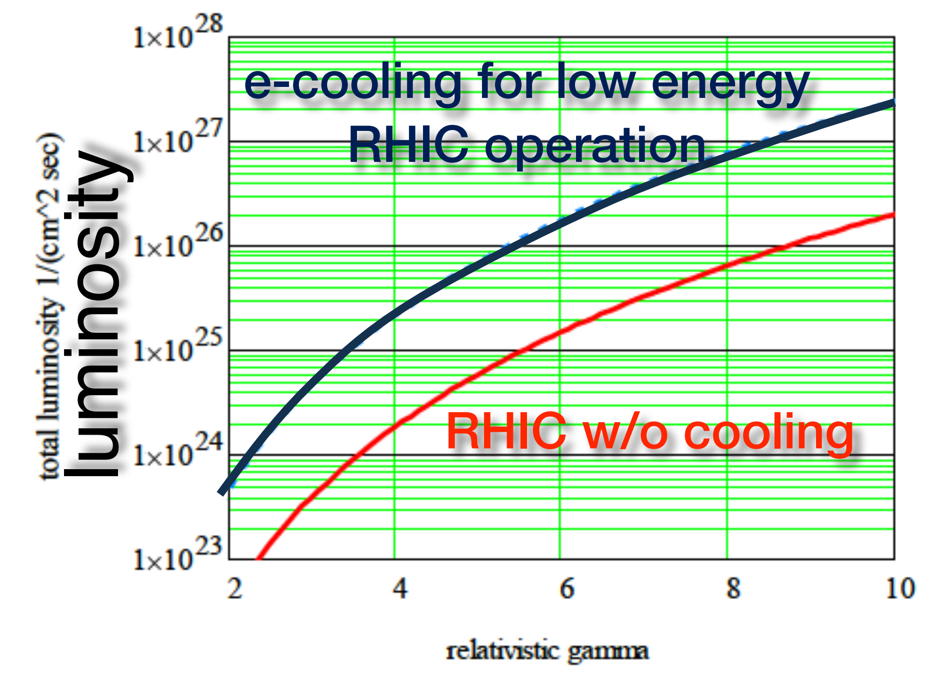

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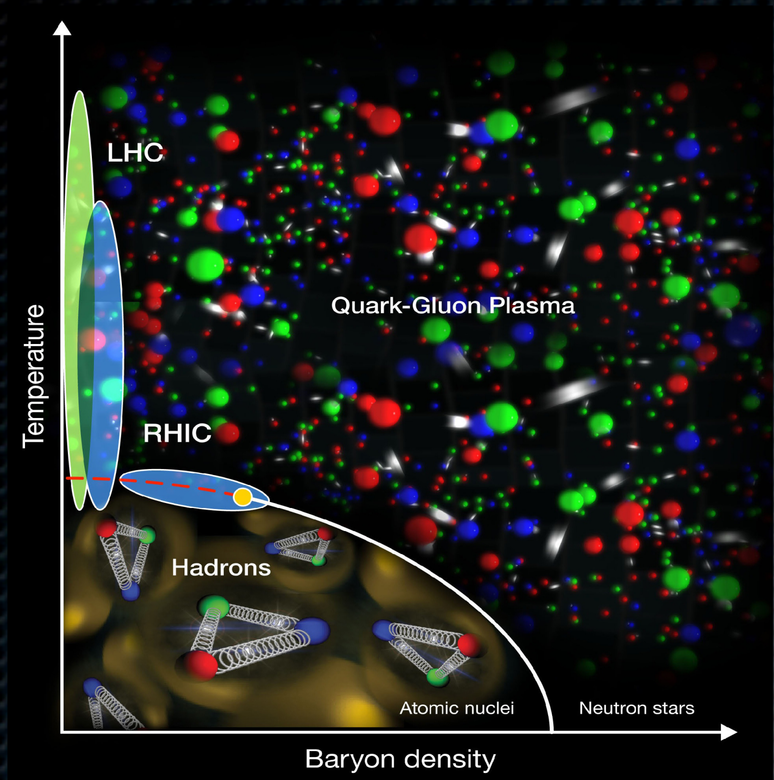

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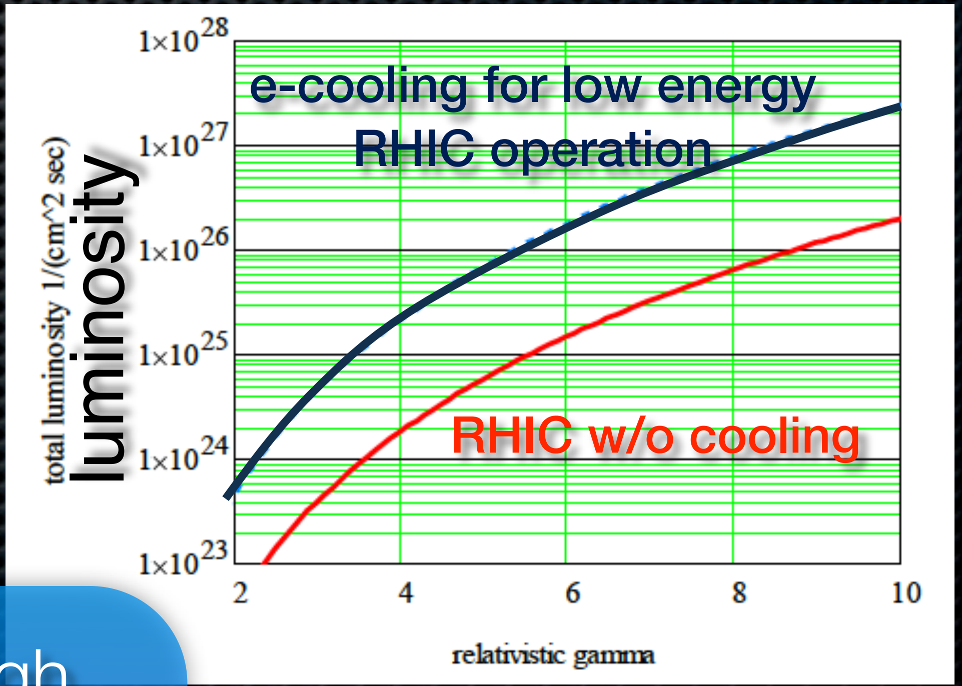
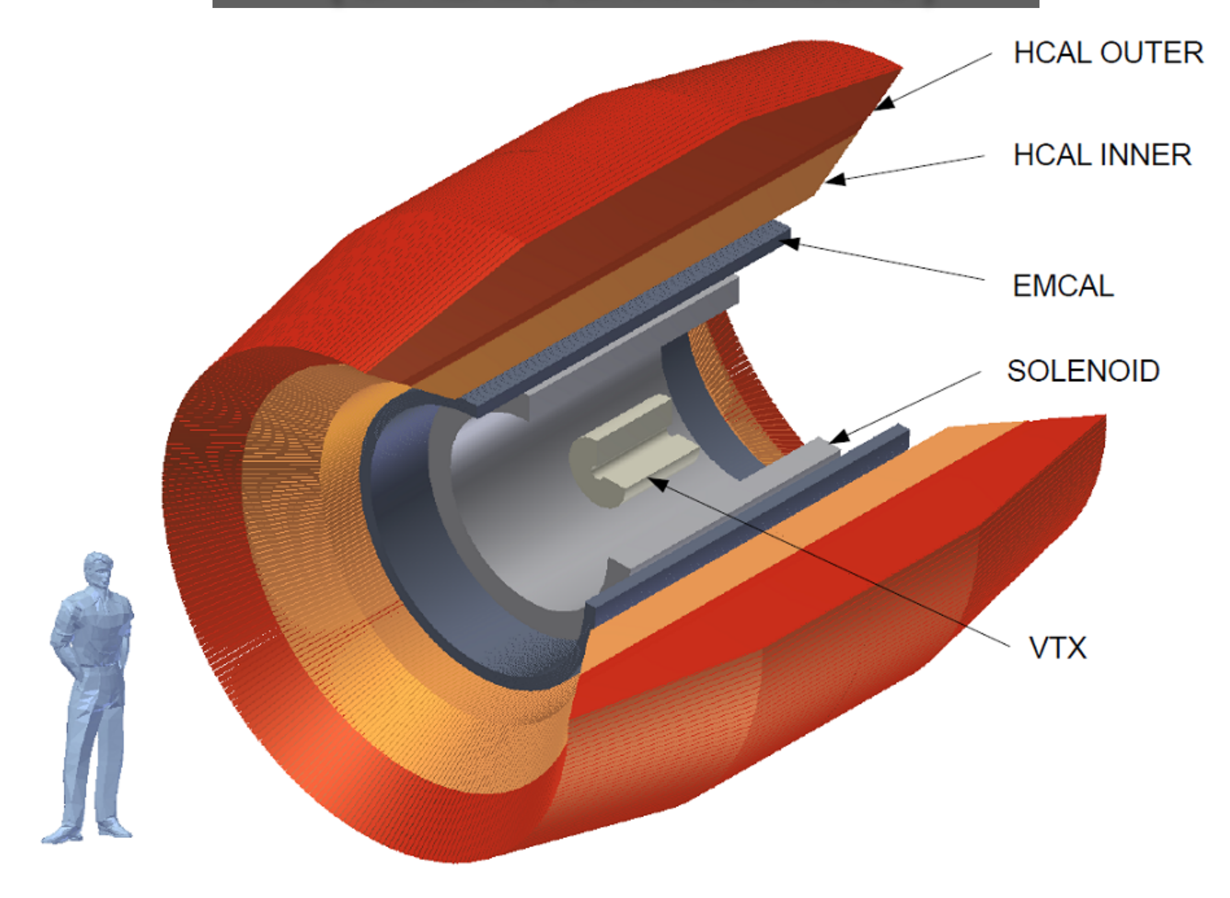


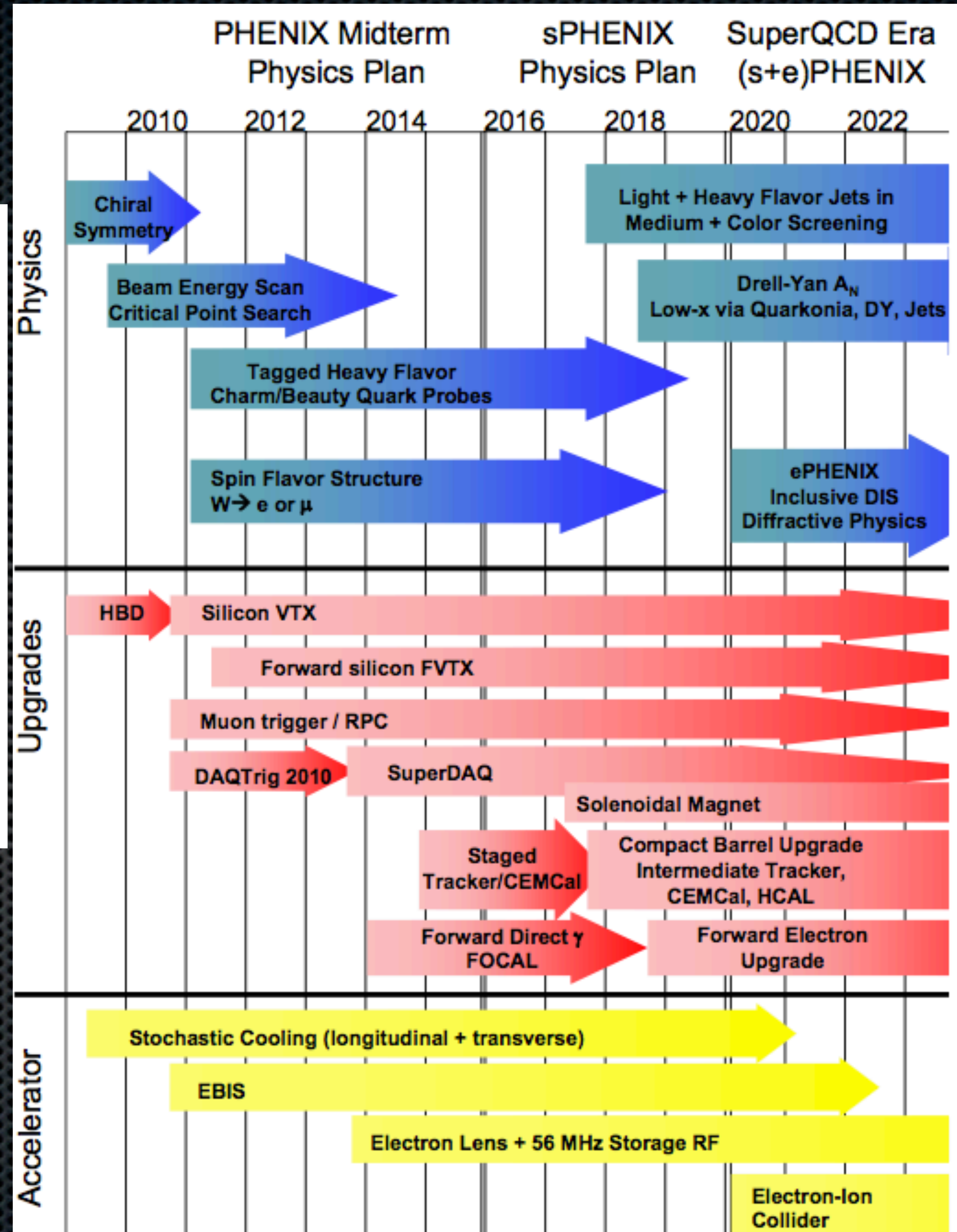
RHIC II high luminosities

sPHENIX

[J. Haggerty, QM2012]
[sPHENIX, arXiv:1207.6378]



- Emphasizes jet physics observables with calorimetry initially
- Full jet reconstruction
- Compact detector
- Data acquisition capable of recording > 10 kHz

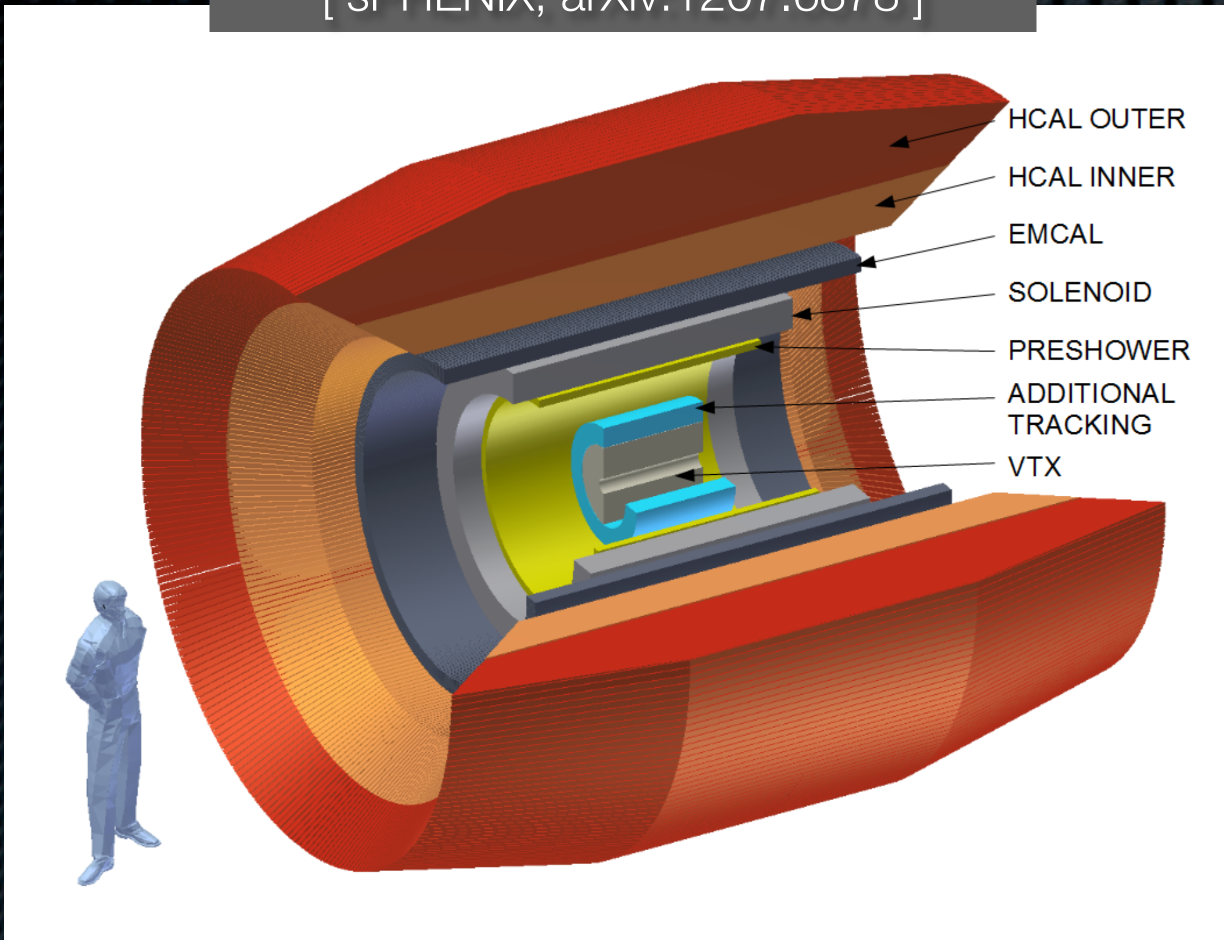


[PHENIX decadal plan 2011-2020]

EBIS = Electron Beam Ion Source

sPHENIX

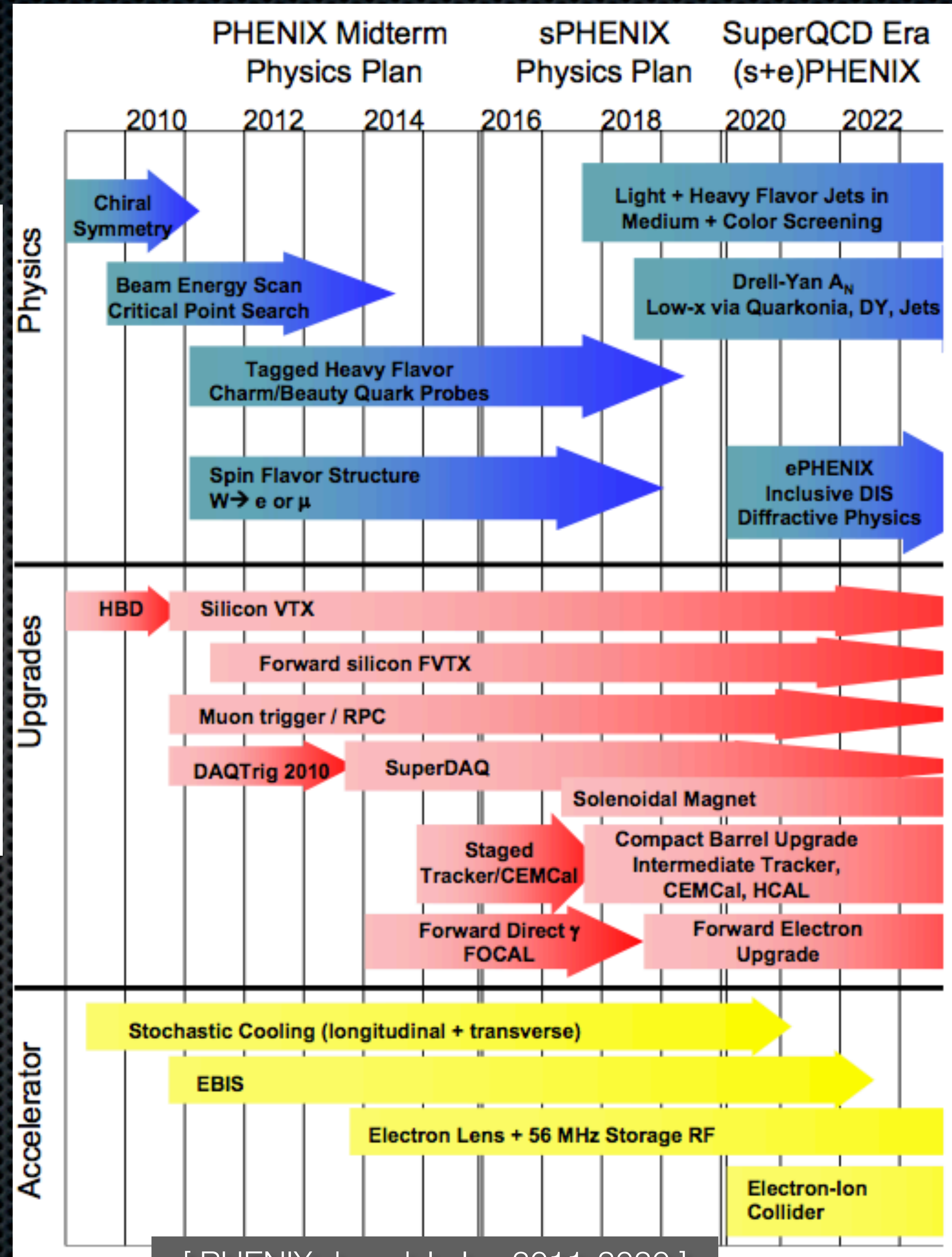
[J. Haggerty, QM2012]
[sPHENIX, arXiv:1207.6378]



upgrade option # 1 :

- separation of Υ states (add. tracking)
- extend up to p_T > 50 GeV single γ from $\pi^0 \to \gamma\gamma$ separation (preshower)

EBIS = Electron Beam Ion Source



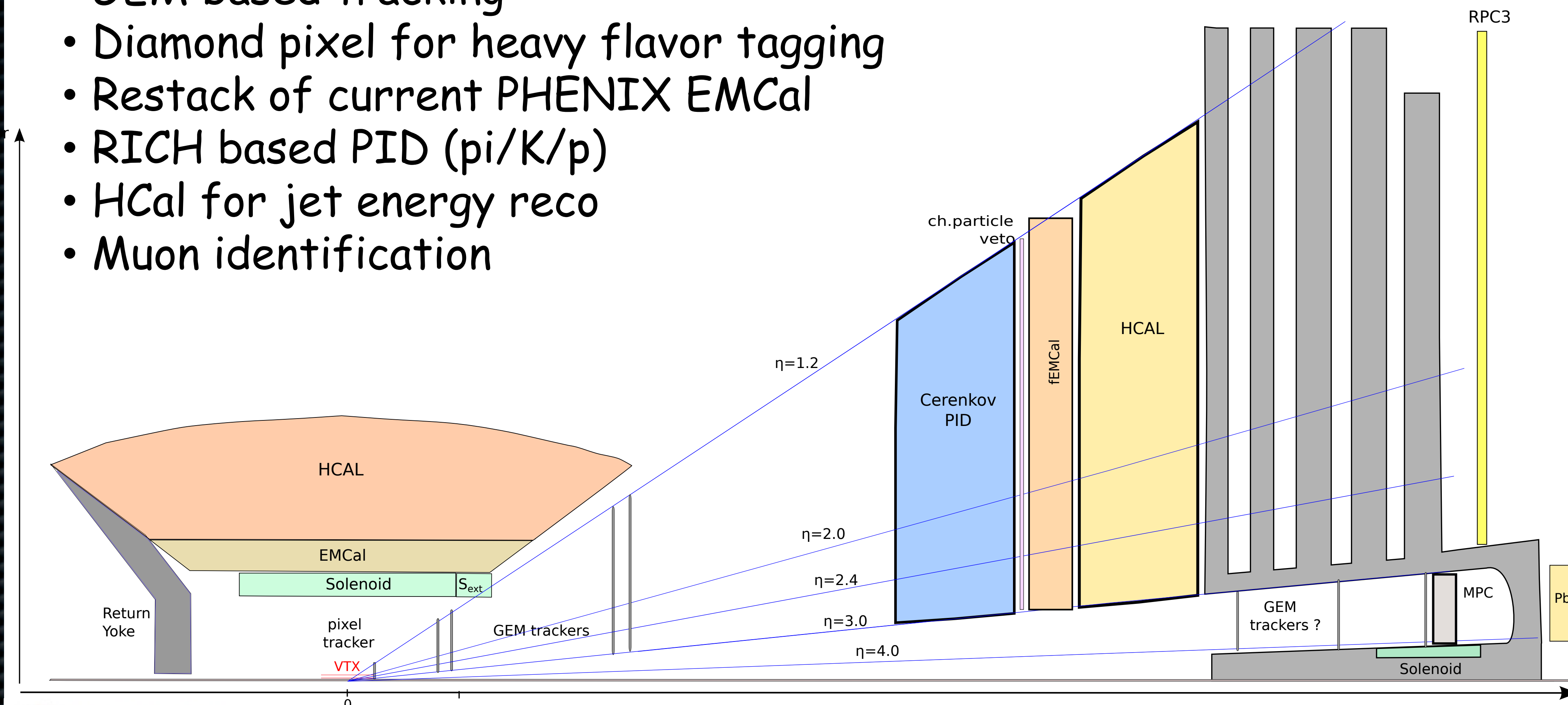
[PHENIX decadal plan 2011-2020]

sPHENIX - ePHENIX

[J. Seele, QM2012]
[sPHENIX, arXiv:1207.6378]

Optimized for jets and photons/DY over a large range in rapidity (η~4)

- Extension/modification of the central solenoid for B field
- GEM based tracking
- Diamond pixel for heavy flavor tagging
- Restack of current PHENIX EMCal
- RICH based PID (pi/K/p)
- HCal for jet energy reco
- Muon identification

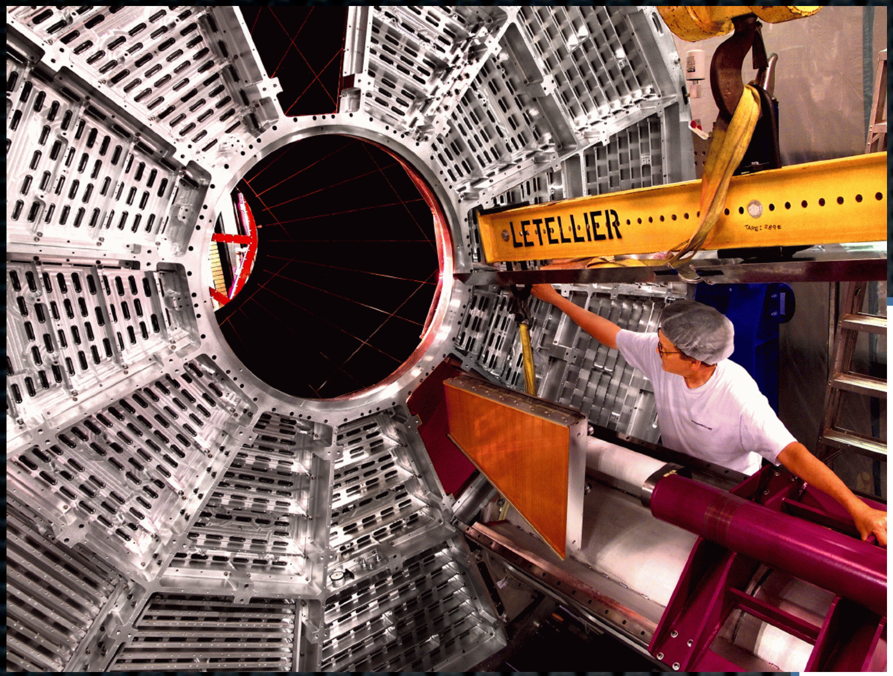


RIKEN BNL Research Center

J. Seele (RBRC) - QM2012 9

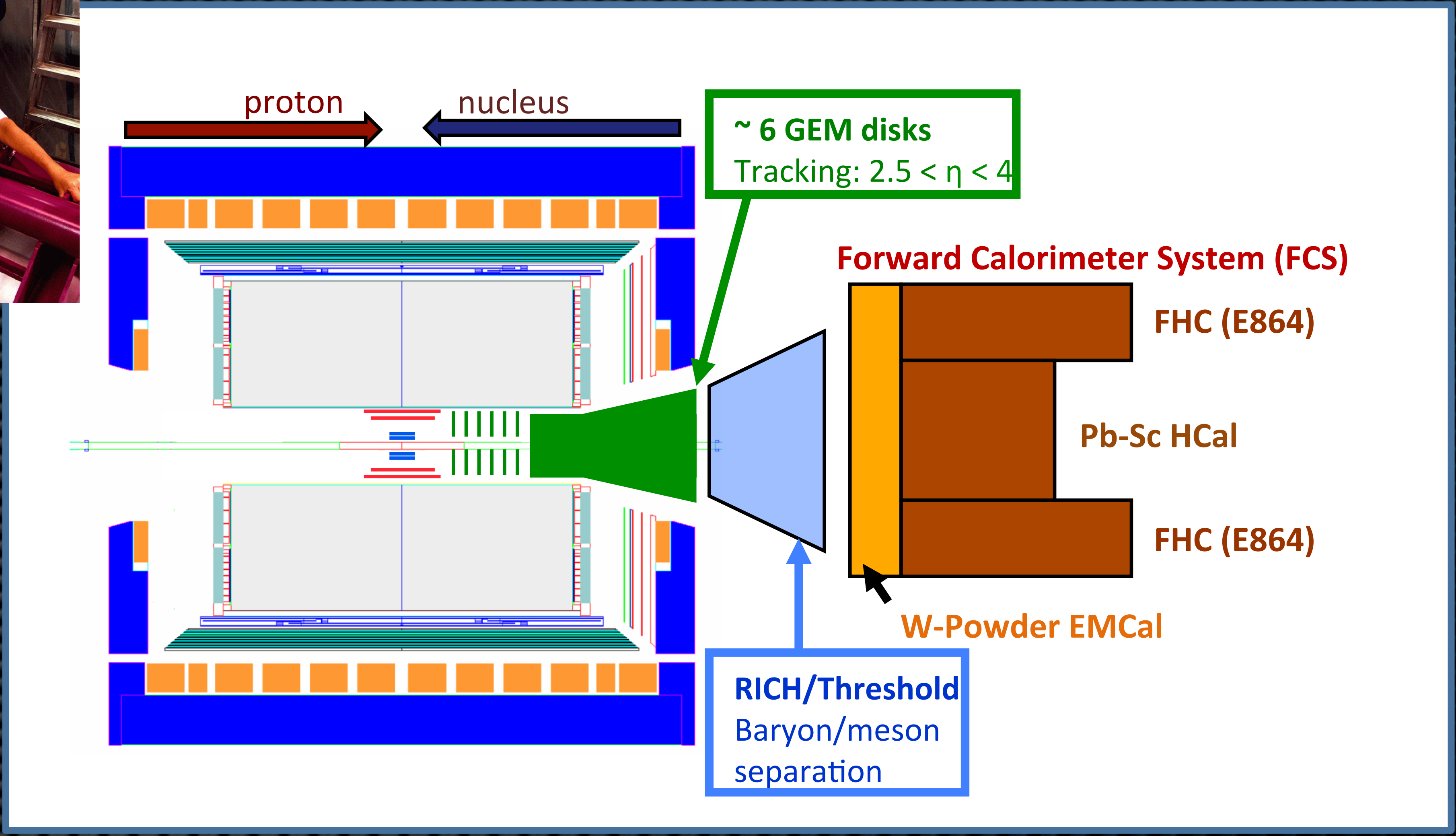
- upgrade option # 2
- also Cold Nuclear Matter studies, spin physics

STAR



STAR Inner TPC Readout
Improved tracking and dE/dx PID
Extend η coverage 1.0-1.7

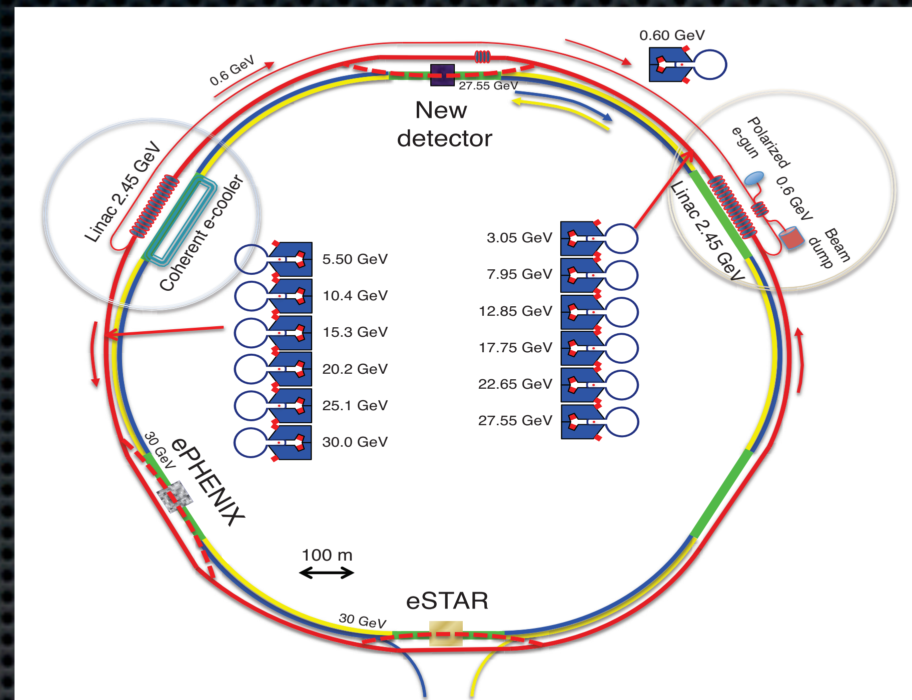
[H. Z. Huang, J. Nagle, QM2012]

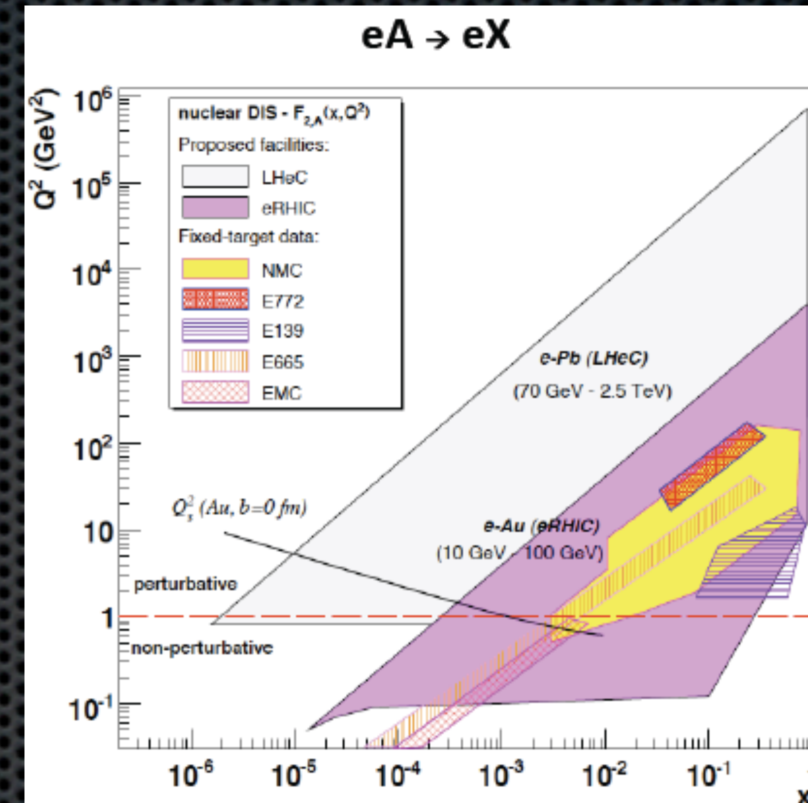


also designed for evolution into EIC detector

LHeC / eRHIC : electron-ion colliders

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

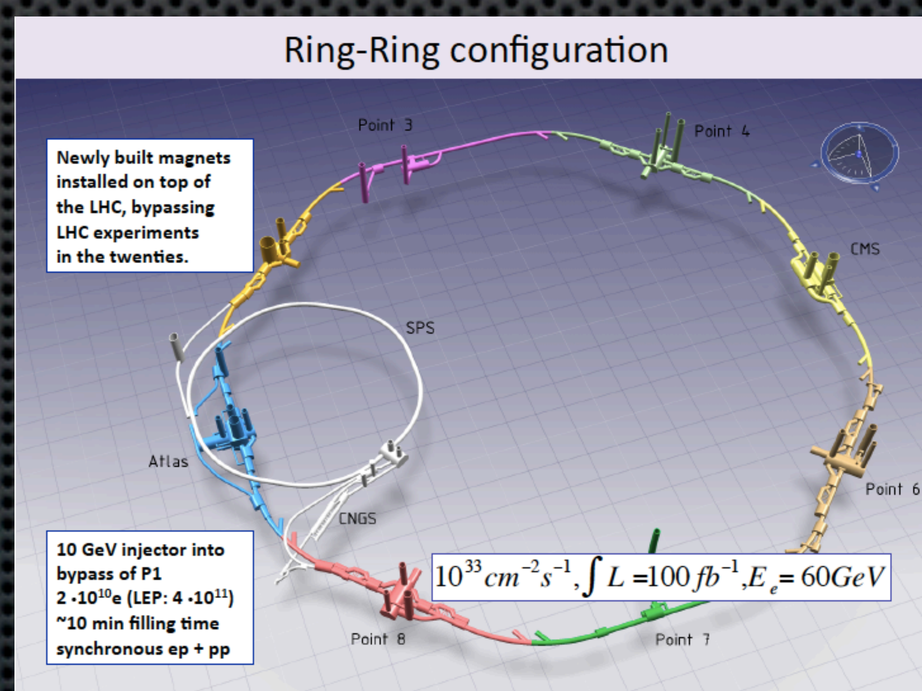


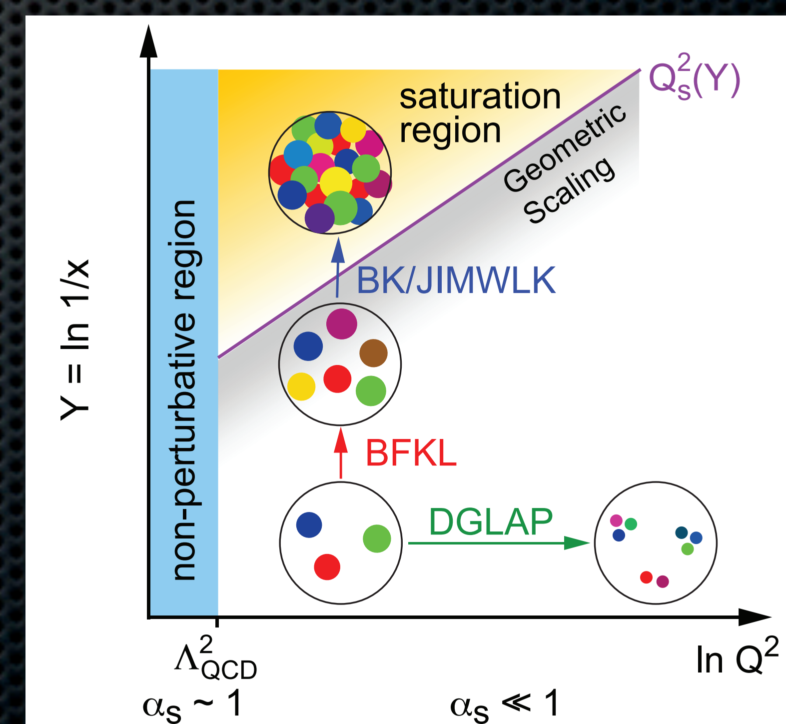


RHIC @ BNL

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

A rough timeline*

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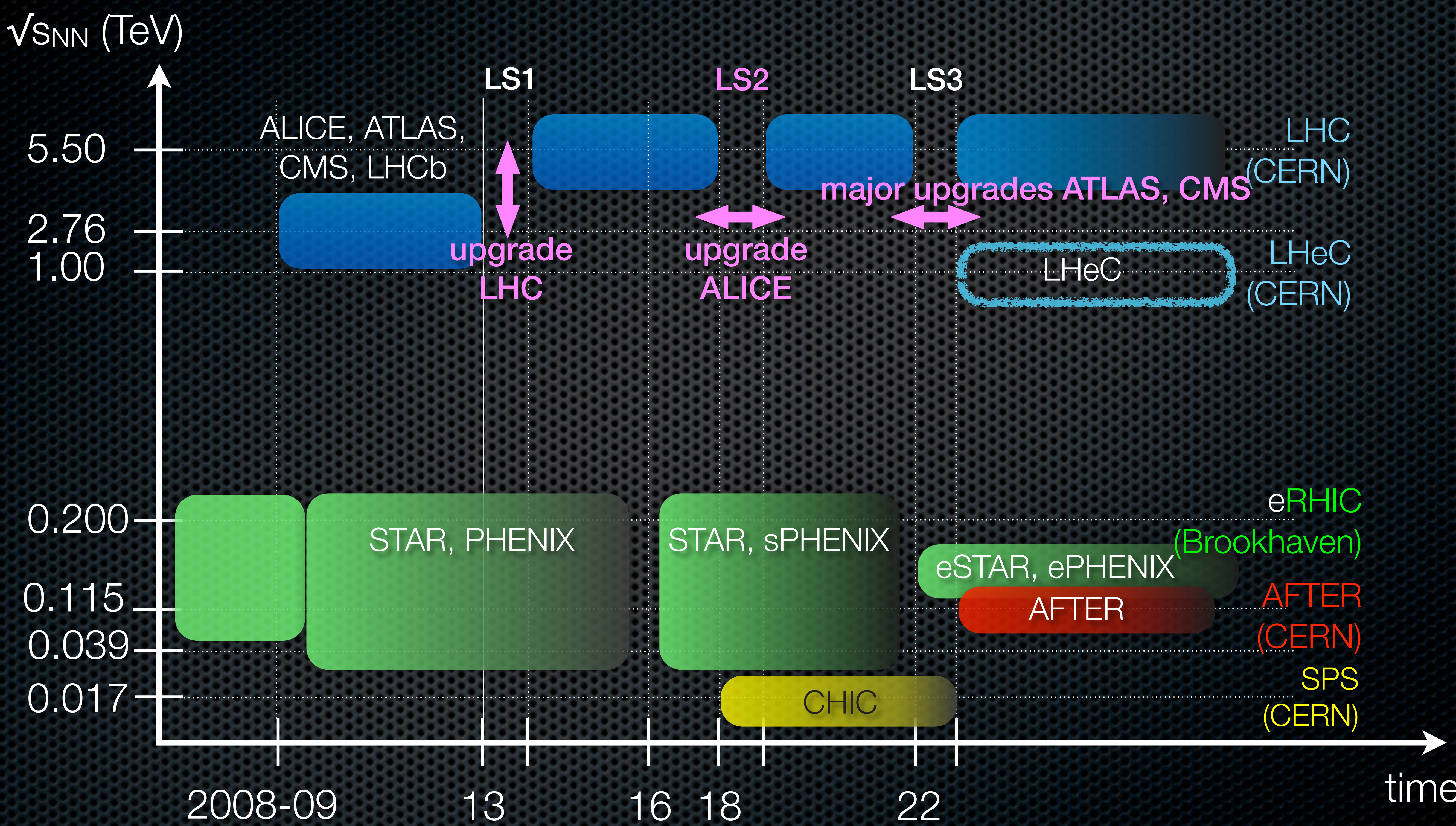
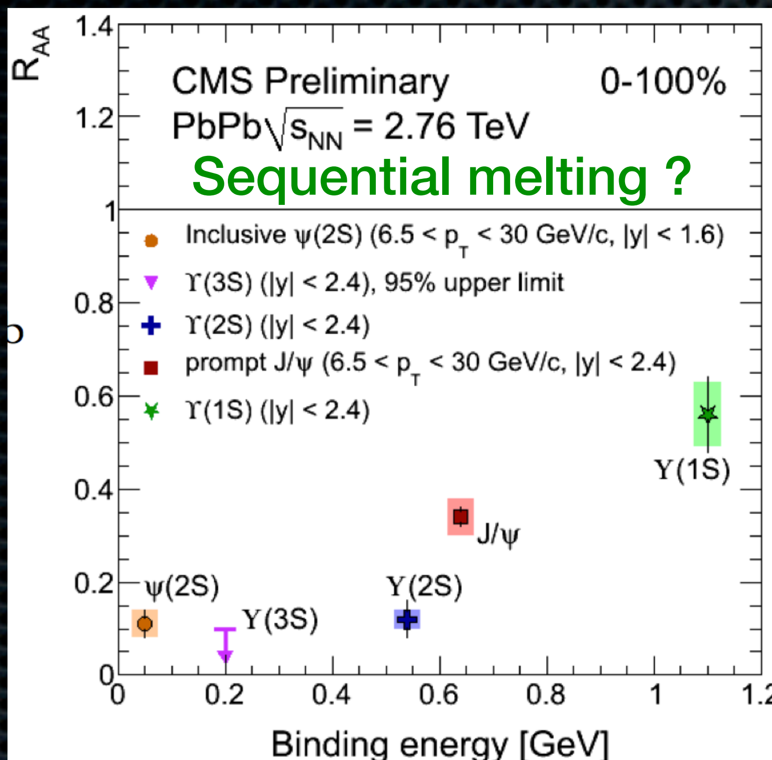


CHIC : χ_c at SPS

high p_T J/ψ, ψ(2S)
ϒ(1S, 2S, 3S)



A fixed target experiment at SPS, specialized in dilepton measurement

Charmonium family as a thermometer at SPS energy

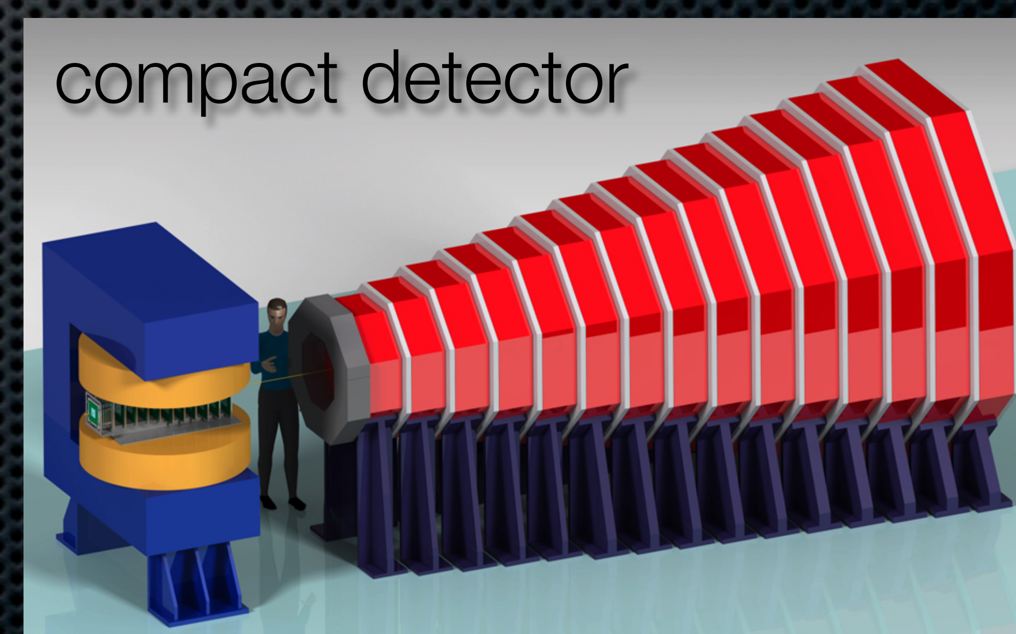
- sequential melting ?
- χ_c is the missing piece (30% prompt J/ψ yield)

Cold Nuclear Matter effects at SPS

- high luminosity in p-A
- wide (x_F) rapidity range $-0.5 < y_{cms} < 2$
- charmonia, open charm

Binding energy

state	η_c	J/ψ	χ_{c0}	χ_{c1}	χ_{c2}	ψ'
mass [GeV]	2.98	3.10	3.42	3.51	3.56	3.69
ΔE [GeV]	0.75	0.64	0.32	0.22	0.18	0.05



CHIC : χ_c at SPS

E. Ferreiro, F. Fleuret

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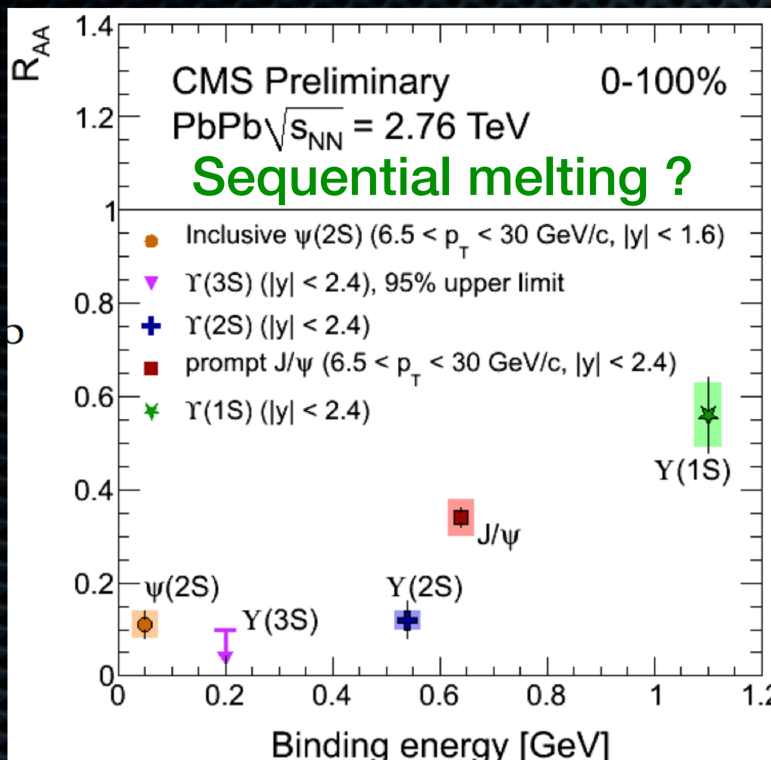

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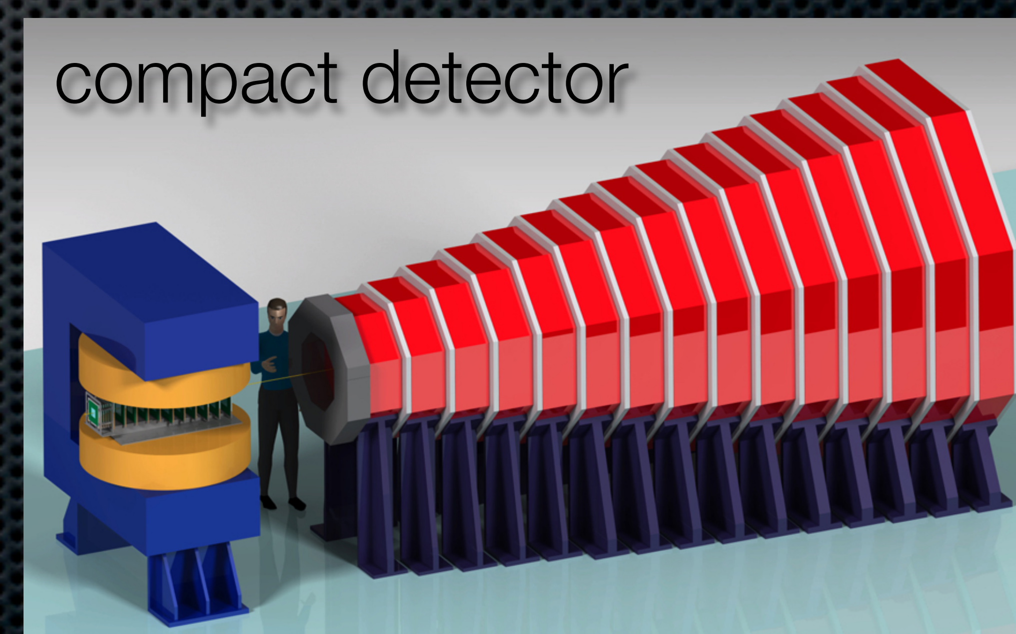
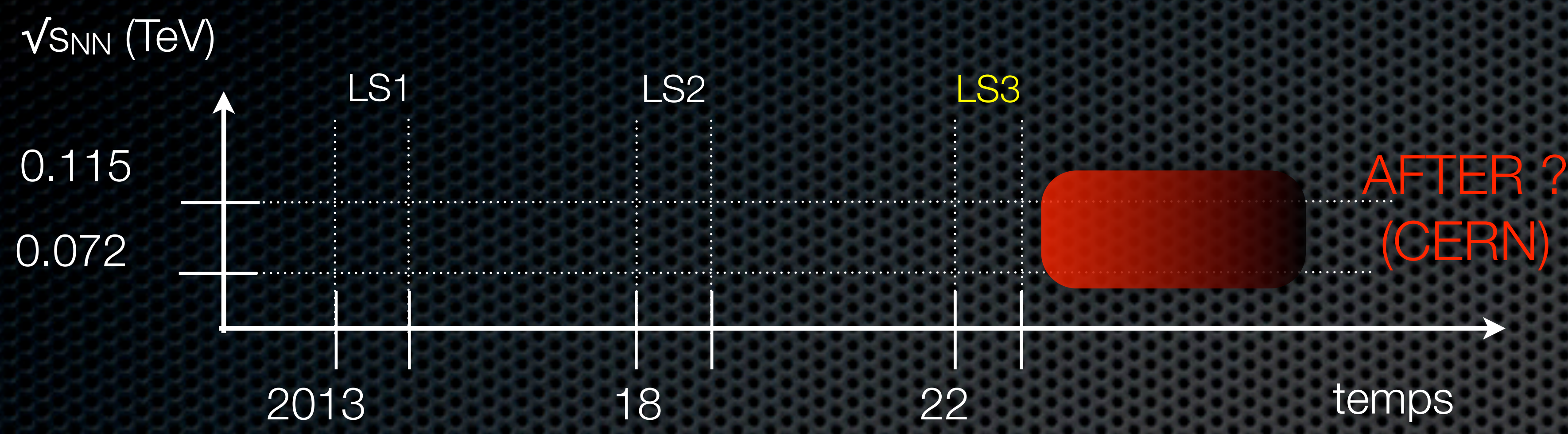


Long term prospectives



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- extend RHIC physics to the high x region for gluons
- era of precision measurement : quarkonium observatory (10^2-10^3 x projected RHIC yields)
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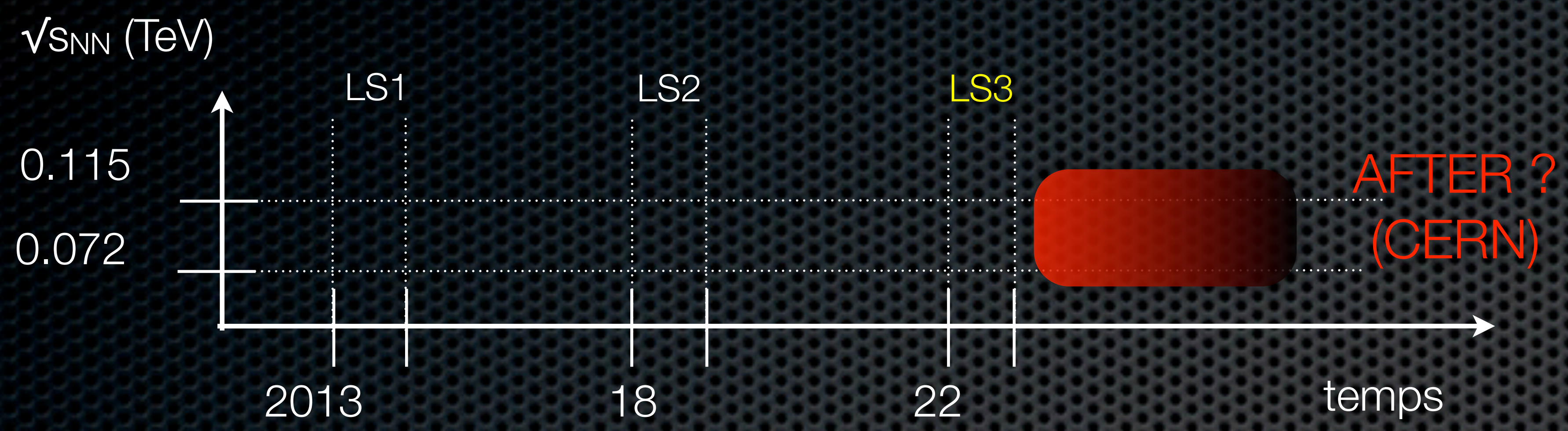
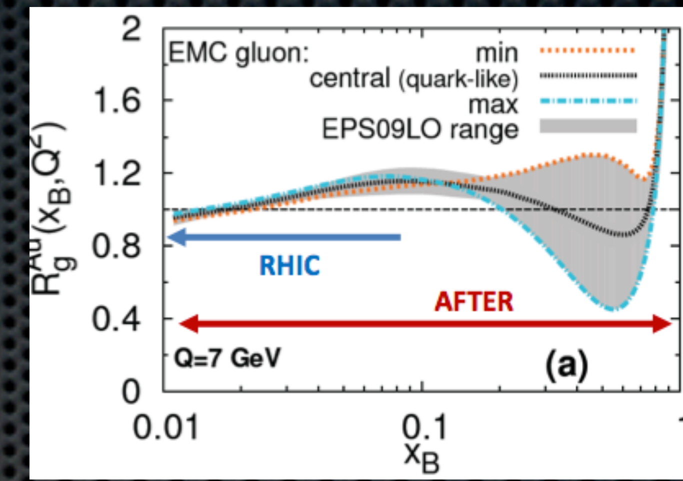


nuclear modification of g PDF in Au



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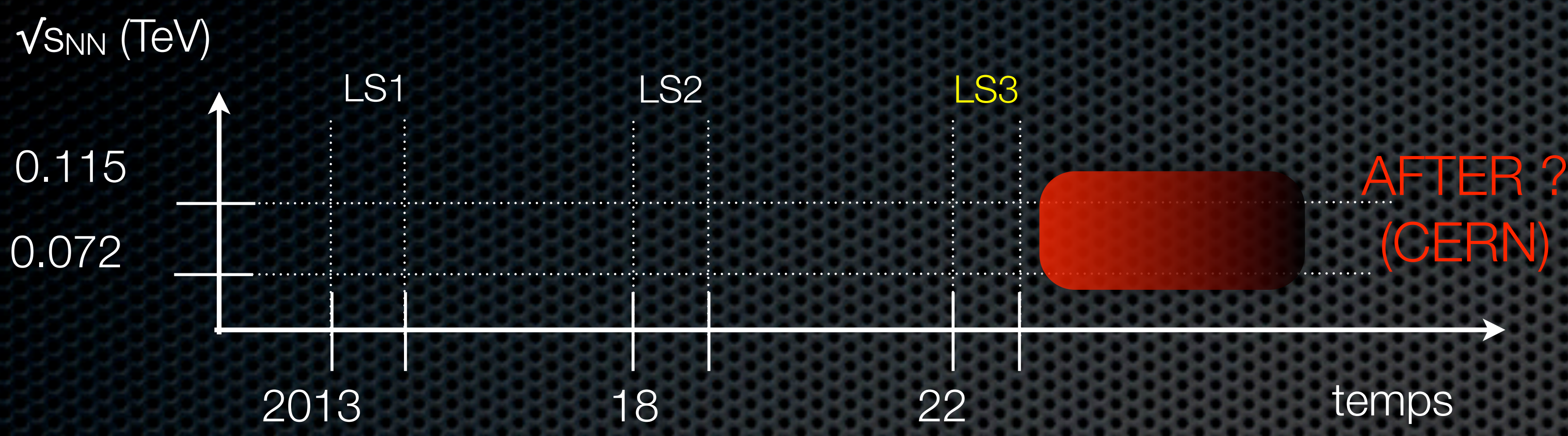

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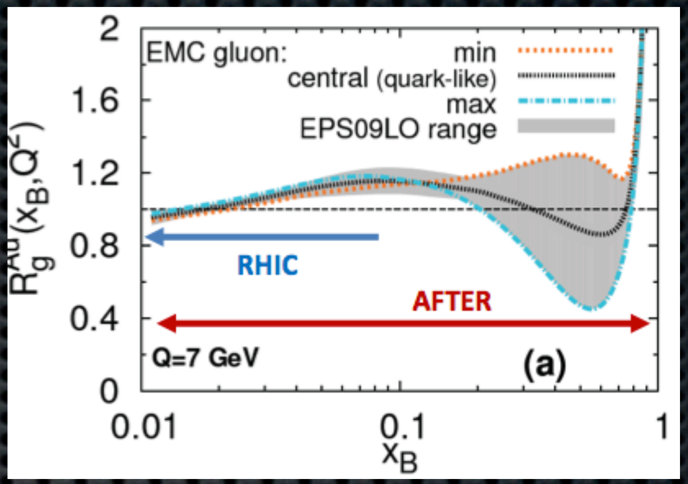
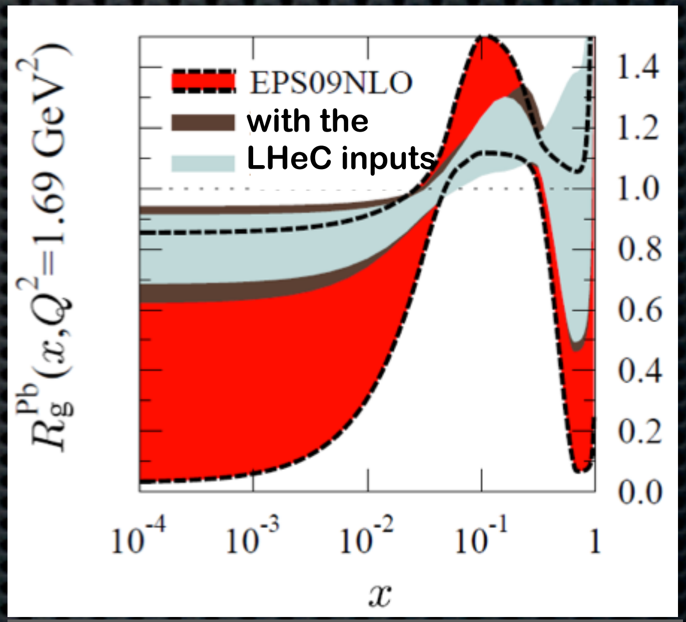


nuclear modification of g PDF in Pb



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

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P. Newman, European Strategy Preparatory Group for Particle Physics (ESPG), Cracow, Sept 2012

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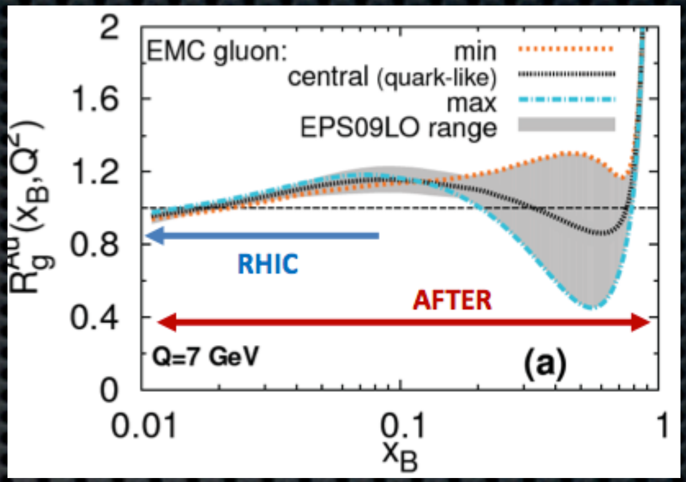

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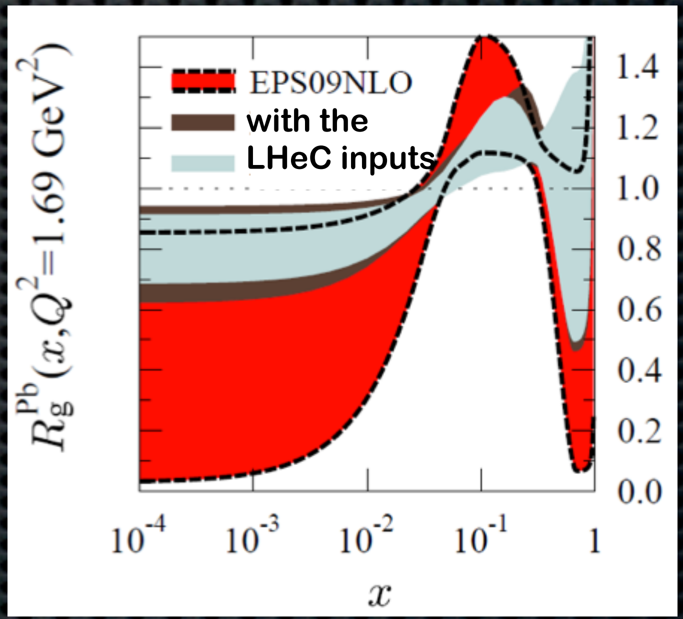

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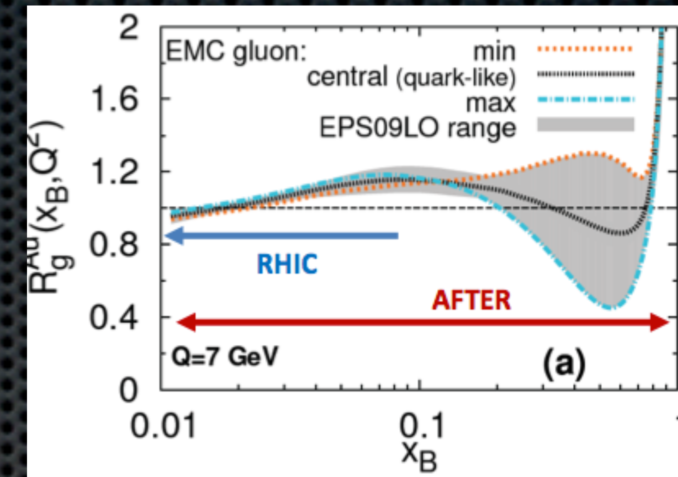

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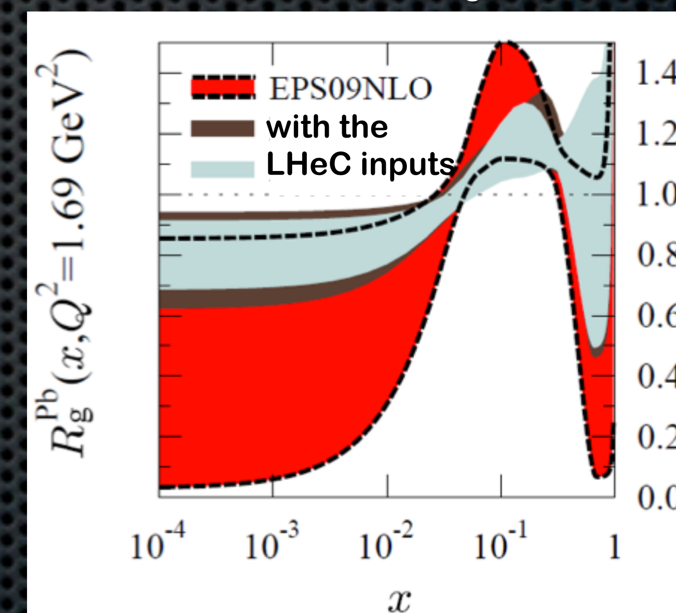

[LHeC CDR, J. Phys. G 39 (2012) 075001]

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)

- first paper on physics opportunities Phys. Rept. 522 (2013) 239
- webpage after.in2p3.fr

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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- multipurpose experiment, modern detection techniques

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  - high luminosity, high boost (y_{CMS}=4.8 @ 115 GeV), target versatility
- multipurpose experiment, modern detection techniques

spin physics

PDF and nPDF at large x_B

heavy quarkonium prod. and Cold Nuclear Matter effects

W, Z prod. near threshold

A Fixed Target ExpeRiment at LHC

Use LHC beams on fixed target :

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

comparable to RHIC energies

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

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UPC

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

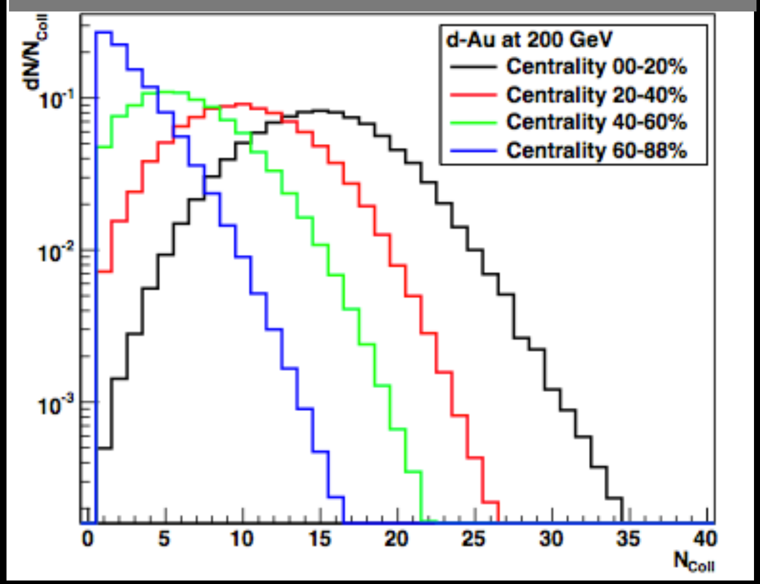
diffractive physics

Physics in p–A and Pb–p

Precision studies of the nuclear matter :

- A dependence (better than <N$_{coll}$>) thanks to target versatility

[PHENIX, arXiv:1204.0777]



<N$_{coll}$> dependence ⇛ A dependence (à la NA50, NA60)

Physics in p–A and Pb–p

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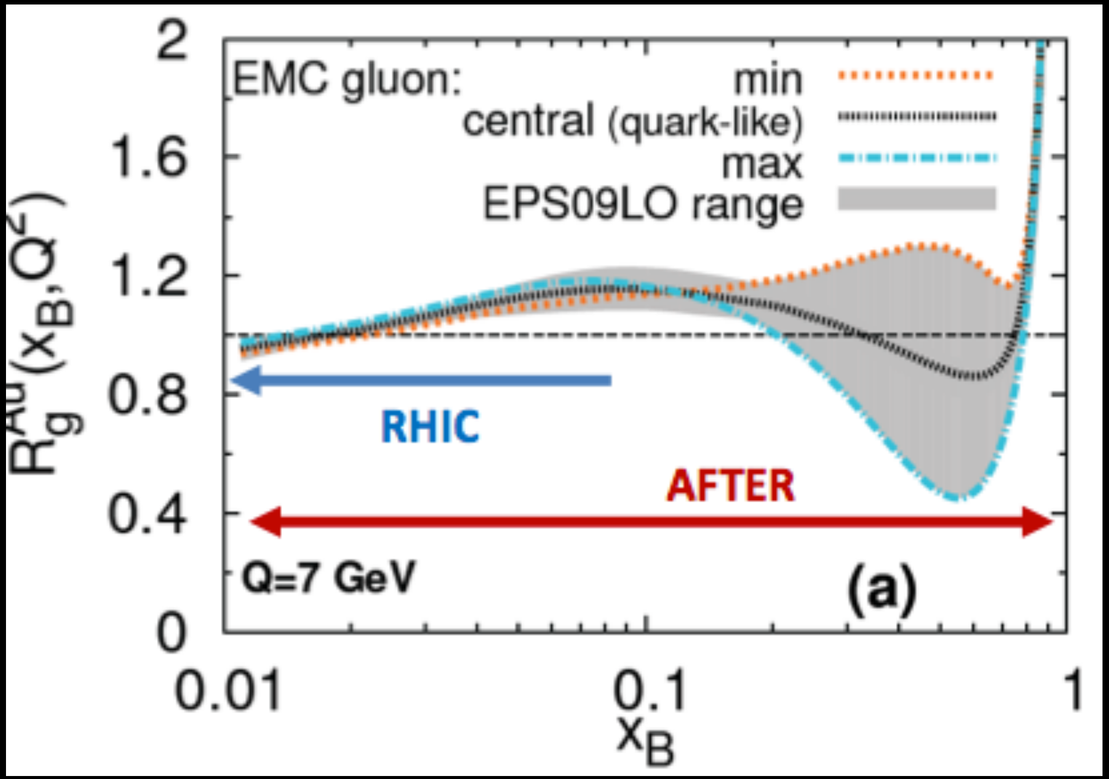

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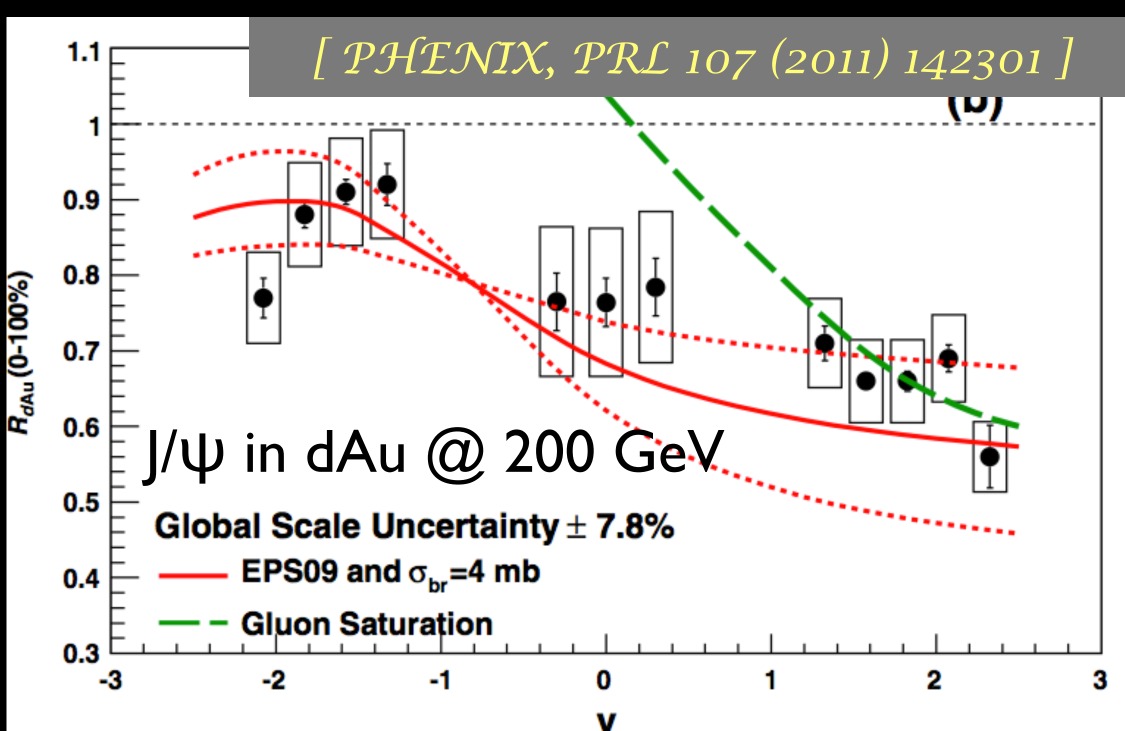
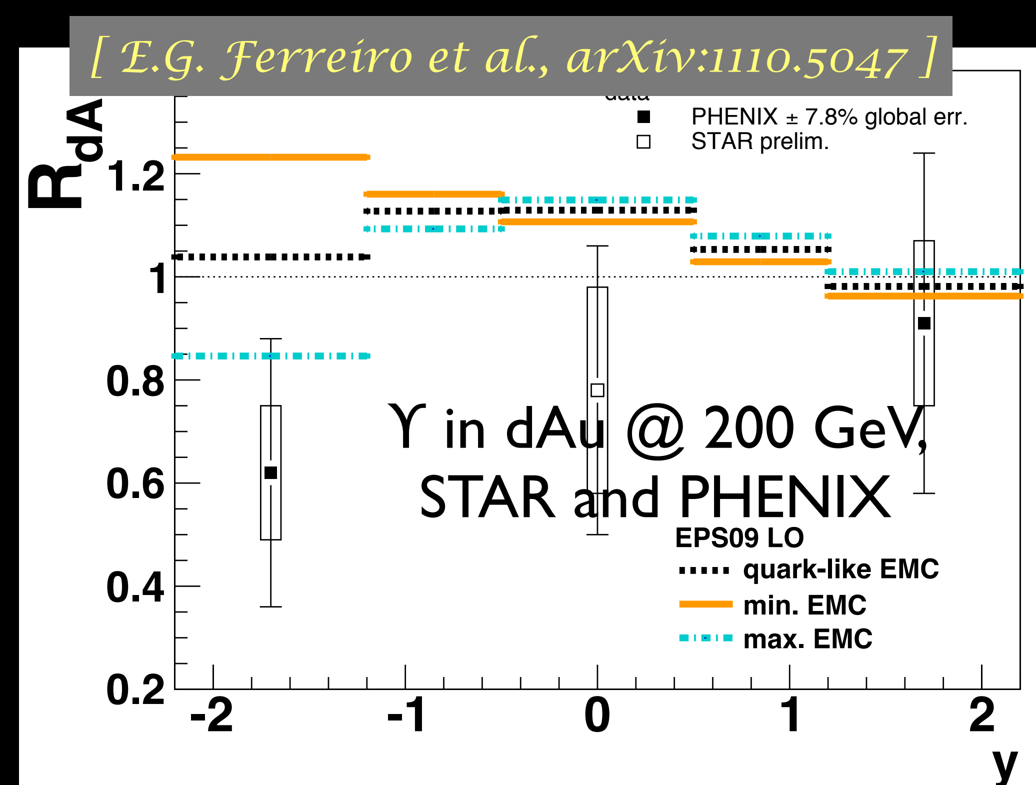


[PHENIX, PRL 107 (2011) 142301]



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

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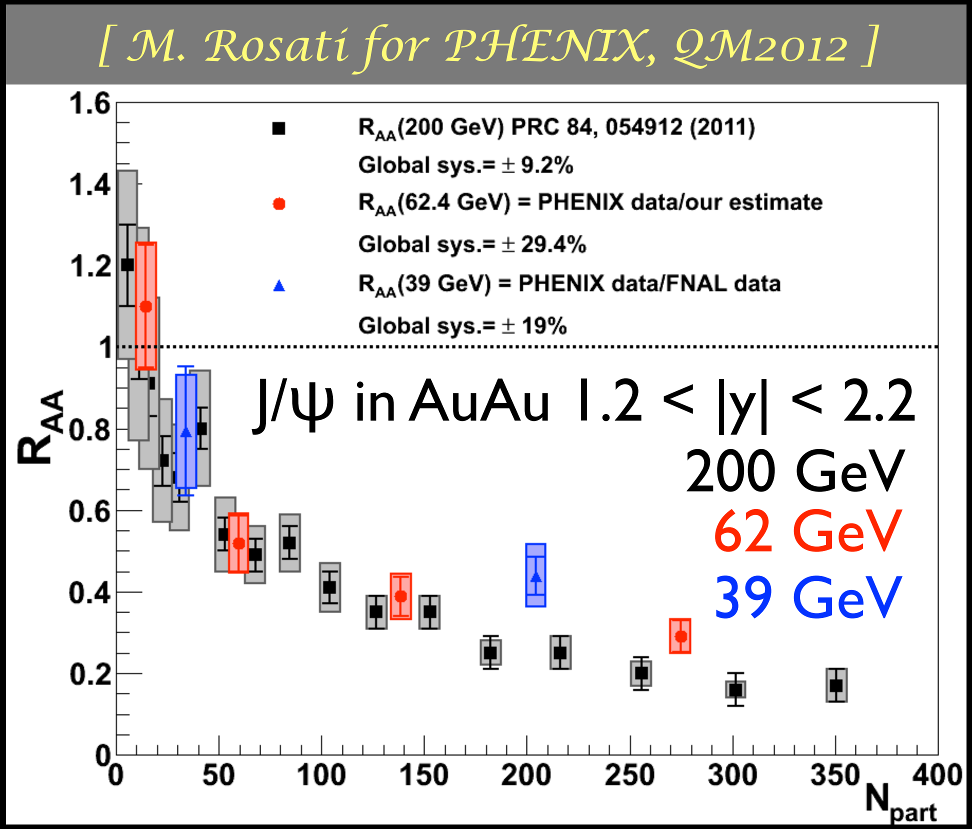
- test QCD factorization in charmonium production at high x_F
- these studies are needed to clear the current picture of heavy quarkonium as a hard probe of QGP from SPS to LHC energies, RHIC-like energies being a key step

Physics in Pb–A

Precision studies of the deconfinement at RHIC energies :

- For e.g. quarkonium studies, a threefold improvement w.r.t. RHIC
  - much higher statistics compared to RHIC @ 62 GeV



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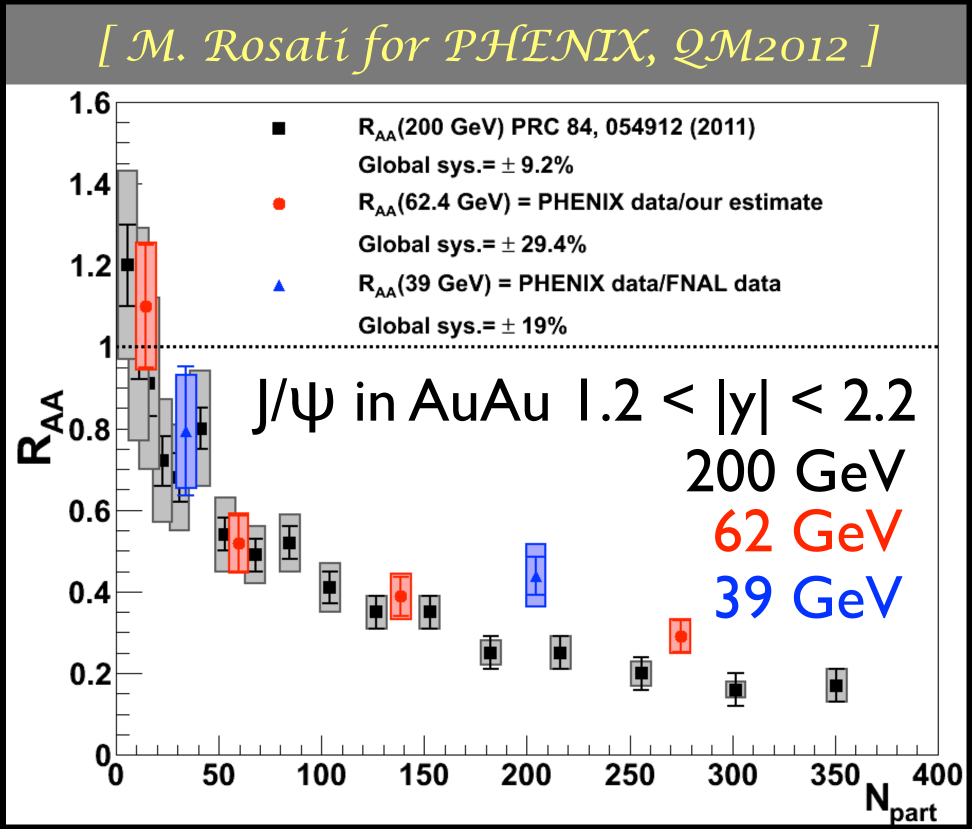

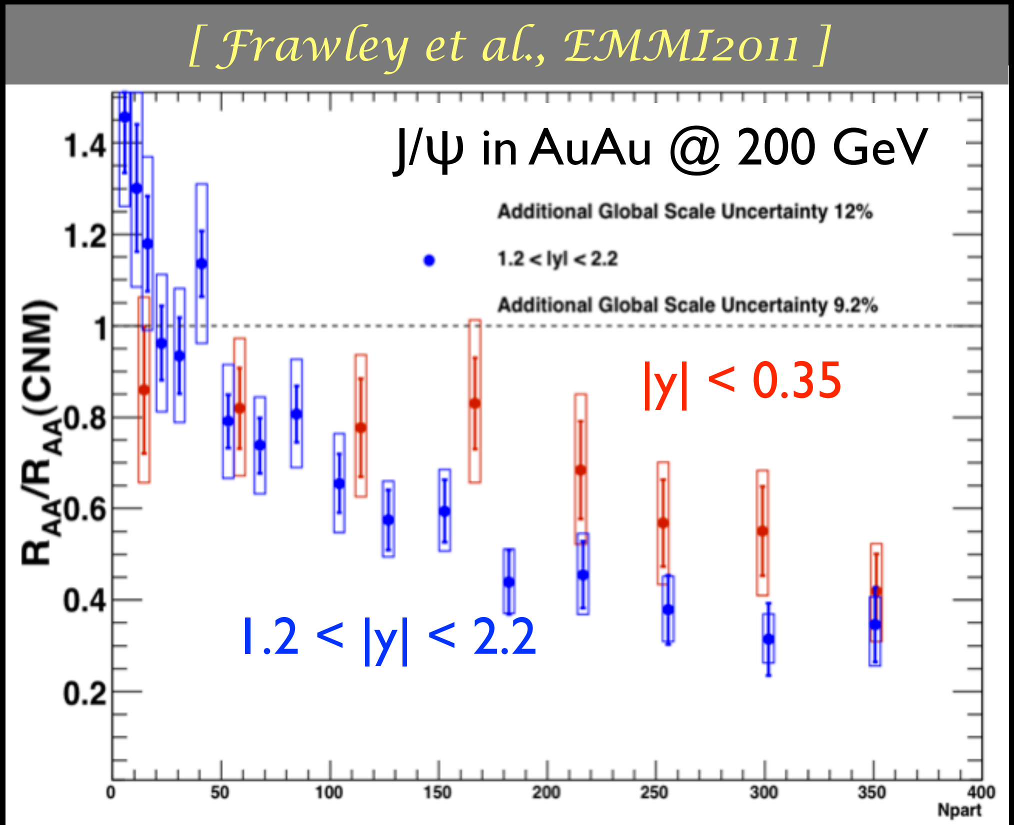

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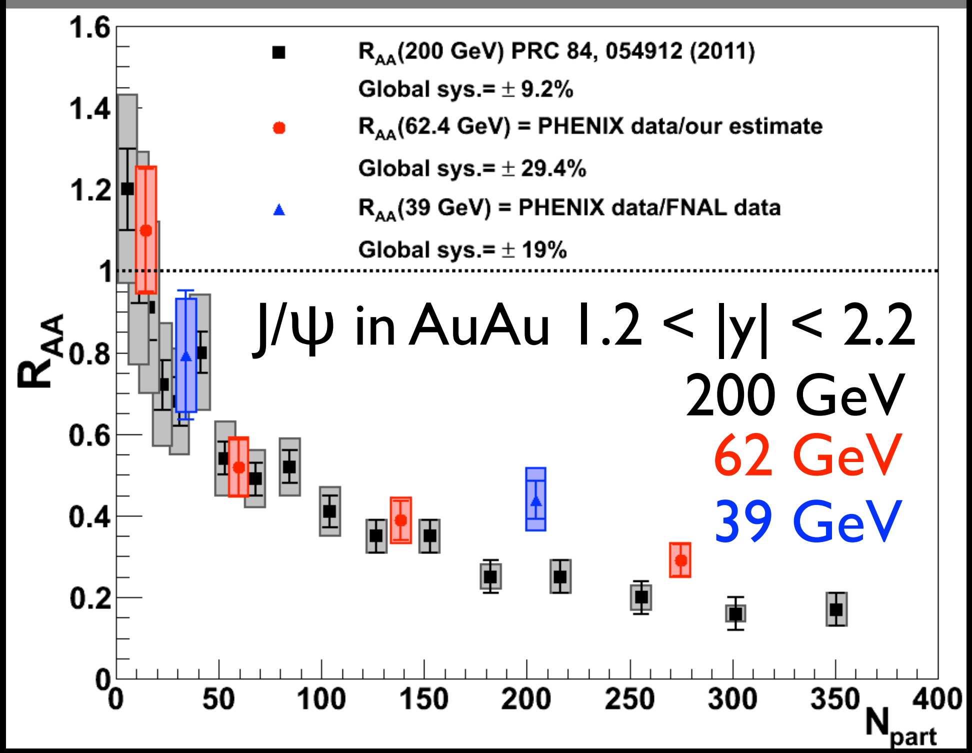
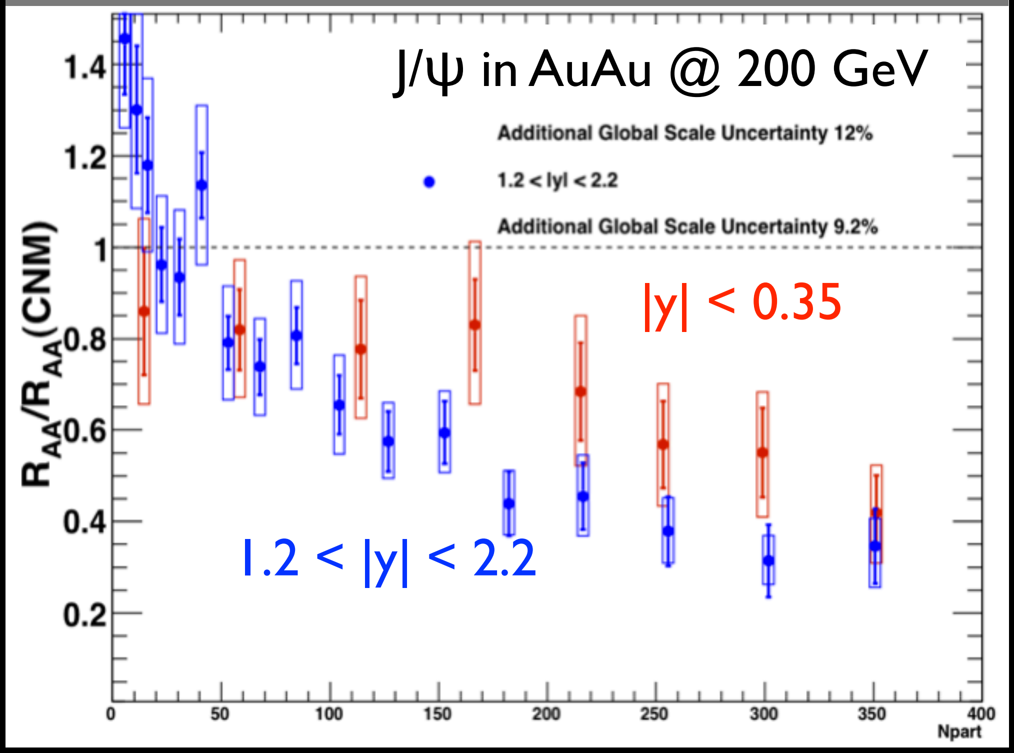
[M. Rosati for PHENIX, QM2012]



[Frawley et al., EMMI2011]



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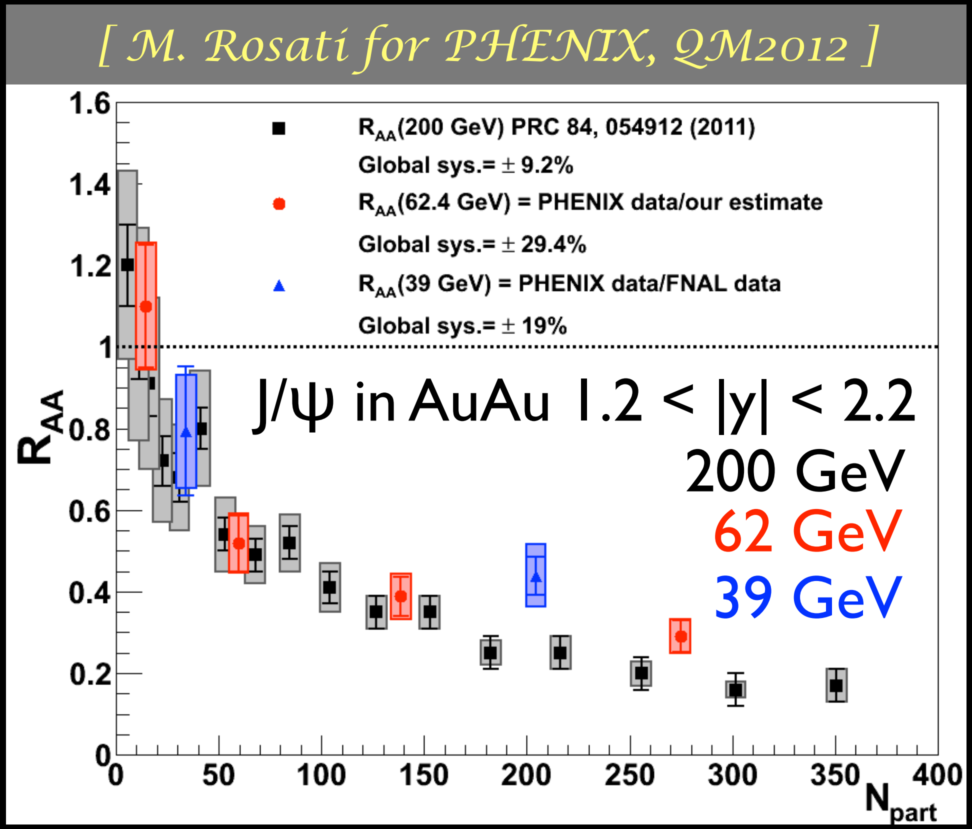
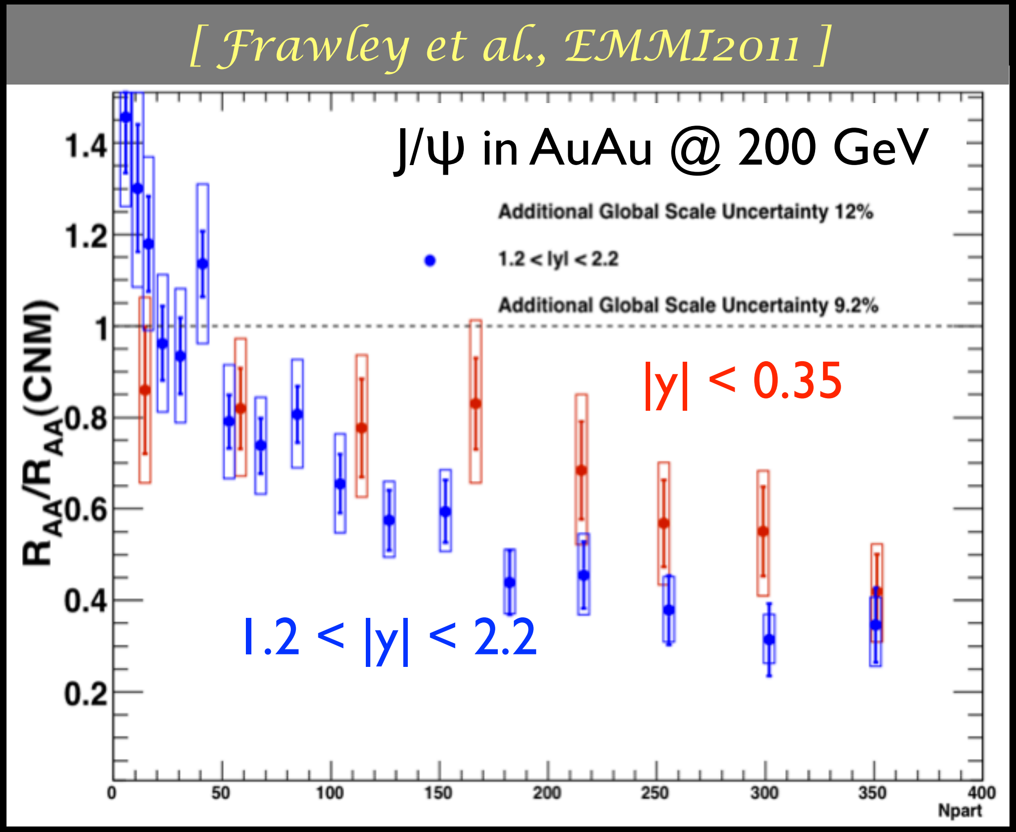
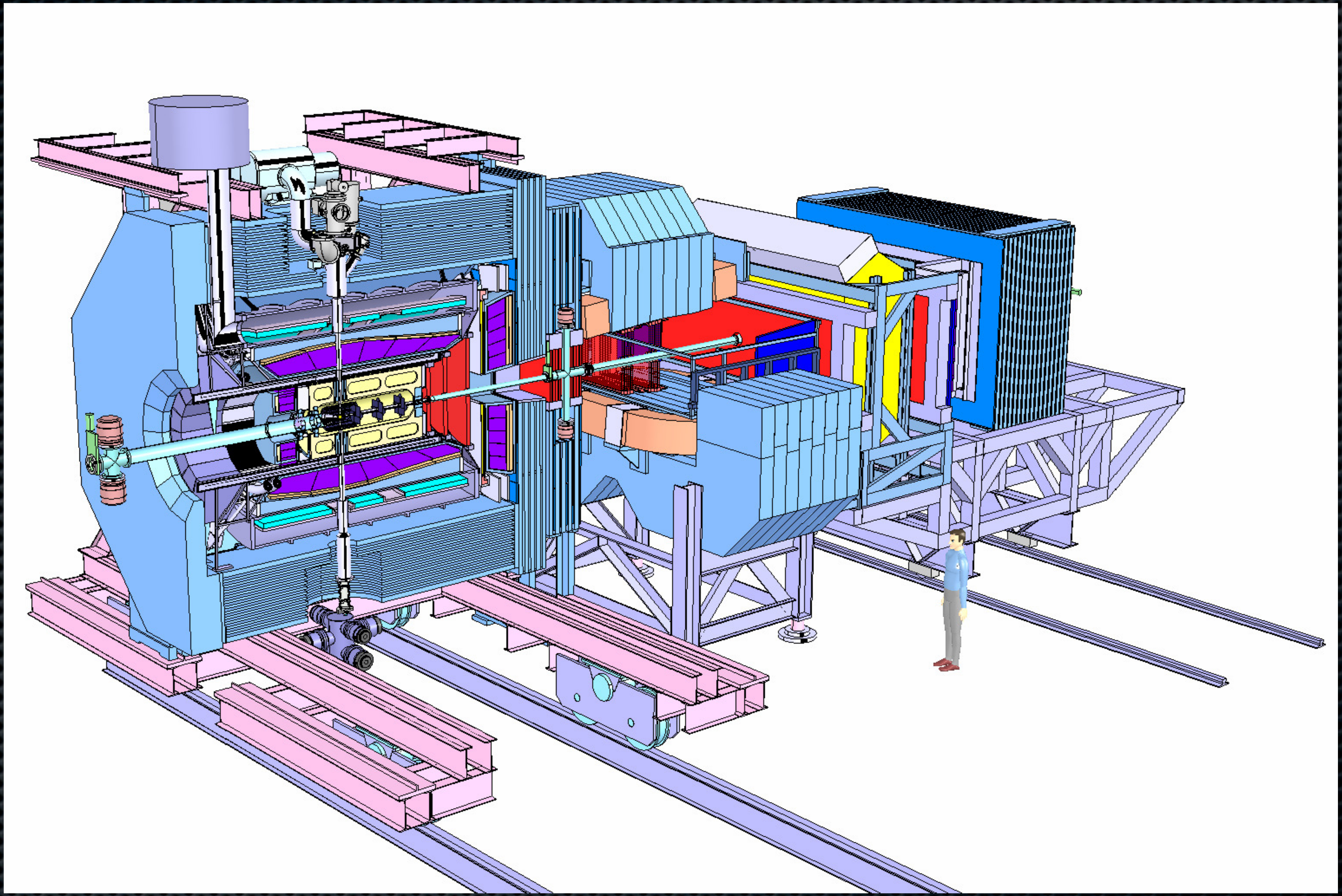




  - measure excited states, especially χ_c and χ_b with improved EMCal

- also jet quenching, direct photon ...

Detector : could be inspired by PANDA



Barrel + forward detector, 2 magnets

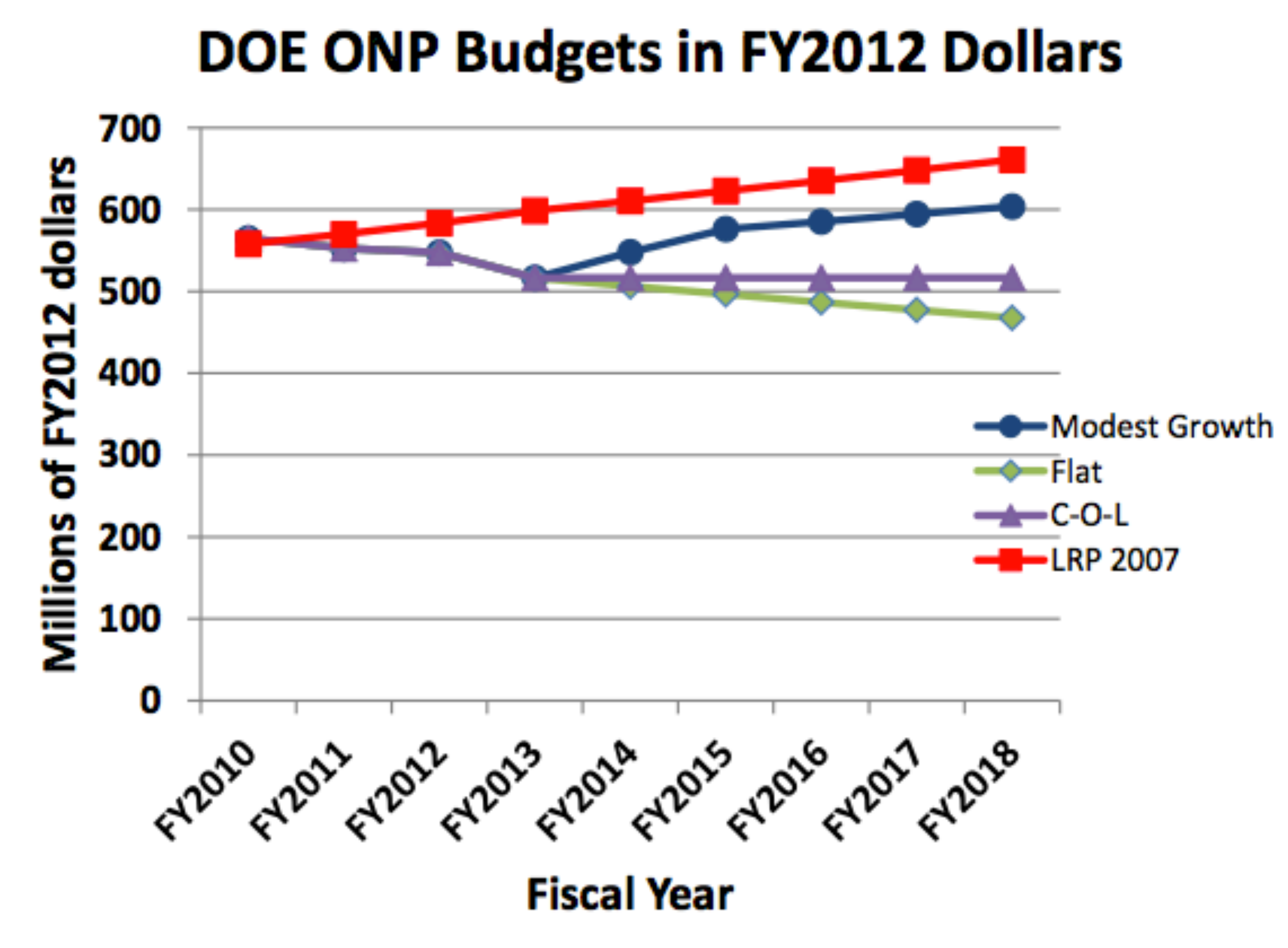
« Faster, Higher, Stronger »

and complementary !

Olympic games, London, 2012

EXTRA

NSAC report

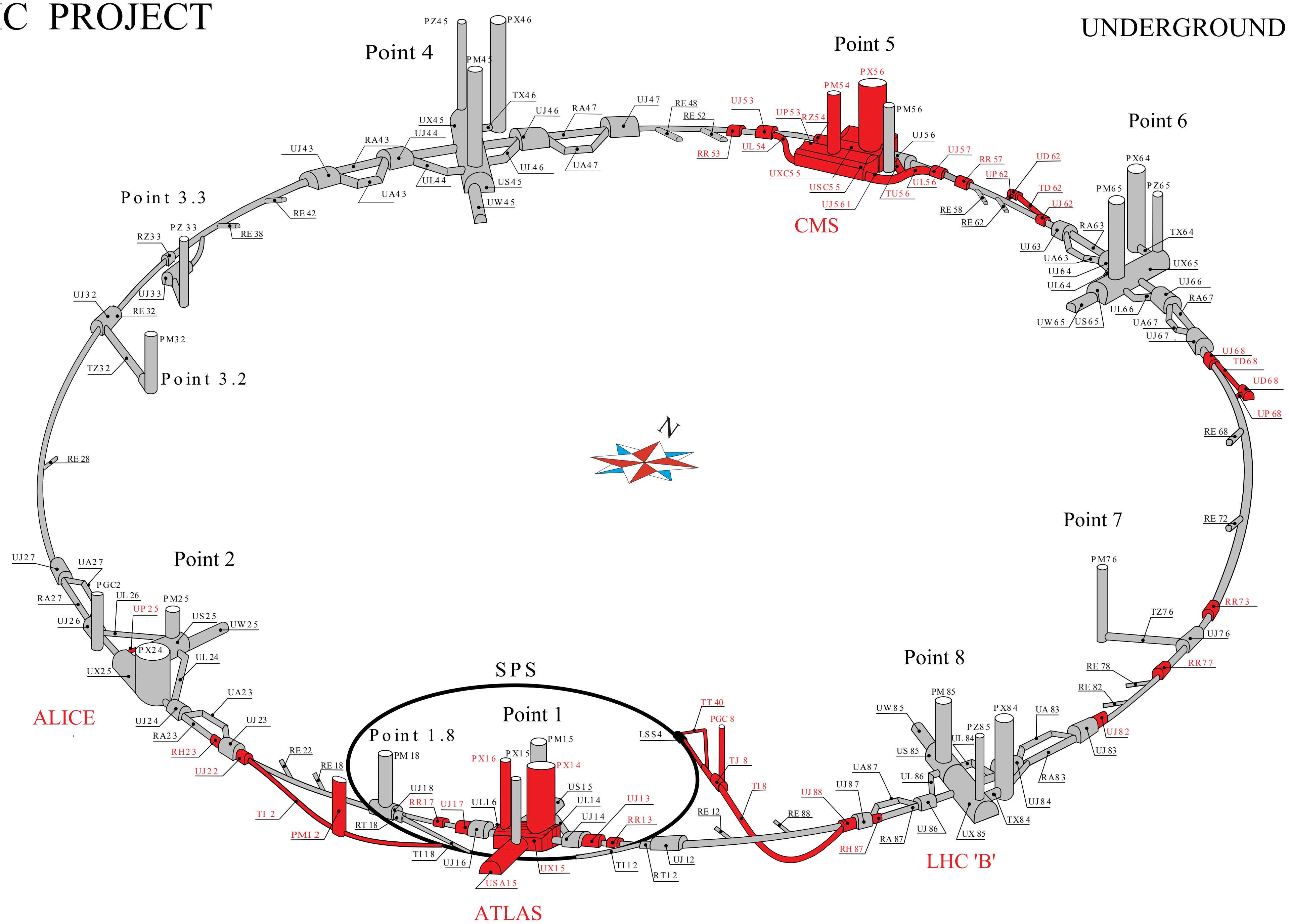


http://science.energy.gov/np/nsac/reports/

budget scenarios discussed above would impact the field. Of the options considered, **the subcommittee was unanimous in endorsing the modest growth budget scenario as the minimum level of support that is needed to maintain a viable long-term U.S. nuclear science program that encompasses the vision of the LRP.** This endorsement, which was made fully recognizing the sacrifices that it would entail, preserves the tools needed for both the present and future program. It preserves a path to realize the long-term vision outlined in the 2007 Long Range Plan, in which there are two large nuclear science facilities in the U.S.: FRIB, devoted to the study of complex nuclei and their applications, and an Electron-Ion Collider (EIC) focused on questions at the frontier of QCD and the nature of the interactions of quarks and gluons.

LHC PROJECT

UNDERGROUND WORKS



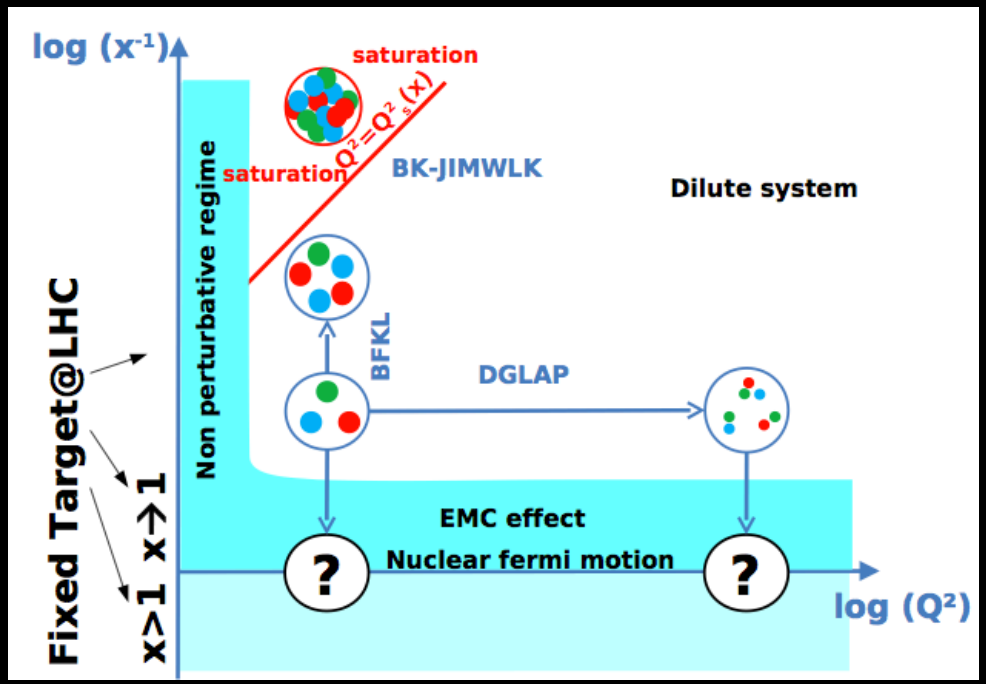
Existing Structures

LHC Project Structures

ST-CE/JLB-hlm
18/04/2003

QCD near the high x frontier

AFTER @ LHC



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

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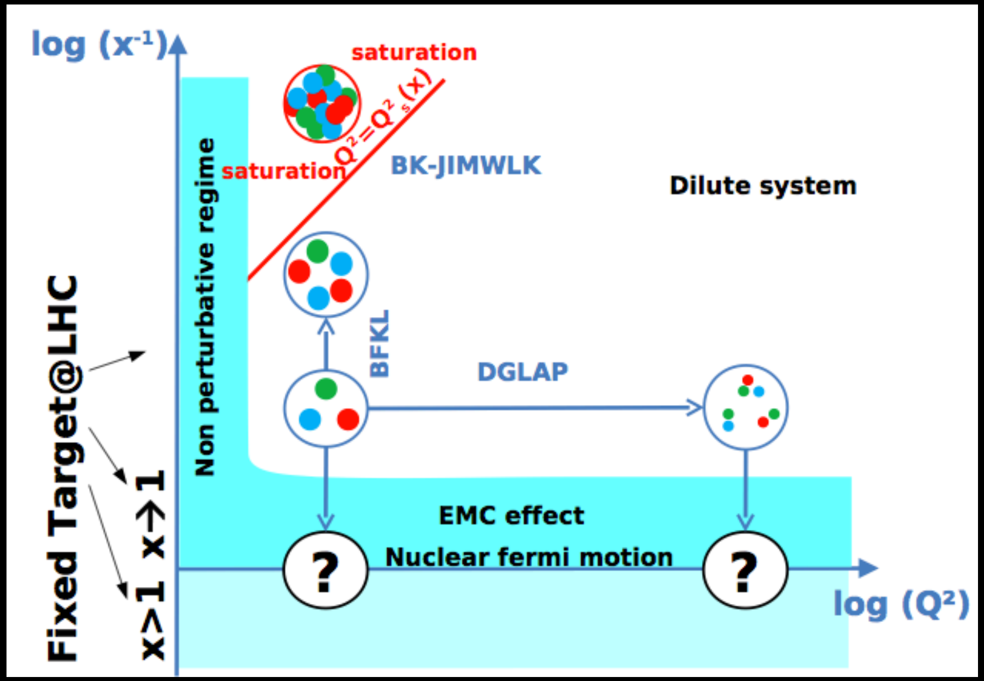

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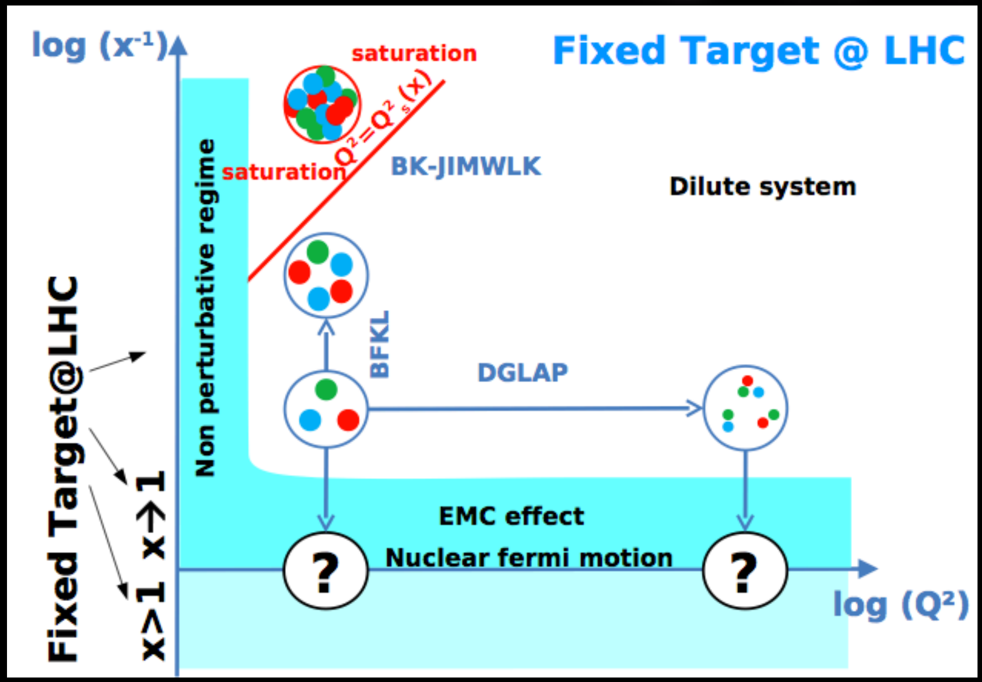
A Fixed Target ExpeRiment @ LHC :

- 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

Physics in p–p(d)

Nucleon partonic structure :
test the high x_B frontier of QCD
$x_B = 0.3 - 1$



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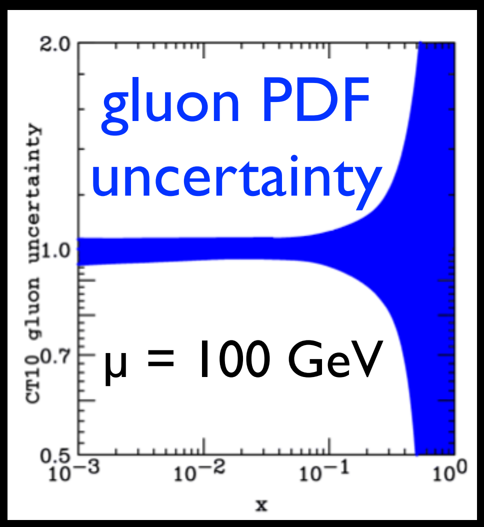
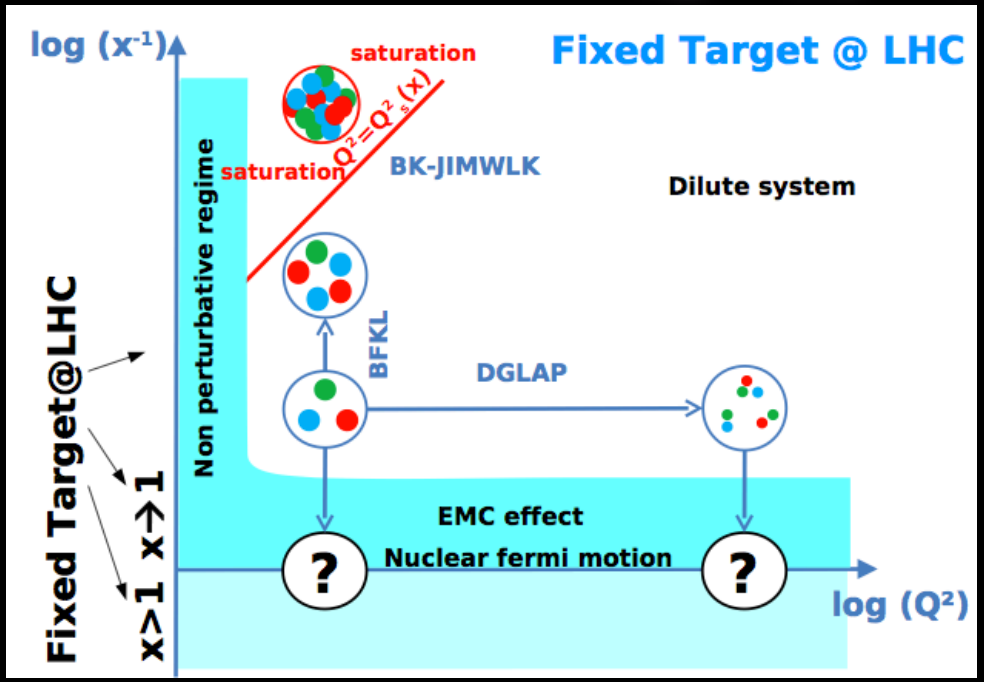


gluon PDF at high x :
with large uncertainties for proton,
unknown for neutron

exp. probes :

- heavy quarkonia
- isolated photons
- high p_T jets (p_T >20 GeV)



Physics in p−p(d)

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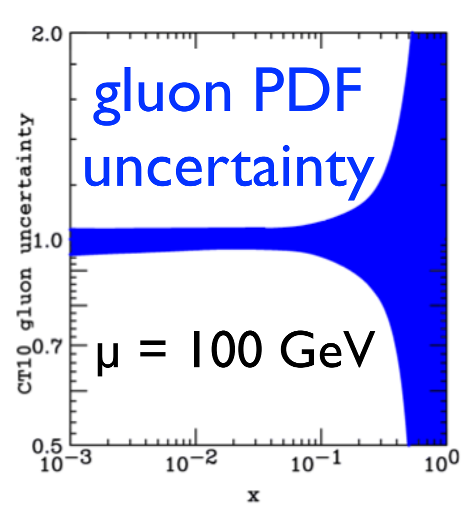

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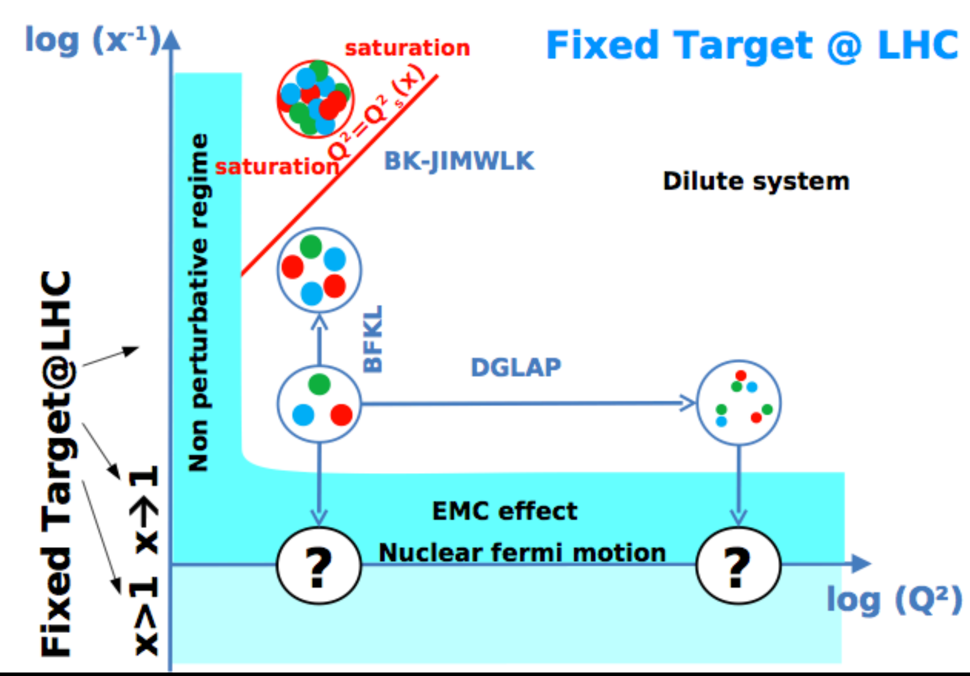

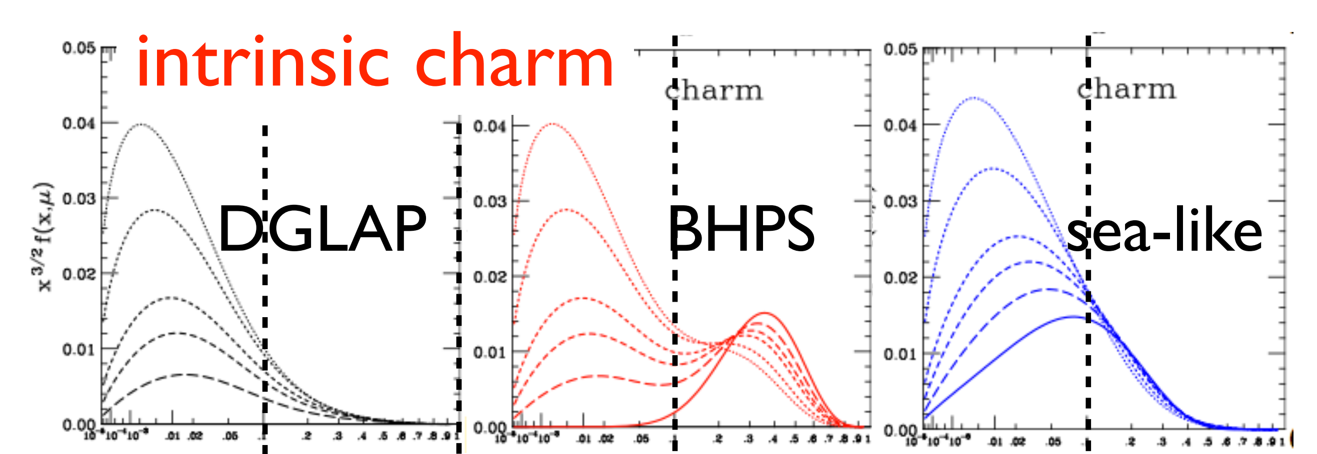

[Pumplin et al., PRD 75 (2007)]

charm 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]

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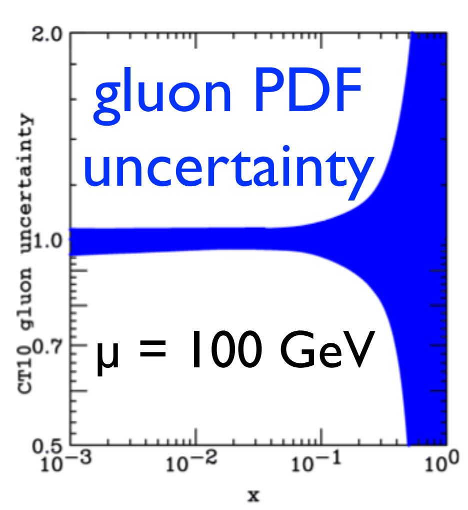

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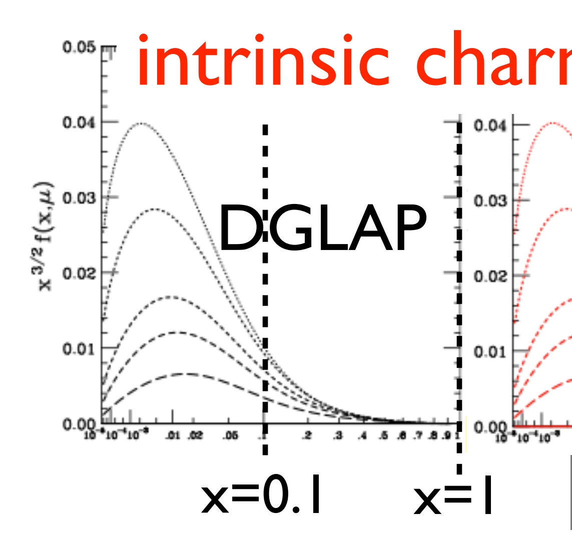
asymetries,
Transverse Momentum Dependent PDFs,
quark and gluon Sivers effect ...

- if using a polarized target
- Drell Yan as a probe of quark PDF



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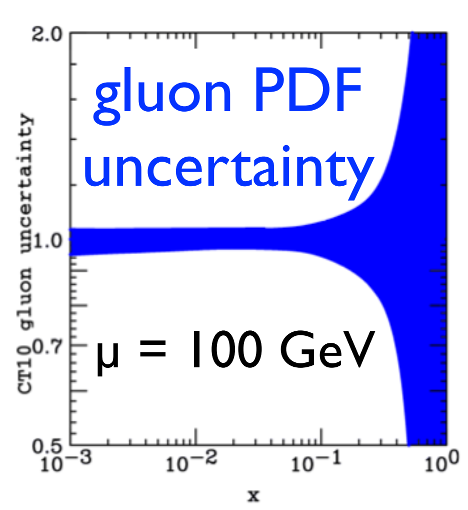

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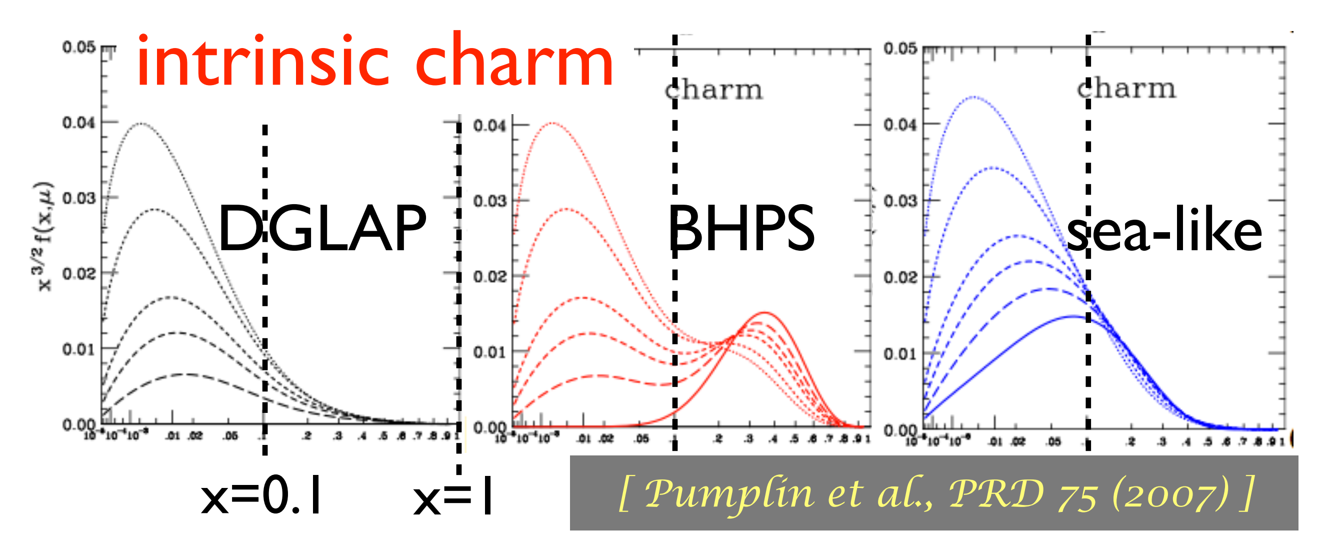

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need high luminosity to reach large x_B
+ detailed studies on heavy QQbar prod. before
using them for gluon PDF extraction

Heavy Quarkonium yields in pH, pA

yield / dy (fb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 115 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, arXiv:1202.6585]

	Target	$\int dt \mathcal{L}$	$\mathcal{B}_{\ell\ell} \frac{dN_{J/\psi}}{dy}\Big\vert_{y=0}$ (J/ψ)	$\mathcal{B}_{\ell\ell} \frac{dN_{\Upsilon}}{dy}\Big\vert_{y=0}$ (Υ)
AFTER	10 cm solid H	2.6	$5.2\ 10^7$	$1.0\ 10^5$
AFTER	10 cm liquid H	2	$4.0\ 10^7$	$8.0\ 10^4$
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AFTER	1 cm Pb	0.16	$6.7\ 10^8$	$1.3\ 10^6$
LHC	pp low P_T LHC (14 TeV)	0.05 ALICE	$3.6\ 10^7$	$1.8\ 10^5$
LHC	pp low P_T LHC (14 TeV)	2 LHCb	$1.4\ 10^9$	$7.2\ 10^6$
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detector geometrical acceptance ~ 8% for J/ψ (4π)→μ+μ−

from simulations with ALICE detector (−4< y <−2.5) used as fixed target exp. at LHC

[Kurepin et al., Phys. Atom. Nucl. 74 (2011)]

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[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, arXiv:1202.6585]

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

pp : 100 x RHIC, comparable to LHCb

pA : 10^2-10^3 x RHIC

detector geometrical acceptance ~ 8% for J/ψ (4π)→μ+μ−

from simulations with ALICE detector (−4< y <−2.5) used as fixed target exp. at LHC

[Kurepin et al., Phys. Atom. Nucl. 74 (2011)]

Heavy Quarkonium yields in PbA

yield / dy (nb^{-1} year^{-1}) @ $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, arXiv:1202.6585]

J/ψ ↓ Υ ↓

	Target	$\int dt \mathcal{L}$	$\mathcal{B}_{\ell\ell} \frac{dN_{J/\psi}}{dy}\Big\vert_{y=0}$	$\mathcal{B}_{\ell\ell} \frac{dN_{\Upsilon}}{dy}\Big\vert_{y=0}$
AFTER	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	$5.7\ 10^6$	$1.1\ 10^4$
RHIC	*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	$4.0\ 10^4$	$6.1\ 10^1$
LHC	*p*Pb LHC (8.8 TeV)	100	$1.0\ 10^7$	$7.5\ 10^4$
	PbPb LHC (5.5 TeV)	0.5	$7.3\ 10^6$	$3.6\ 10^4$

Heavy Quarkonium yields in PbA

yield / dy (nb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 72 GeV

J/ψ ↓ ϒ ↓

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, arXiv:1202.6585]

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PbA :

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

Heavy Quarkonium yields in PbA

yield / dy (nb^{-1} $year^{-1}$) @ $\sqrt{s}$ = 72 GeV

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, arXiv:1202.6585]

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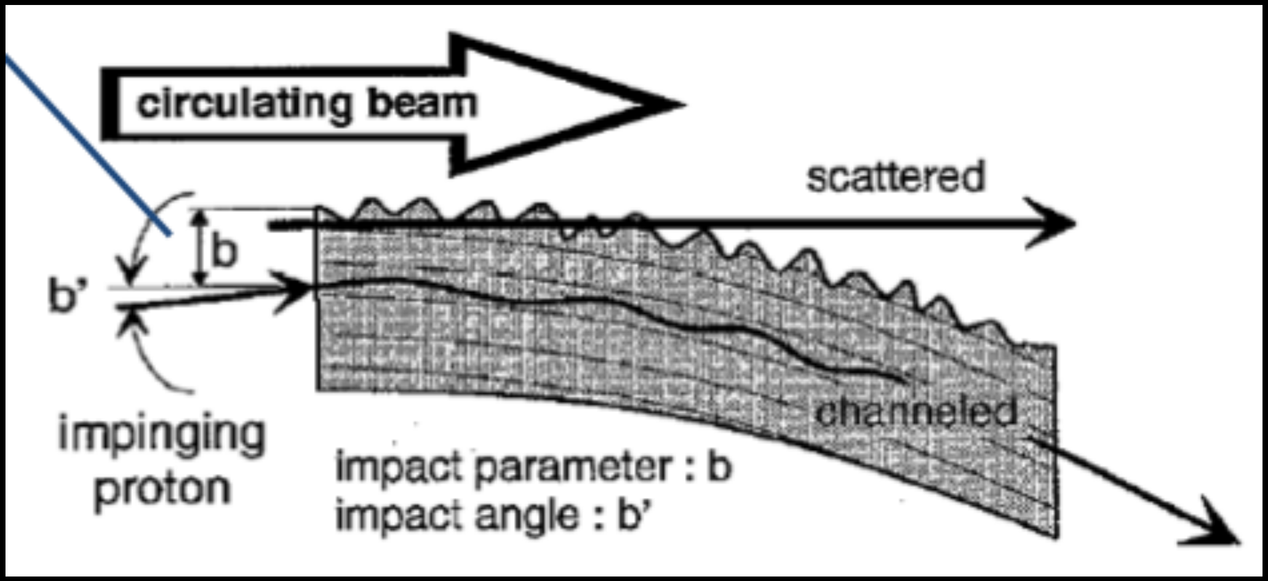
PbA :

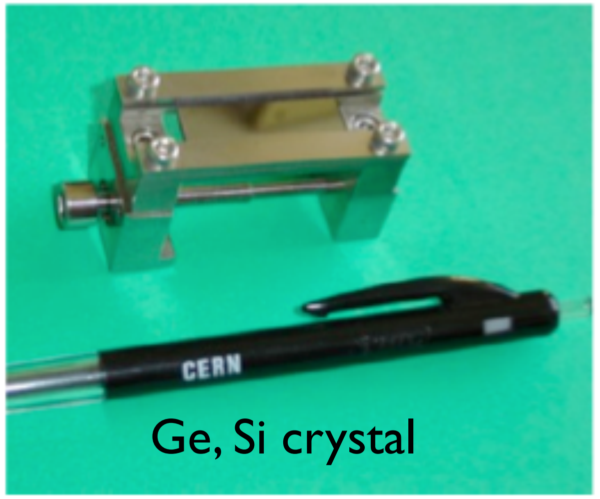
same stat. w.r.t. RHIC @ 200 GeV and LHC

10^2 x RHIC @ 62 GeV

LHC beam extraction

Use strong crystalline field in bent crystals :



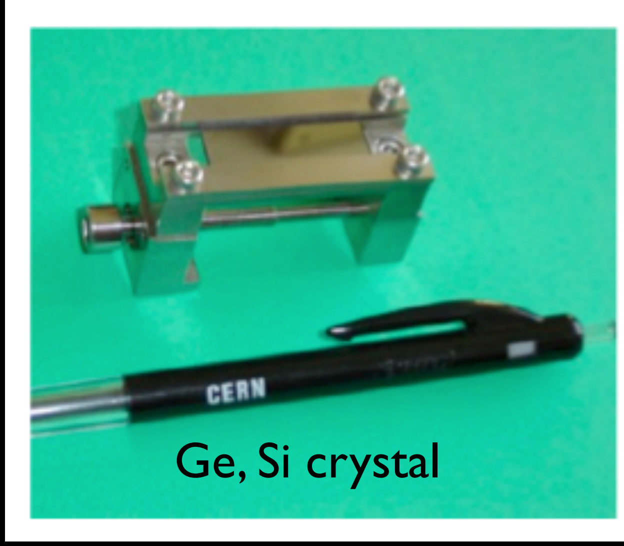


Ge, Si crystal

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) 10002]*
  - test @ LHC approved by LHCC ☛ LUA9 (2013)
  - ion beam : test at SPS *[W. Scandale et al., PLB 703 (2011) 547]*



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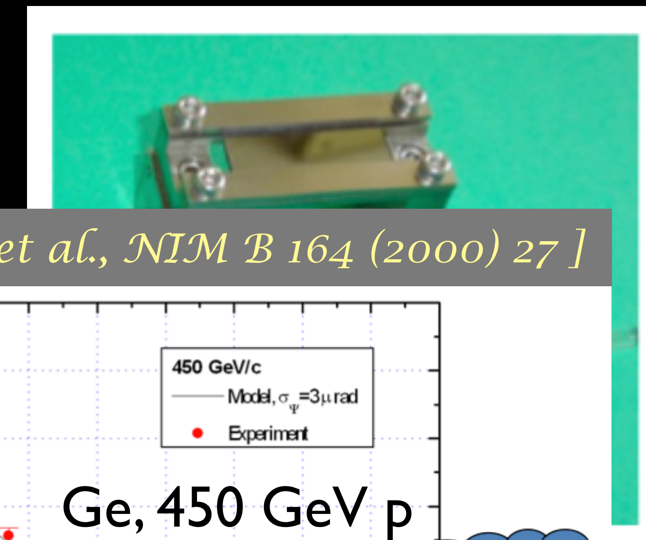
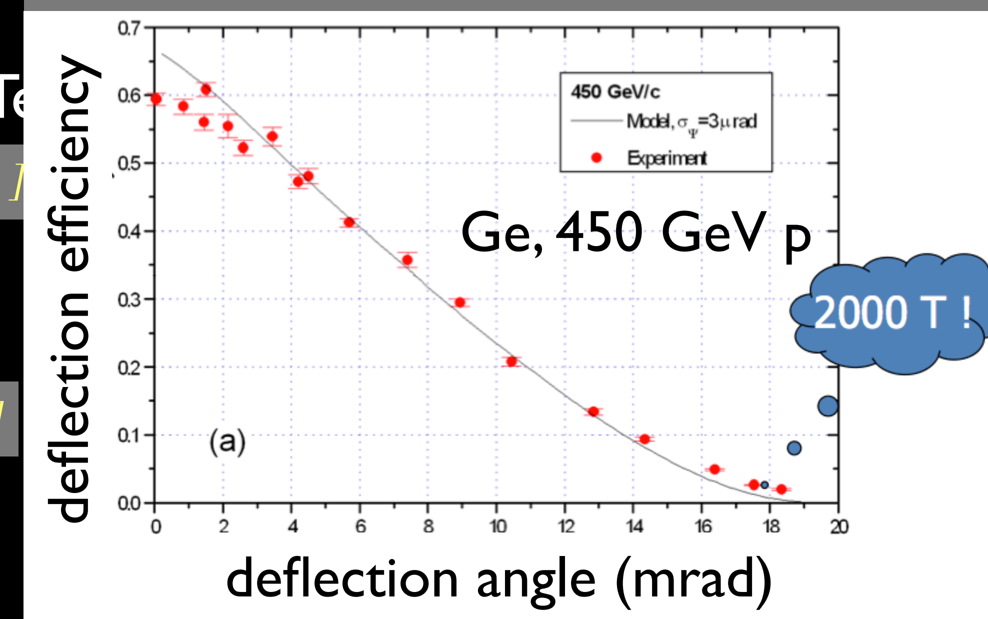


[A. Baurichter et al., NIM B 164 (2000) 27]



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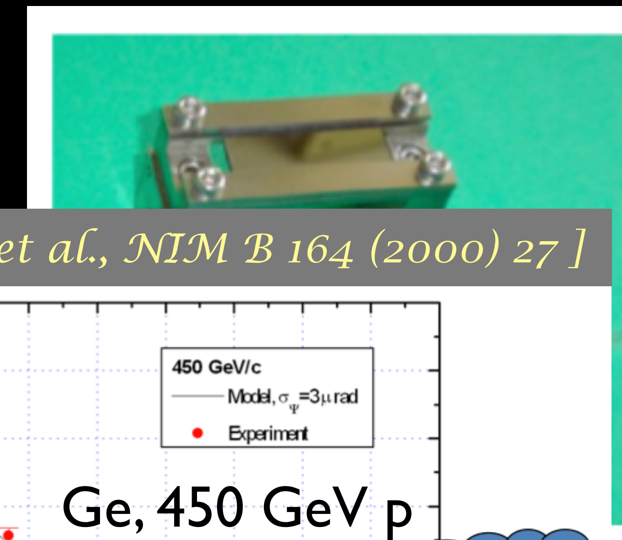
- for extraction and collimation
  - extremely small emittance : beam size 950m after the extraction (in the extraction direction) ~ 0.3mm



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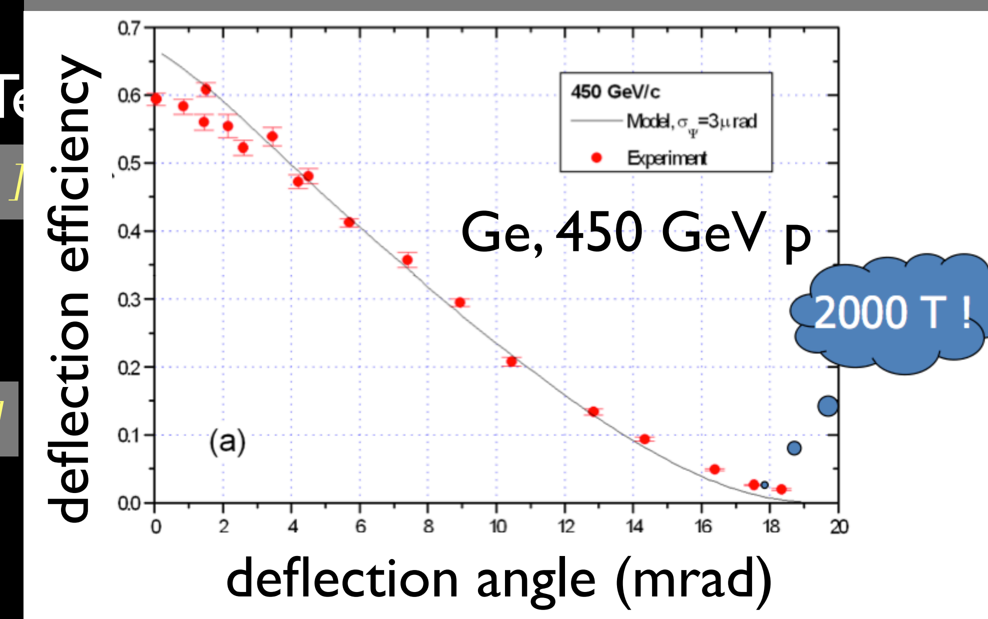
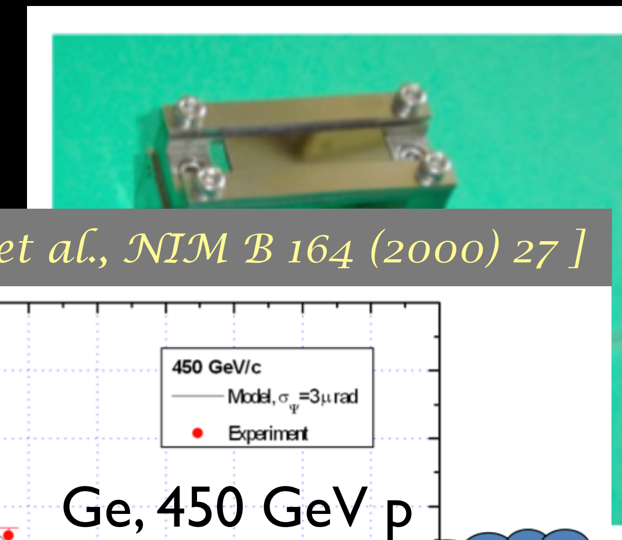


LHC beam extraction



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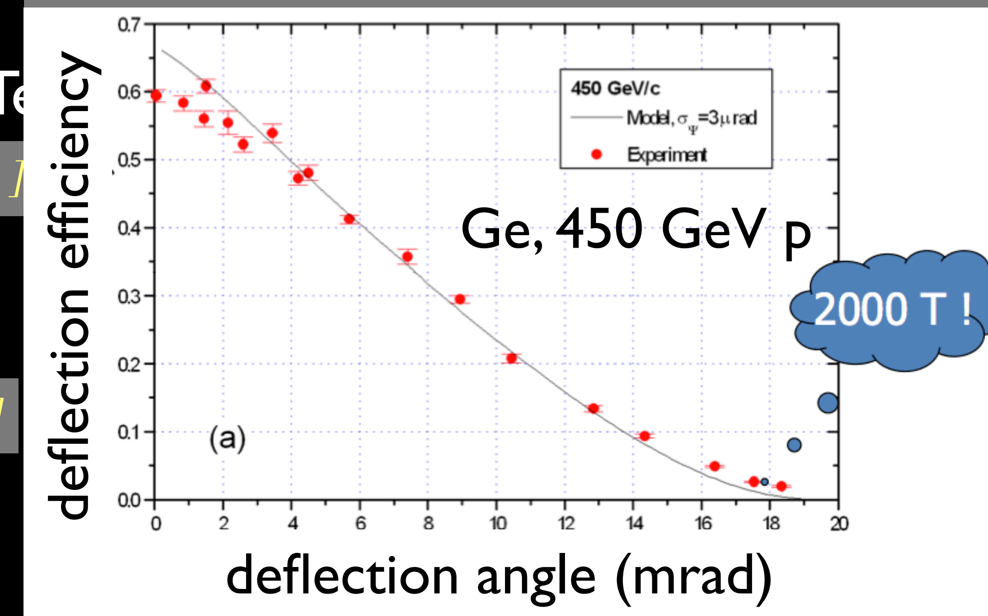

- for extraction and collimation
  - extremely small emittance : beam size 950m after the extraction (in the extraction direction) ~ 0.3mm
- Proposal : insertion in the halo (7σ) of the proton LHC beam
  - here with a deflection 0.275 mrad [E Uggerhoj and U.I. Uggerhoj, NIM B 234 (2005) 31]
  - extraction 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
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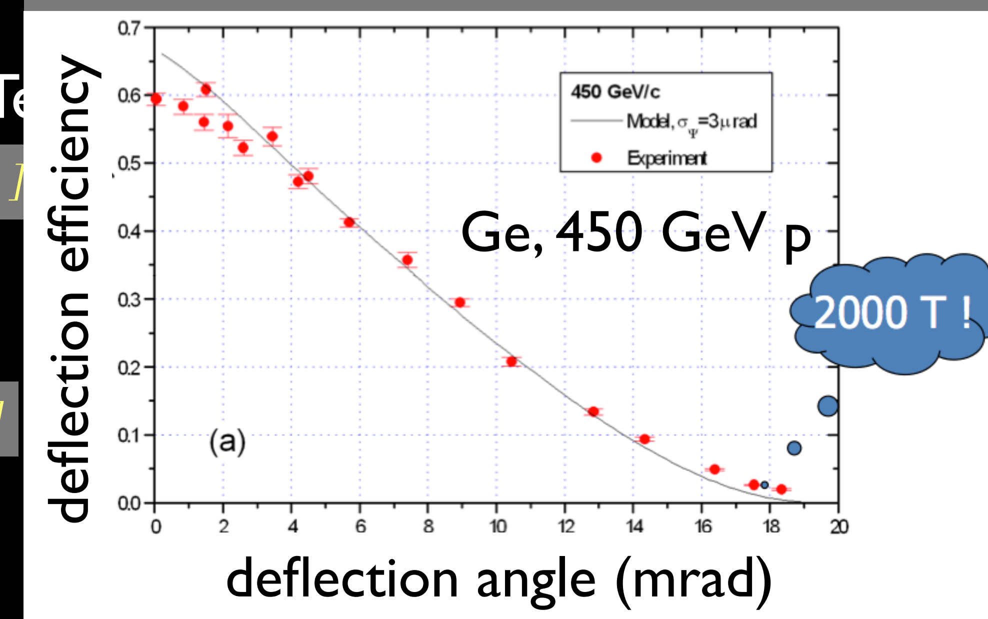

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no performance decrease of the LHC

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detector upgrades - ATLAS

LS1(2013-14): - additional pixel layer (Insertable B-layer, IBL)
→ improve b-tagging

LS2(2017-18): - fast tracking trigger (FTK)
→ improve high-multiplicity tracking
- calorimeter readout and trigger upgrade
→ improve selectivity of photon and electron trigger
- new forward muon detectors
→ improved muon triggers

LS3(2022): - replacement of inner detector (pixel and strips, reduced material budget)
→ improve tracking and resolution

detector upgrades - CMS

By end of LS2:
- new pixel vertex detector
- upgraded trigger
- extension of forward muon system
- refurbishment of hadron calo electronics
- DAQ upgrade

Important for Heavy-ion running at 50 kHz:
- HLT input limitation (3kHz) requires 0.95 rejection at Level 1 (0.5 achieved so far)

→ dedicated R&D effort started on Level 1 upgrade, largely driven by HI needs and HI community

LS3 (2022):
- new inner tracker
- trigger and DAQ
- ...