News in Quarkonium Production, now and AFTER ...

J.P. Lansberg

IPN Orsay – Paris-Sud U. – Paris Saclay U. –CNRS/IN2P3

10th France-China Particle Physics Laboratory Workshop

Tsinghua U., Beijing, March 27 - 30, 2017

March 29, 2017

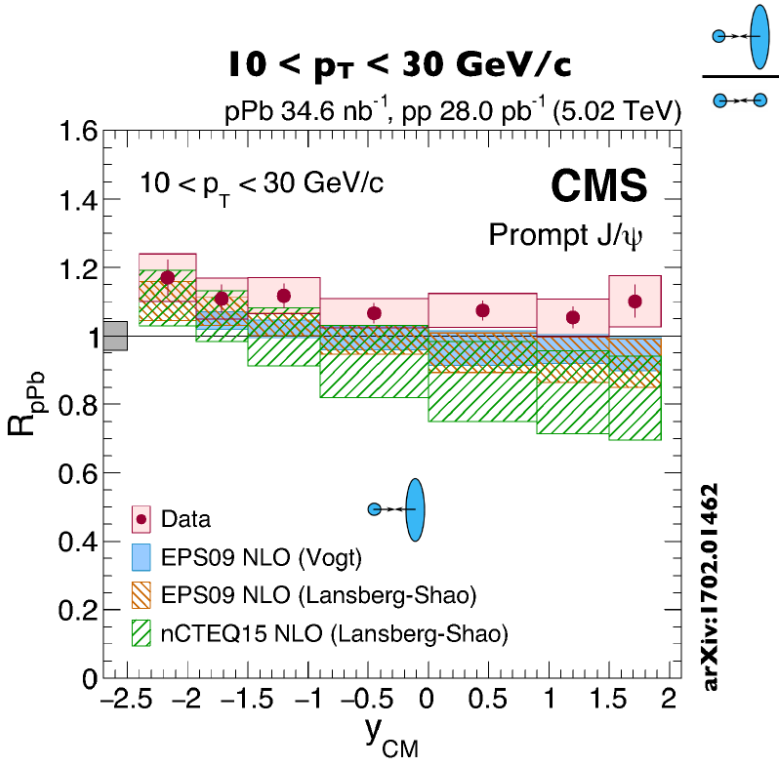
Our FCPPL collaboration

Theory of quarkonia + fixed-target experiment at the LHC

	France	China
Leaders	J.P. Lansberg (IPNO)	J.X. Wang (IHEP)
Permanent	C. Hadjidakis (IPNO) I. Hrivnacova (IPNO) C. Lorcé (CPhT-X) L. Massacrier (IPNO)	B. Gong (IHEP) K.T. Chao (PKU) Y. Mao (PKU) Y.Q. Ma (PKU) Y. Gao (Tsinghua) Z. Yang (Tsinghua) Z. Tang (USTC) J. He (UCAS) H.F. Zhang (Chongqing) Y.J. Zhang (Beihang)
Non-permanent	H.S. Shao (LPTHE; → CR2) N. Yamanaka (IPNO) F. Scarpa (IPNO)	L.P. Sun (PKU)

Realisations (1)

Theory collaboration with H.S. Shao (ex-PKU)



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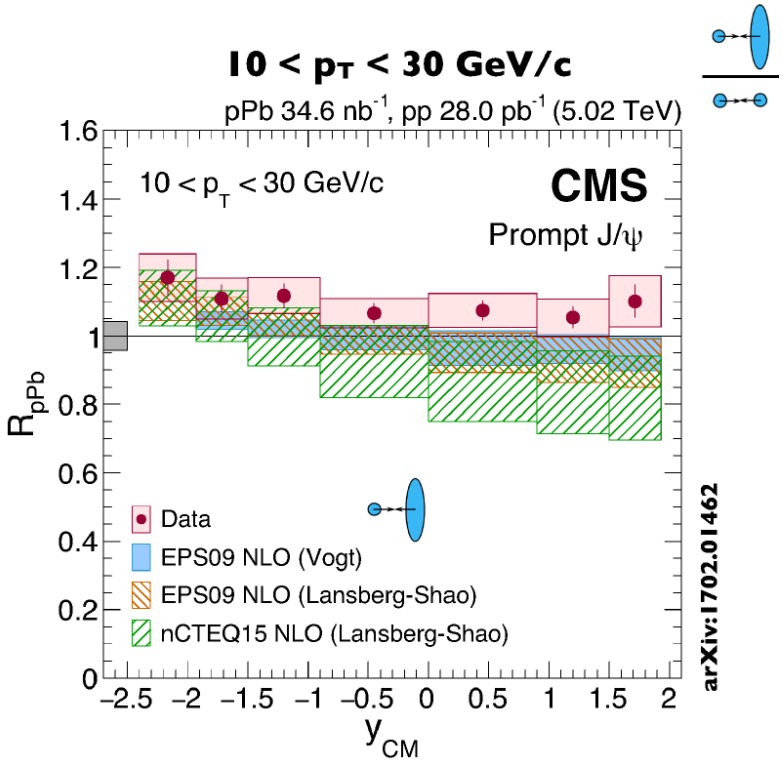
- Automated code to evaluate the impact of nuclear PDF **[Eur.Phys.J. C77 (2017) 1]**
  - Partonic scattering amplitude fit to *pp* data
  - Any nuclear PDF set available in LHAPDF5 or 6 can be used
  - Applied to J/ψ, Υ, D and B
  - Extensive comparison with LHC data



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- $Z + b$ via non prompt J/ψ **[Nucl.Phys. B916 (2017) 132]**
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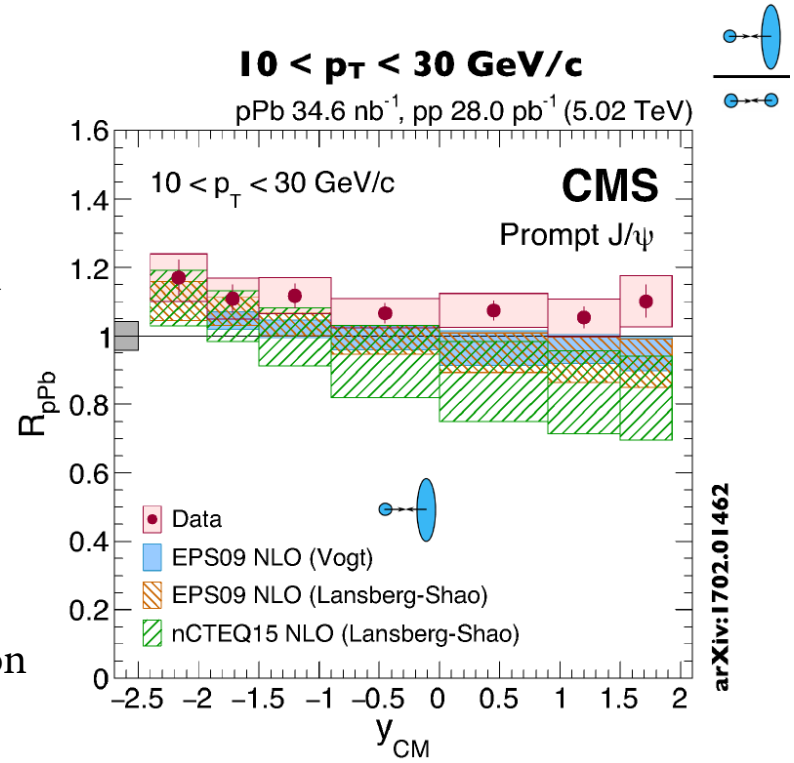
  - No theory prediction available when the data came out
  - Good theory-data agreement with our MG5@NLO evaluation



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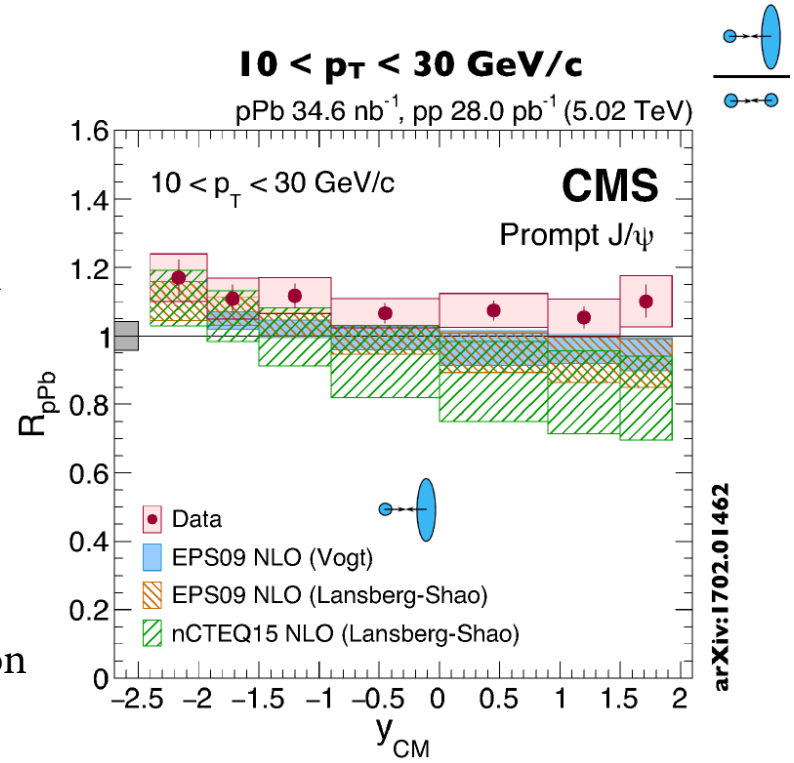
- NLO computation of $Z + J/\psi$ **[JHEP 1610 (2016) 153]**
  - Measured by ATLAS
  - Significant tension with theory; $\Delta\phi$ spectrum hints at a large SPS yield (peak at $\Delta\phi \simeq \pi$)
  - Our NLO evaluation gives an upper limit on the SPS; tension confirmed (?)
  - BUT we also claim that the interpretation of the $\Delta\phi$ spectrum could be misleading
    [raw count spectrum prone to large acceptance corrections]
  - Discrepancy with the ATLAS data a priori solved



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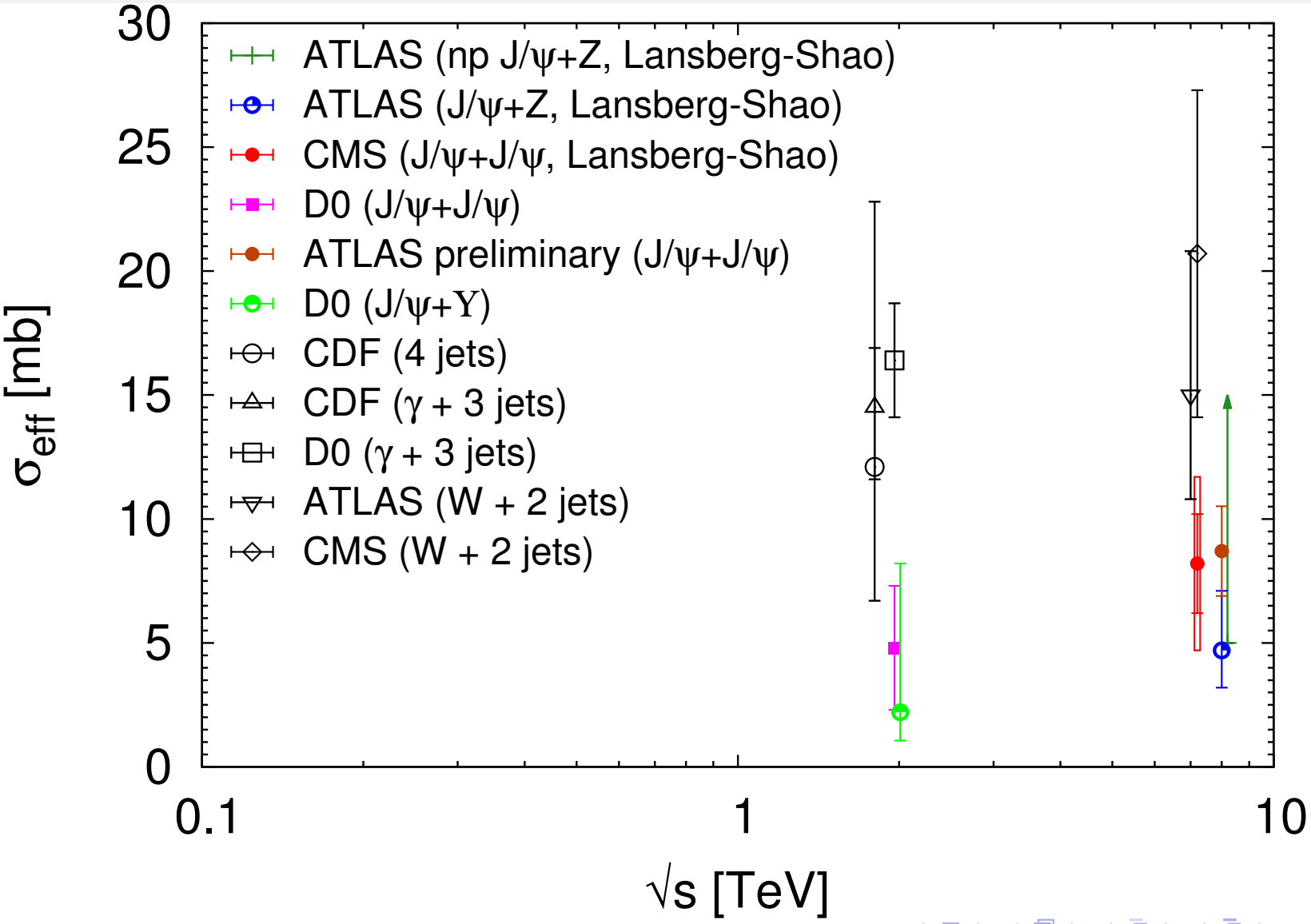


Realisations (2)

Topical collection in Few Body Systems: New observables in quarkonium production

- Following a workshop at ECT*-Trento
- 45+ participants with a strong FCPPL participation
- The collection will gather more than a dozen of papers
- 9 published so far

ECT*

EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS
TRENTO, ITALY
Institutional Member of the European Expert Committee NUPECC

Castello di Trento ("Trint"), watercolor 19.8 x 27.7, painted by A. Dürer on his way back from Venice (1495). British Museum, London

New observables in quarkonium production
Trento, 29 Feb 2016 to 04 Mar 2016

Main Topics

Quarkonium production remains one of the long standing puzzles of QCD. As such, it still deserves full attention from both experimentalists and theorists. The main topics of the workshop will be:

- Quarkonium production in *pp*, *pA* and *AA* collisions: where do we stand?
- Transverse Momentum Dependent factorisation in quarkonium production
- Associated quarkonium production and double-parton scatterings
- Excited-quarkonium production from *pp* to *AA* collisions
- Quarkonium-pair production: when TMDs meet Quark Gluon Plasma
- Experimental requirements for forthcoming measurements

Key Participants

M. Anselmino (Torino University and INFN), F. Arleo (Ecole polytechnique, Palaiseau), R. Arnaldi (INFN Torino), I. C. Arsene (University of Oslo), D. Boer (University of Groningen), R. Boussarié (LPT Orsay), M. Calderon de la Barca Sanchez (University of California Davis), I. Cherednikov (University of Antwerp), C. da Silva (Los Alamo National Lab), D. d'Enterria (CERN, Switzerland), B. Ducloué (University of Jyvaskyla), P. B. Gossiaux (SUBATECH, Nantes), C. Hadjidakis (IPN Orsay), V. Kartvelishvili (Lancaster University), T. Kasemets (Nikhef/VU, Amsterdam), D. Kikola (Warsaw University of Technology), L. Kratschmer (Hephy, Vienna), Y.-Q. Ma (Peking University), L. Massacrier (LAL and IPN Orsay), Z. E. Meziani (Temple U., Philadelphia) A. Mukherjee (IIT Bombay), P. Petreczky (Brookhaven National Lab), S. Porteboeuf (LPC, Clermont-Ferrand), D. Price (University of Manchester), J.W. Qiu (Brookhaven National Lab), A. Rakotozafindrabe (CEA/IRFU, Gif-sur-Yvette), K. Redlich (University of Wroclaw and Duke University), F. Scarpa, (IPN Orsay & University of Groningen), M. Schlegel (University of Tübingen), E. Scomparin (INFN Torino), H. S. Shao (CERN), P. Taels (University of Antwerp & CEA/IPHT, Gif-sur-Yvette), B. Trzeciak (Utrecht University), Z. Tang (University of Science and Technology of China, Hefei), A. Vairo (TUM, Munich), J. X. Wang (IHEP, Peking), K. Watanabe (Central China Normal University, Wuhan), M. A. Winn (Heidelberg University), H. F. Zhang (Chongqing University of Posts and Telecommunications), P. F. Zhuang (Tsinghua University, Peking).

Organisers

J.P. Lansberg (IPN Orsay, CNRS-IN2P3, Univ. Paris-Sud, Université Paris-Saclay, France)
T. Dahms (Excellence Cluster Universe - TUM, Munich, Germany)
E.G. Ferreiro (IGFAE, University of Santiago de Compostela, Spain)
C. Pisano (University of Antwerp, Belgium & University of Pavia, Italy)

Director of the ECT*: Professor Jochen Wambach (ECT*)

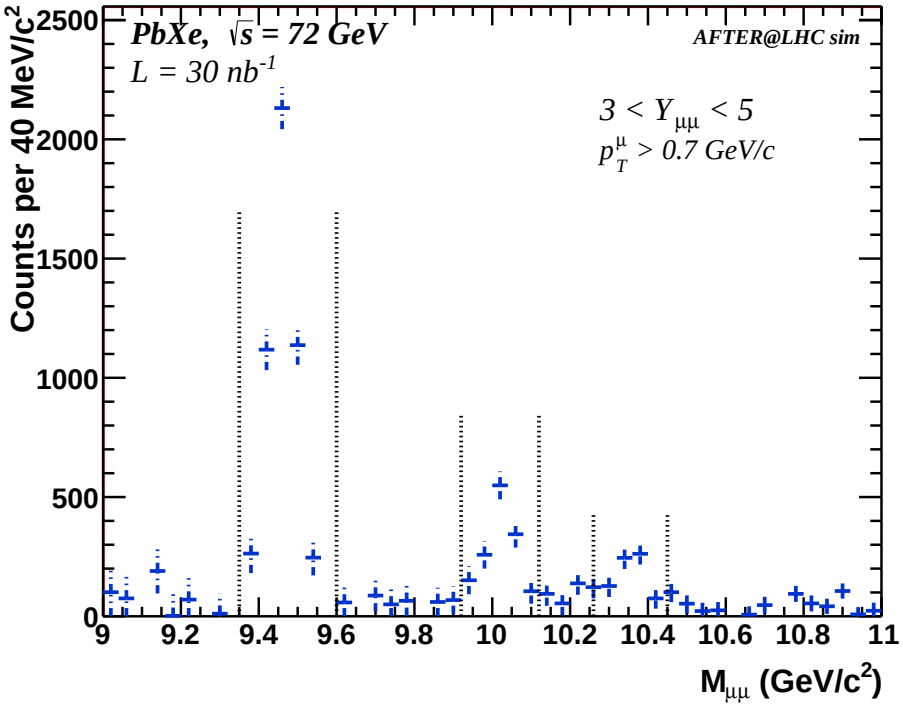
The ECT* is sponsored by the "Fondazione Bruno Kessler" in collaboration with the "Assessorato alla Cultura" (Provincia Autonoma di Trento), funding agencies of EU Member and Associated States and has the support of the Department of Physics of the University of Trento.

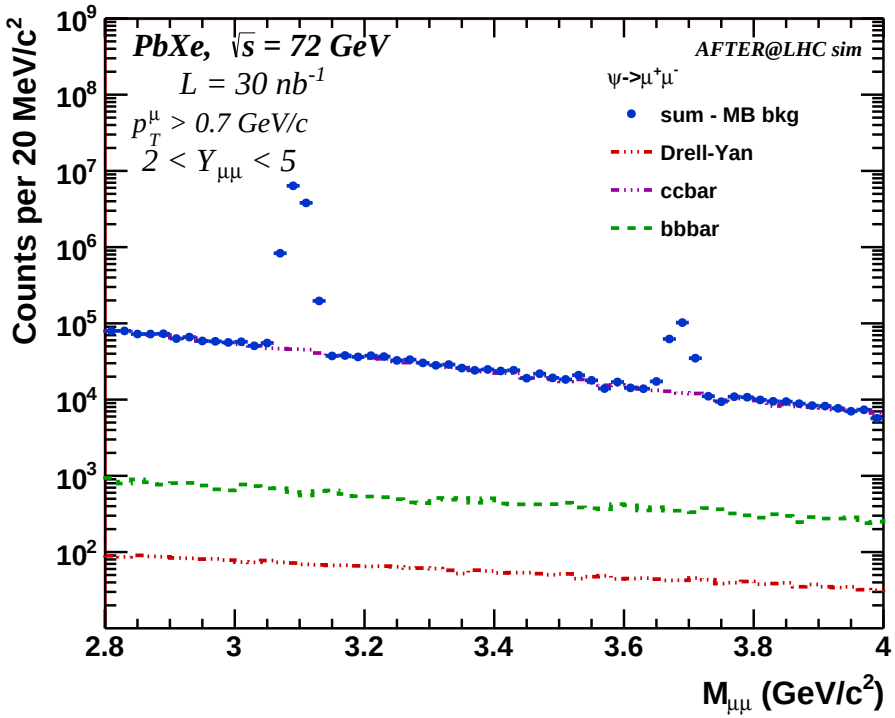
For local organization please contact: Gianmaria Ziglio - ECT* Secretariat - Villa Tambosi - Strada delle Tabarelle 286 - 38123 Villazzano (Trento) - Italy
Tel.:(+39-0461) 314721 Fax:(+39-0461) 314750, E-mail: **ect@ectstar.eu or visit http://www.ectstar.eu**

Realisations (3)

Heavy-ion studies in the fixed target mode

B. Trzeciak, C. Hadjidakis, L. Massacrier, .., JPL, .., A. Uras, Z. Yang, arXiv:1703.03726 [nucl-ex]





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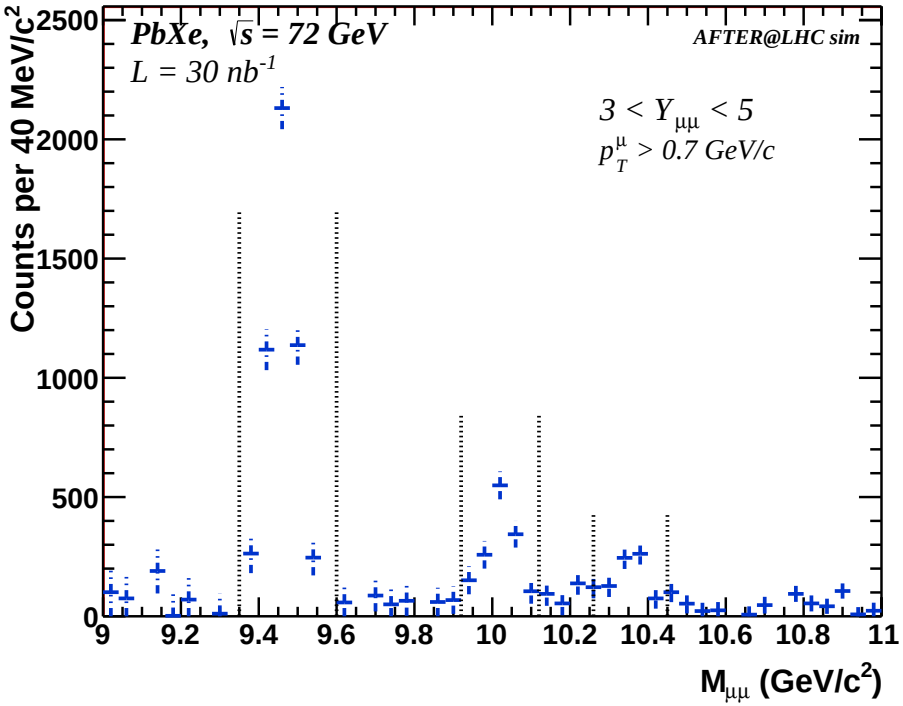
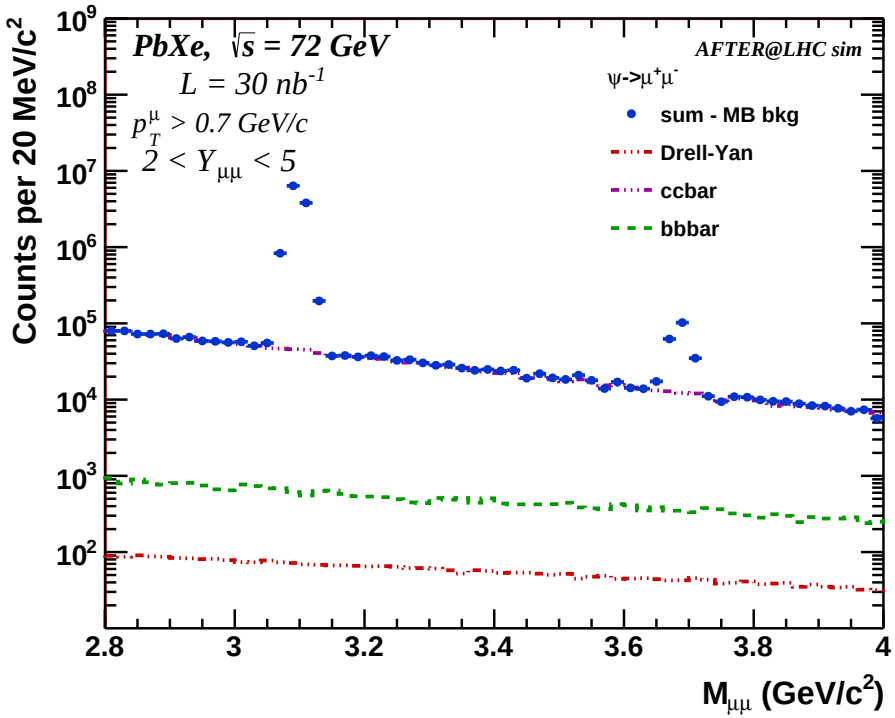




The quarkonium sequential suppression can be studied in a completely new energy domain between SPS and RHIC

+ 2 proceedings

1) Single-Transverse-Spin-Asymmetry studies with a fixed-target experiment using the LHC beams (AFTER@LHC). By J.P. Lansberg et al.. [arXiv:1610.05228 [hep-ex]]. PoS DIS2016 (2016) 241.

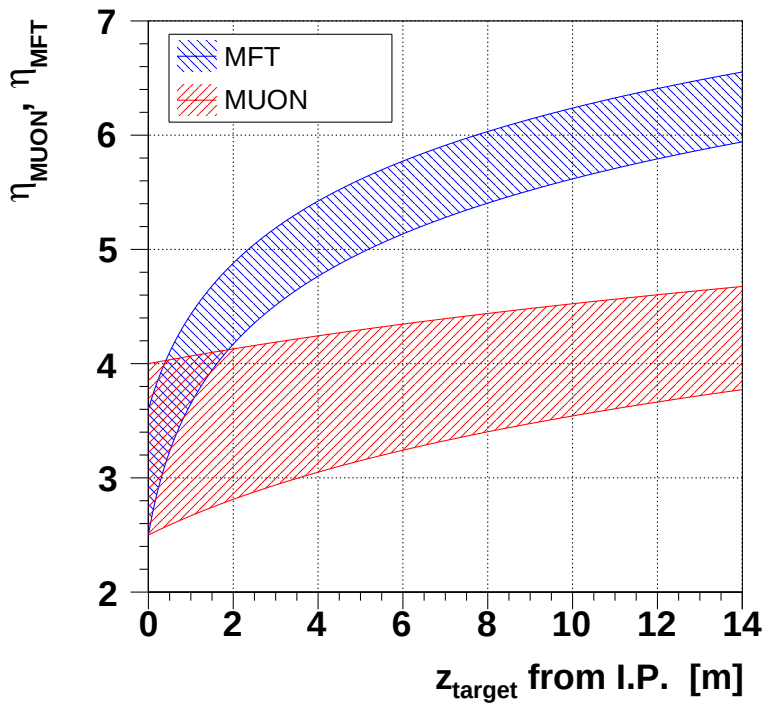
2) Physics case for a polarised target for AFTER@LHC By Jean-Philippe Lansberg et al.. [arXiv:1602.06857 [nucl-ex]]. PoS PSTP2015 (2016) 042

Realisations (3-bis)

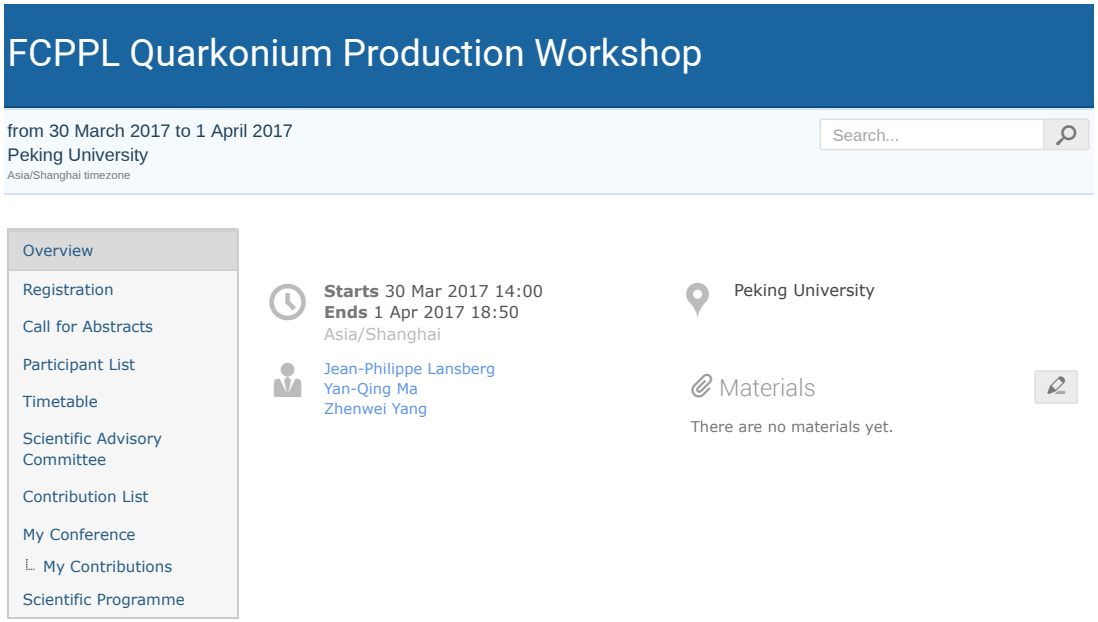
ALICE acceptance in the fixed-target mode

B. Trzeciak, C. Hadjidakis, L. Massacrier, .., JPL, .., A. Uras, Z. Yang, arXiv:1703.03726 [nucl-ex]

- First look at the muon acceptance in the fixed-target mode as a function of the target position
- Central barrel currently studied
- Different options are possible
- If the target is outside the barrel, a dedicated tracker will be needed near the target: no overlap between the MFT and the muon-chamber acceptances
- Topic to be discussed in the "Physics Beyond Colliders" working group `http://pbc.web.cern.ch/`



Realisations (4) (from tomorrow until Saturday)



- Organised by Y.Q. Ma, Z. Yang and JPL; 25+ participants
- 5 sessions on quarkonium production:
  - proton-proton collisions
  - proton-nucleus collisions
  - nucleus-nucleus collisions
  - LHC fixed-target prospects
  - new observables
- Everybody is welcome to join (B105, West Building of School of Physics, PKU; 20 min. walk from here)

Projects (1)

Advance our studies of new quarkonium observables at NLO

with L.P. SUN (PKU), J.X. Wang (IHEP), H.F Zhang (Chongqing), Y.Z. Zhang (Beihang), H.S. Shao (future CR2)

We wish to perform new NLO studies of

- $\psi + \psi$ measured by LHCb, CMS, D0, ATLAS
- $\psi + W$ measured by ATLAS
- $\Upsilon + \Upsilon$ measured by CMS
- $\psi + \Upsilon$ measured by D0
- $\psi + D$ measured by LHCb
- η_c measured by LHCb

and then make the link with gluon TMD extractions

$J/\psi + \ell\ell$ **: JPL, C. Pisano and M. Schlegel, arXiv:1702.00305 [hep-ph].**

Projects (2)

Fixed target studies at the LHC

with Z. Yang (Tsinghua) (possibly with J.He (UCAS))

- Use the LHCb-SMOG to refine our simulations (pp, pA and $pp^{\uparrow}$)
- Evaluate the feasibility of a polarised gas target in LHCb and ALICE
- Evaluate the feasibility of a solid target illuminated by a bent crystal in ALICE
- Evaluate the performance of ALICE (Acceptance, DAQ, ...)

  with A. Uras (IPNL), G. Martinez (Subatech)
- All this in view of the CDR to be made by the end of 2018 for "Physics Beyond Colliders"

Conclusion

- Our multi-faceted FCPPL consortium is doing very well !

  [L. Massacrier got a CNRS CR2 position last year; H.S. Shao will get one this year !]

- Fruitful franco-chinese exchanges on various topics

  [Newcomers : H.F. Zhang (Chongqing) and Y.J. Zhang (Beihang)]

- Regular publications and communications
- Many prospects both for the theory and the experimental sides

  [Not all mentioned]

- AFTER@LHC has been included as a core project in the CERN "Physics Beyond Colliders" initiative
- We start to look at the possibilities for ALICE in the fixed target mode
- Workshop to finalise the AFTER@LHC EoI in June in Orsay

Part I

Backup

Why a fixed-target experiment at the LHC ?

- Advance our understanding of the large-x gluon, antiquark and heavy-quark content in the nucleon & nucleus

Why a fixed-target experiment at the LHC ?

- **Advance our understanding of the large-x gluon, antiquark and heavy-quark content in the nucleon & nucleus**
  - Very large PDF uncertainties for $x \gtrsim 0.5$.

    [could be crucial to characterise possible BSM discoveries]
  - Proton charm content important to high-energy neutrino & cosmic-rays physics
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- **Heavy-ion collisions towards large rapidities**
  - Explore the longitudinal expansion of QGP formation with new hard probes
  - Test the factorisation of cold nuclear effects from $p + A$ to $A + B$ collisions
  - Test the formation of azimuthal asymmetries: hydrodynamics vs. initial-state radiation

Fixed-target collisions at the LHC: main kinematical features

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Energy range

7 TeV proton beam on a fixed target

c.m.s. energy: $\sqrt{s} = \sqrt{2m_N E_p} \approx 115\,\mathrm{GeV}$	**Rapidity shift:** $y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.8$
Boost: $\gamma = \sqrt{s}/(2m_N) \approx 60$	

2.76 TeV Pb beam on a fixed target

c.m.s. energy: $\sqrt{s_{NN}} = \sqrt{2m_N E_{\mathrm{Pb}}} \approx 72\,\mathrm{GeV}$	**Rapidity shift:** $y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.3$
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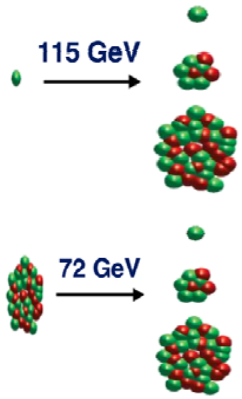

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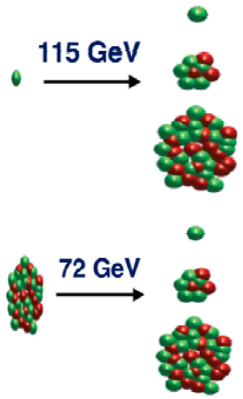

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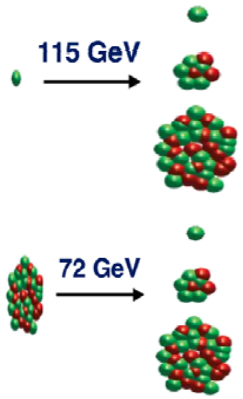

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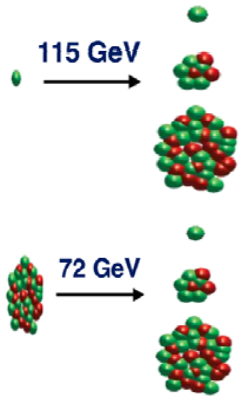

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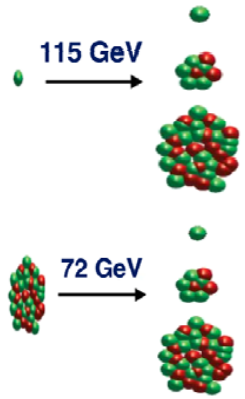

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- Allows for backward physics up to high x_{target} $(\equiv x_2)$ [uncharted for proton-nucleus; most relevant for p-$p^{\uparrow}$ with large $x^{\uparrow}$]

High-x frontier

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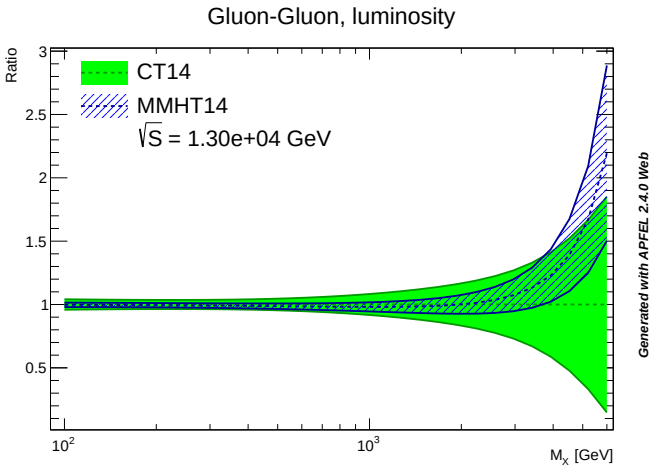

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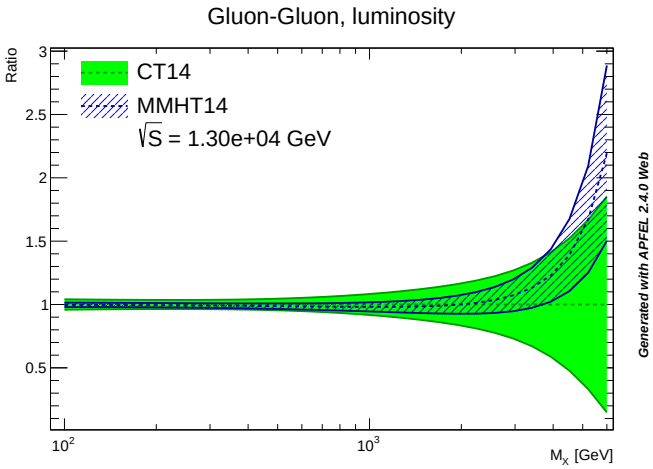

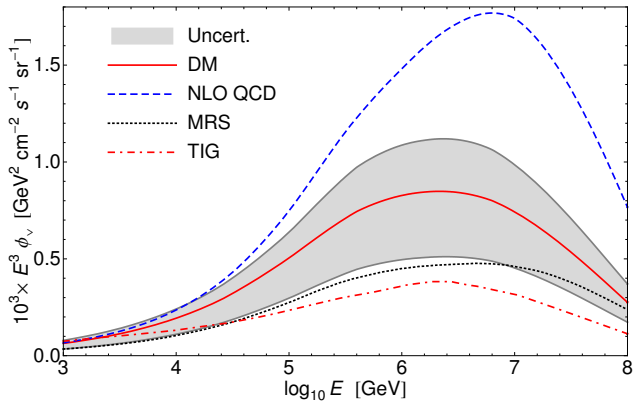

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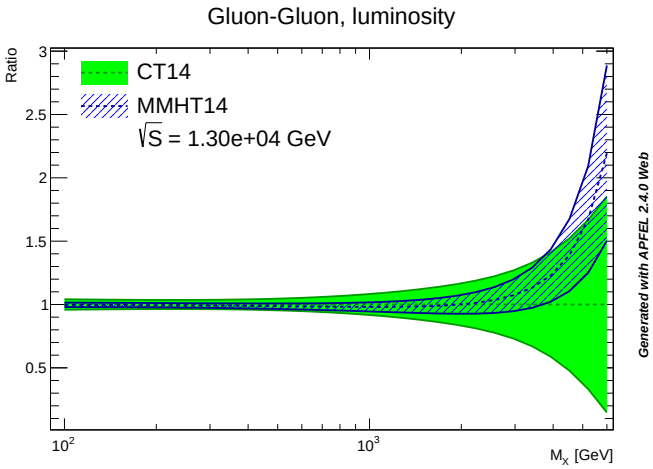

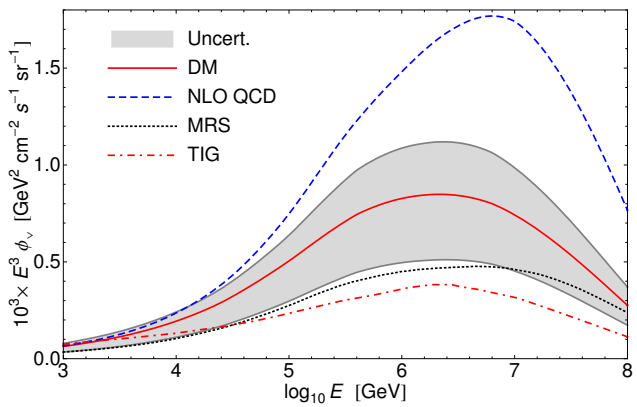

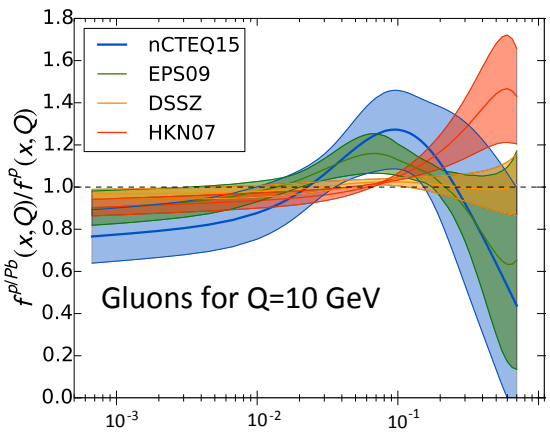

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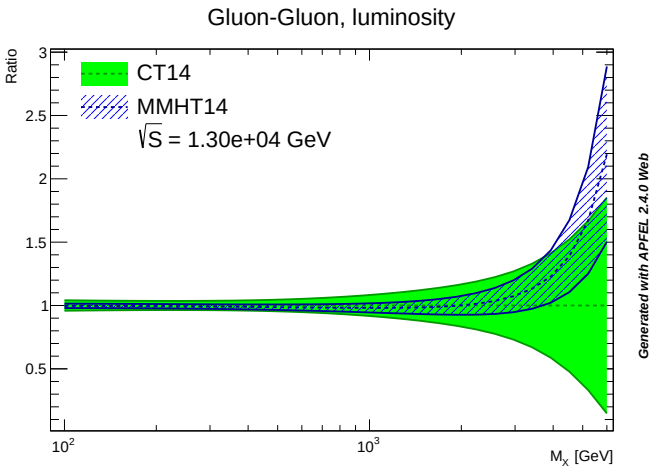

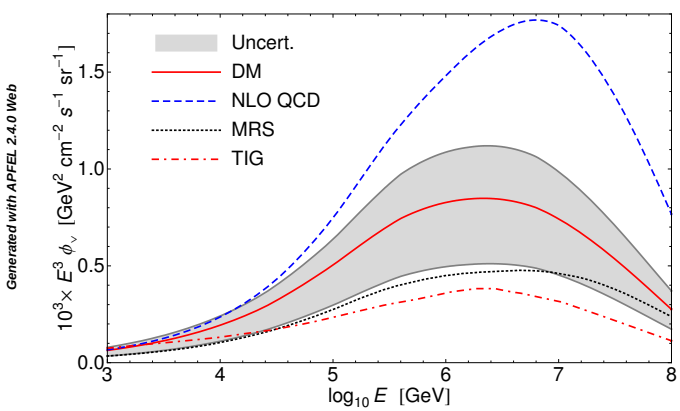

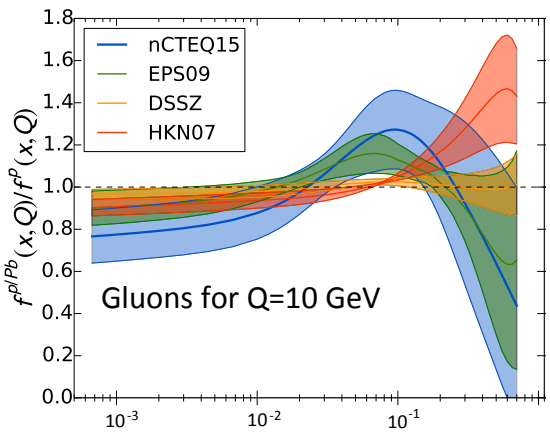

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Advance our understanding of the dynamics and spin of gluons and quarks inside (un)polarised nucleons

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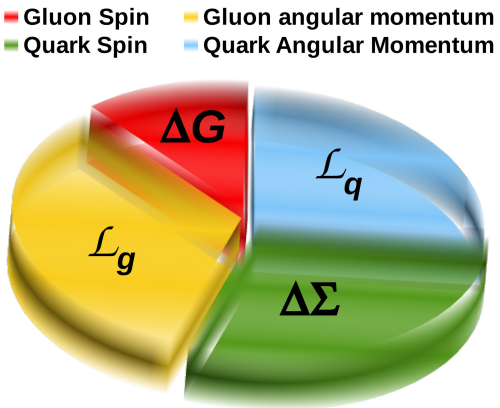

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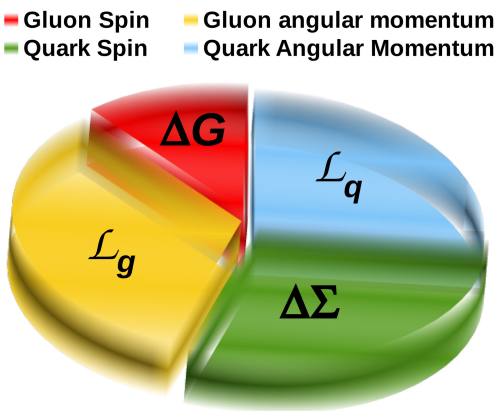

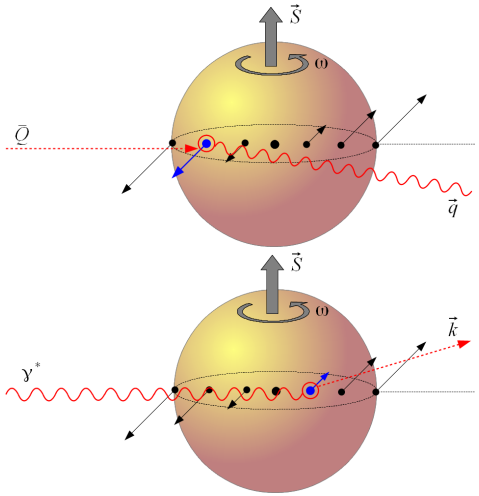

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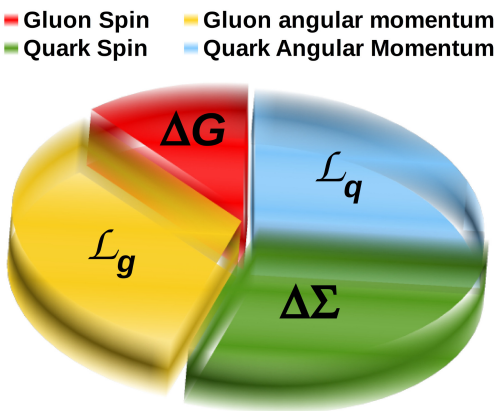
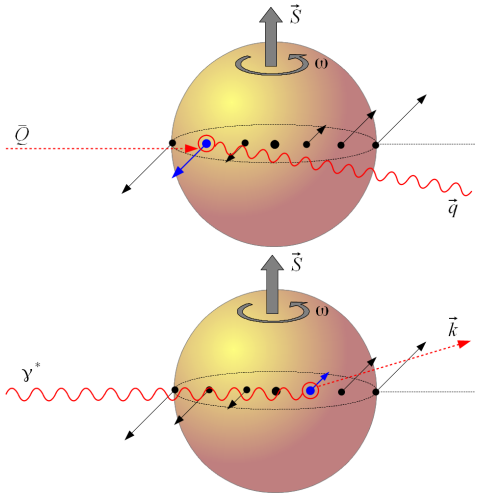
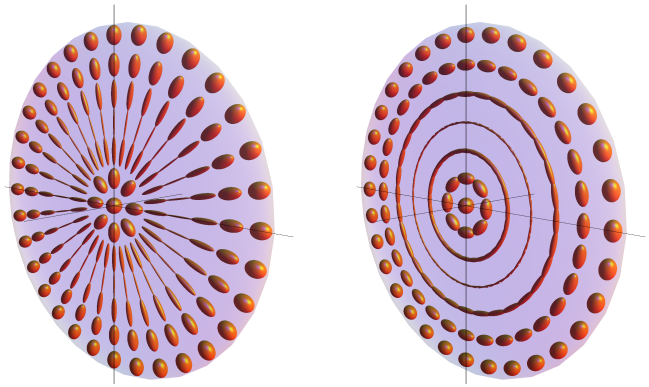
[once measured, allows for spin physics without polarised proton, e.g. at the LHC]







heavy-ion collisions from one colliding nucleus rest frame

Heavy-ion collisions towards large rapidities

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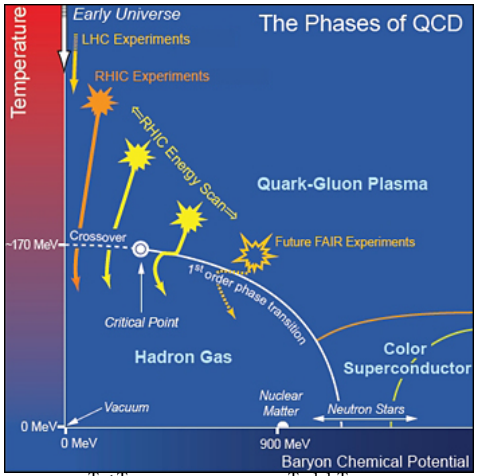

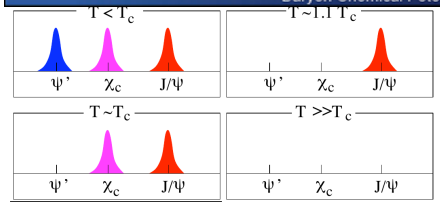

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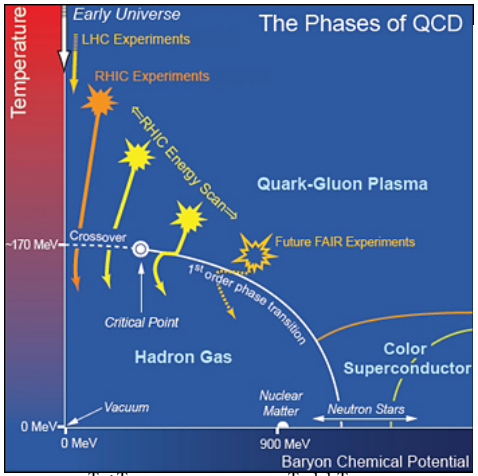

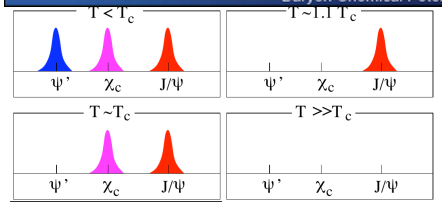

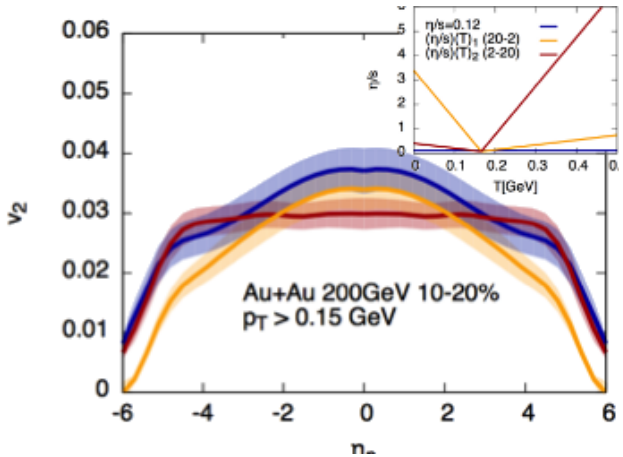

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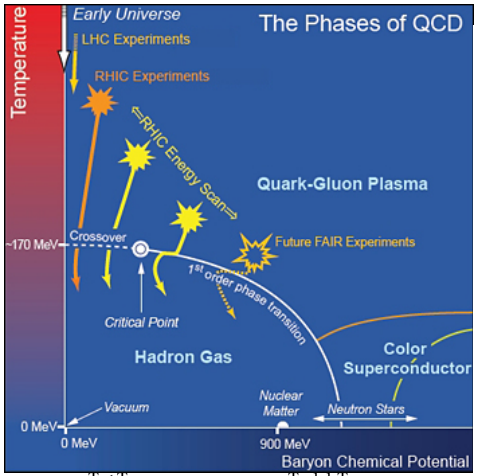

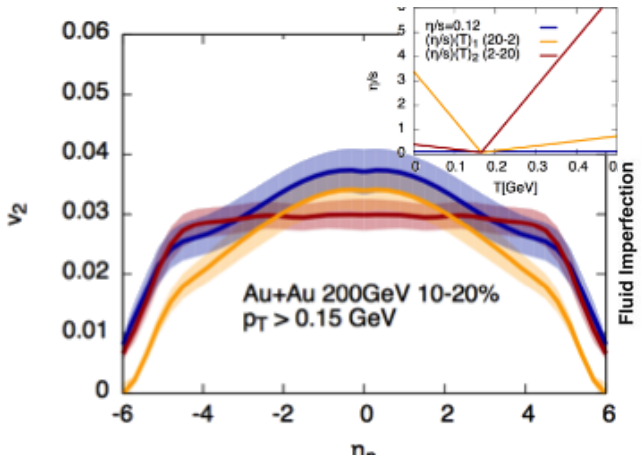

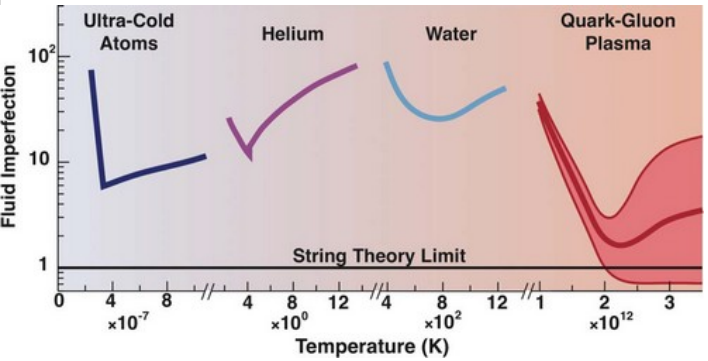

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