Learning about the nucleon and nucleus structure with quarkonia

J.P. Lansberg

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

11th France-China Particle Physics Laboratory Workshop

Marseille, France, May 22 - 25, 2018

May 23, 2018

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) H.S. Shao (LPTHE)	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	N. Yamanaka (IPNO) M. Ozcelik (IPNO) F. Scarpa (IPNO - GU)	L.P. An (Tsinghua) W.J. Kong (Tsinghua)

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Theory collaboration with H.S. Shao & H.F. Zhang (Chongqing) + Y.J. Zhang (Beihang)

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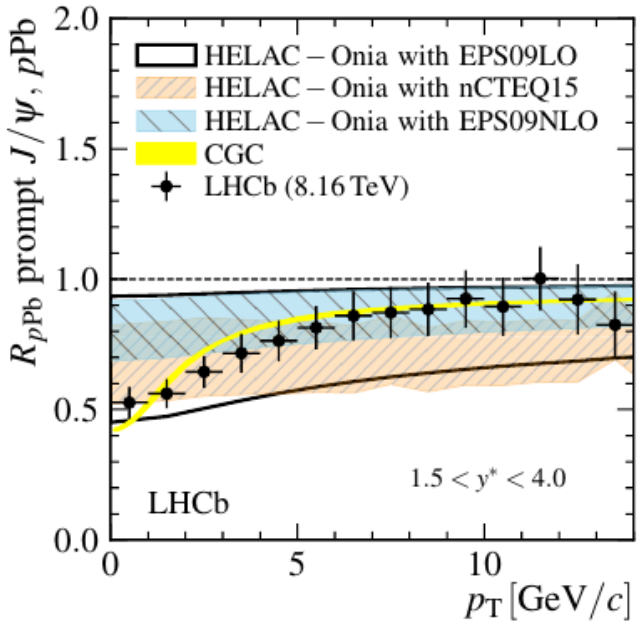

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  - The same is expected for the $2S$ states. Less data on $\psi(2S)$ than for $J/\psi \rightarrow$ the impact of $\eta_c(2S)$ data can be even more crucial
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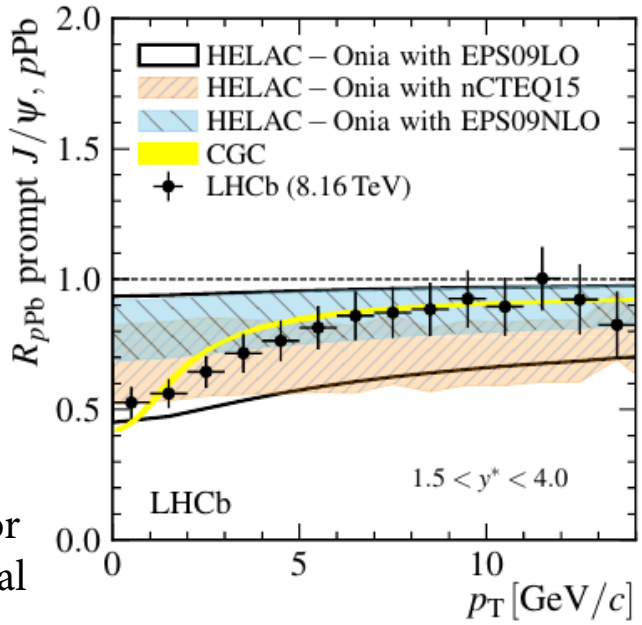

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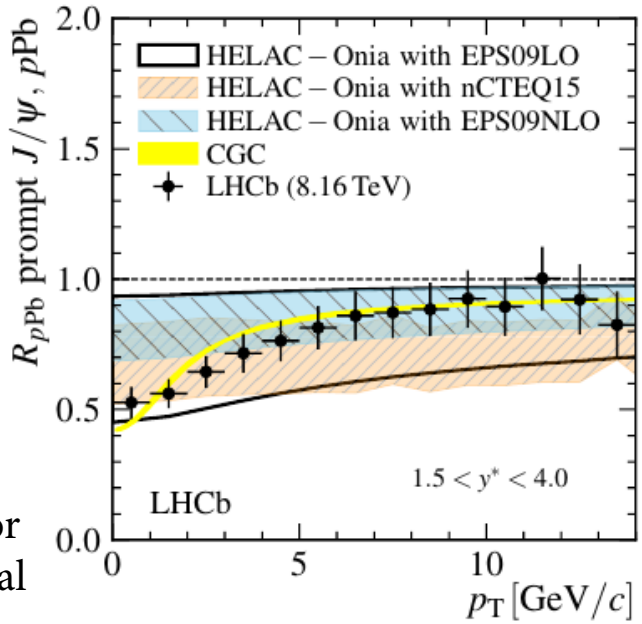

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- NLO computation of $W + J/\psi$ **[PLB 781 (2018) 485]**
  - Measured by ATLAS with significant tension with theory; $\Delta\phi$ spectrum hints at a large SPS yield
  - Our NLO evaluation gives an upper limit on the SPS; tension confirmed
  - BUT 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 solved with a dominant DPS yield (similar situation as $Z + J/\psi$)
  - Fit of σ_{eff} characterising the correlation of partons inside the protons

Realisations (1-bis)

Harvesting quarkonium data with H.S. Shao

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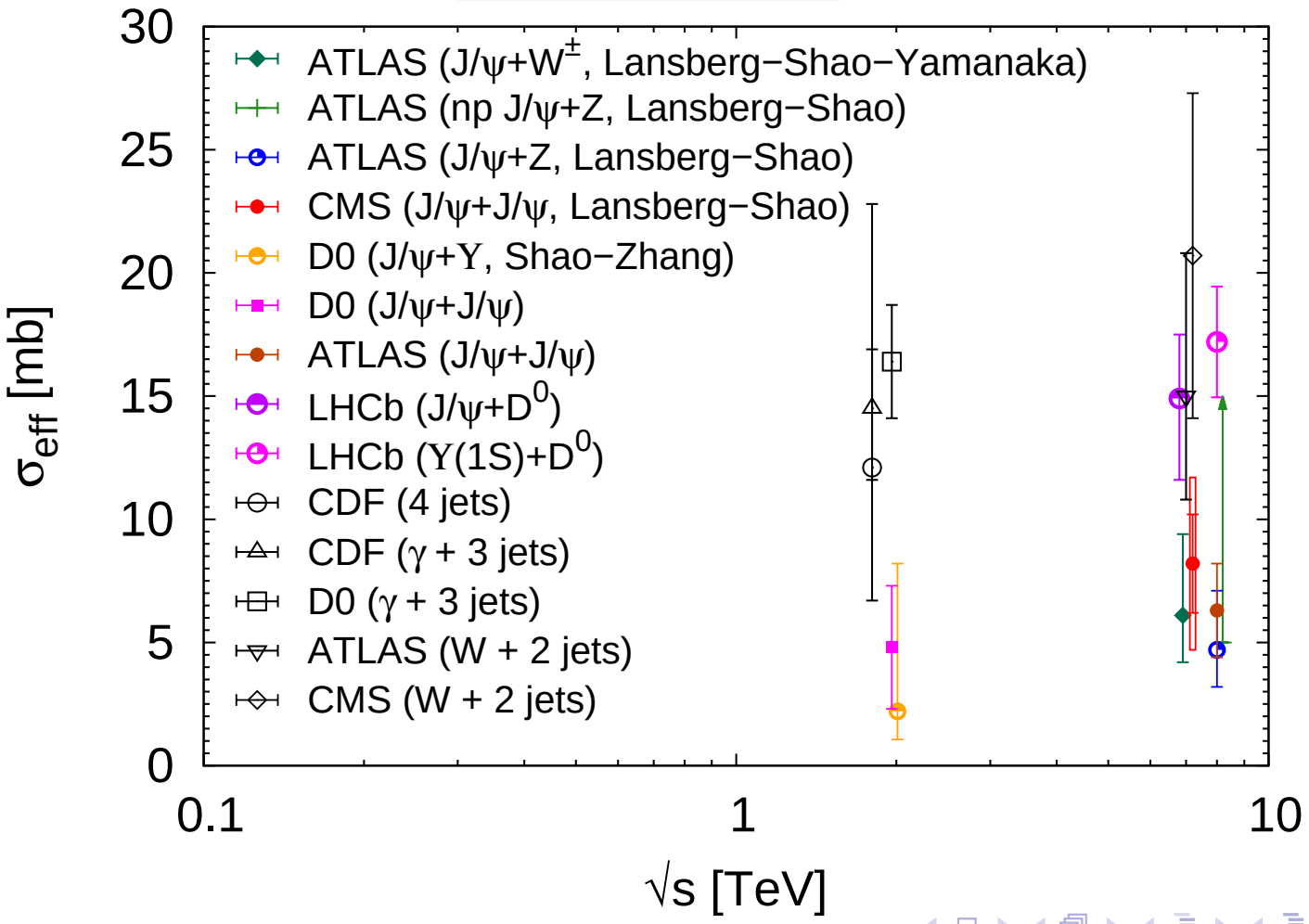

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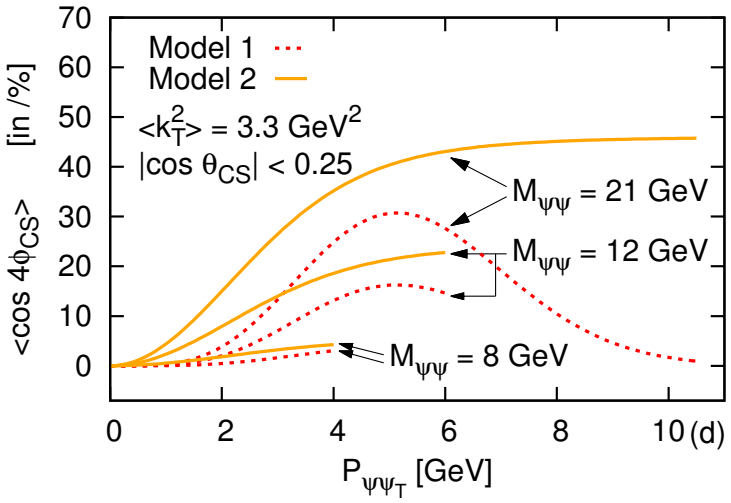

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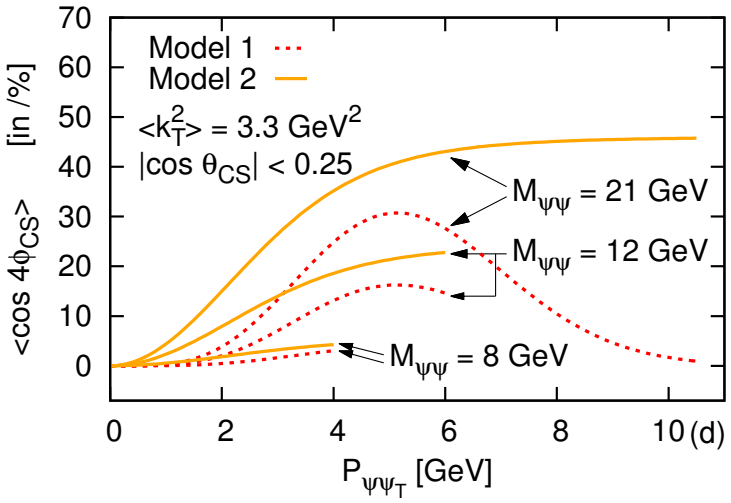

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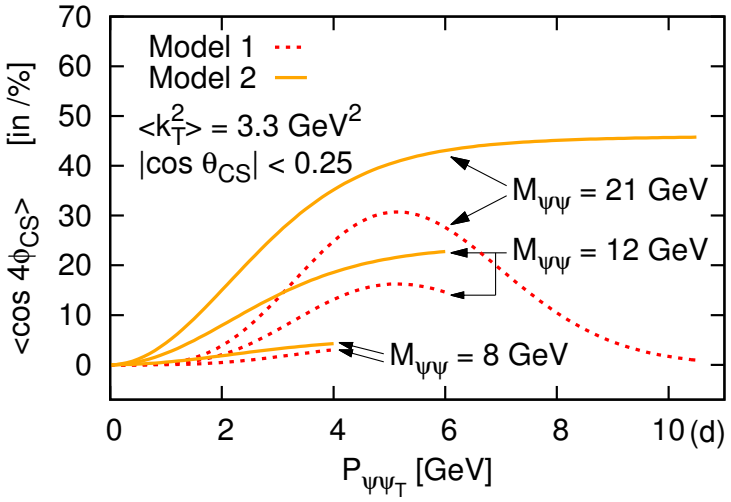

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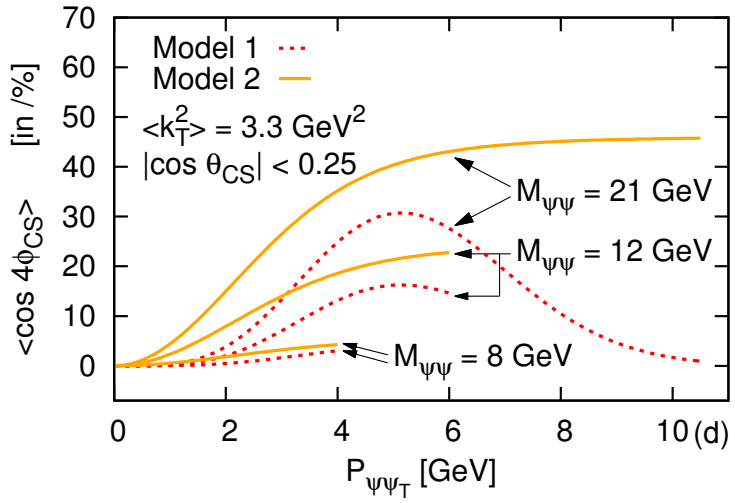

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  - A dedicated target (polarisation and pumping) will allow for an extremely wide physics case extending by far that of BNL-RHIC and CERN-SPS
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- Mid/long term project (which I will not repeat in the project description)

Projects (1)

Advance our studies of new quarkonium observables at NLO

with J.X. Wang (IHEP), H.F Zhang (Chongqing), Y.Z. Zhang (Beihang), H.S. Shao (LPTHE)

We wish to perform new NLO studies of

- $\psi + \psi$ measured by LHCb, CMS, D0, ATLAS [on-going]
- $\Upsilon + \Upsilon$ measured by CMS [on-going]
- $\psi + \Upsilon$ measured by D0 [on-going]
- $\psi + D$ measured by LHCb
- η_c measured by LHCb

and then make the link with gluon TMD extractions (e.g. the linearly polarised gluons)

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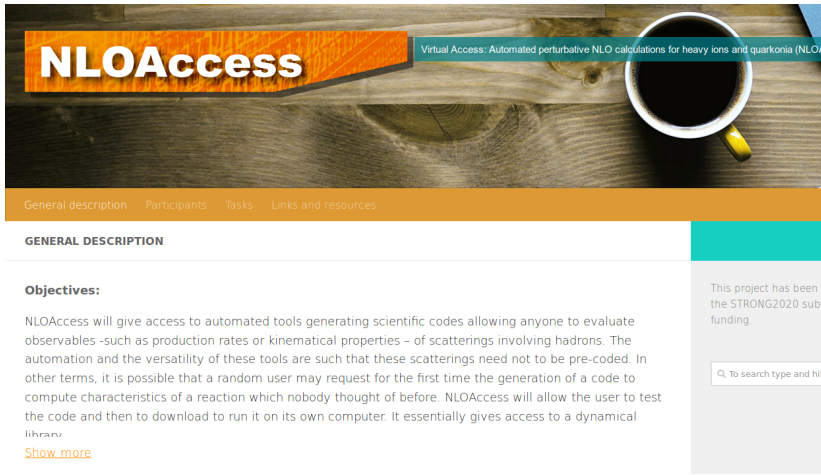

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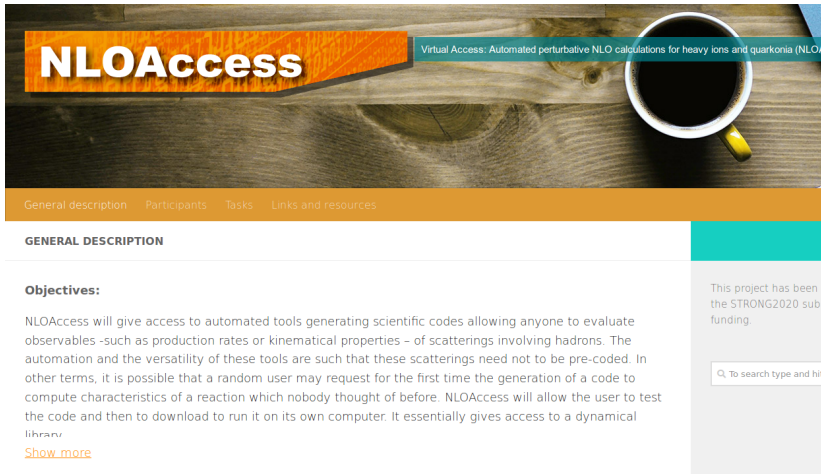

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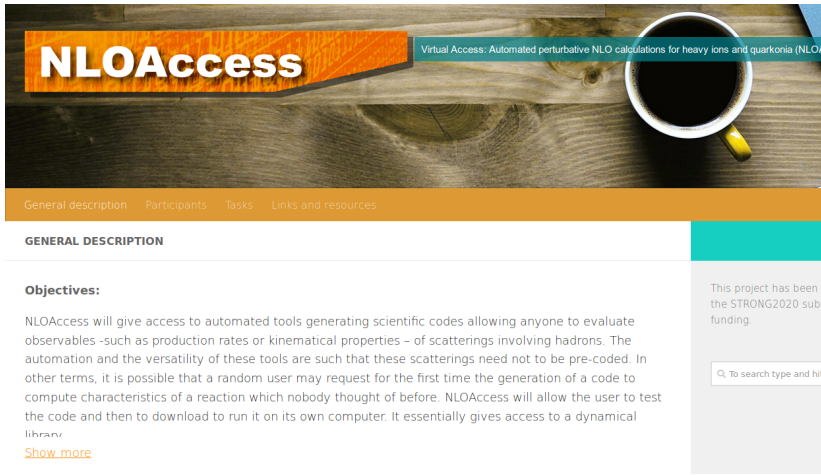

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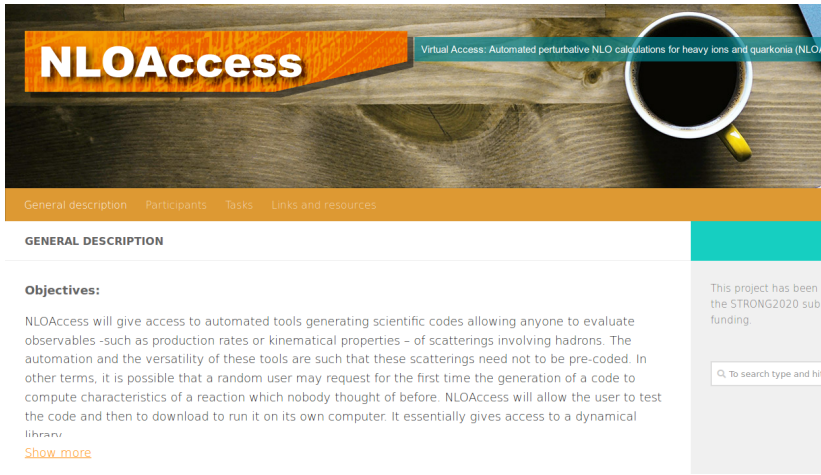

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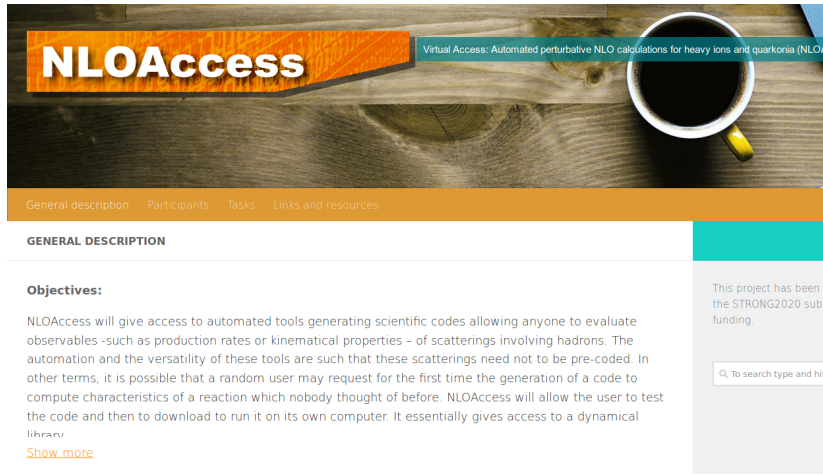

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- When the portal is functional (in a few months from now), we will investigate the possibility to have a mirror of the web portal in China

Conclusion

- Our multi-faceted FCPPL consortium is doing very well !
- Fruitful franco-chinese exchanges on various topics

  [Our exchanges with China extend beyond the LIA: visit of G.Z. Xu (Liaoning) in January]
- Regular publications and communications e.g. Talk of Z. Yang at ICHEP2018
- Many prospects both for the theory and the experimental sides
- The efforts of the AFTER@LHC study group are fruitful: a FT program at the LHC is more realistic than ever
- New collaboration on a web portal dedicated to quarkonia
- If the schedule allows for it, we will organise again a FCPPL Quarkonium satellite Workshop next year

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

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  - Very large PDF uncertainties for $x \gtrsim 0.5$.

    [could be crucial to characterise possible BSM discoveries]
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  - 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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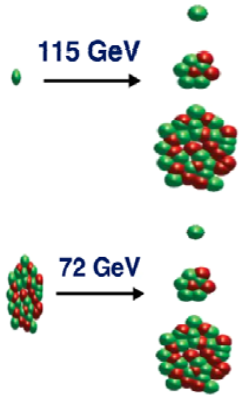
Energy range

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:** $y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.3$
Boost: $\gamma \approx 40$	



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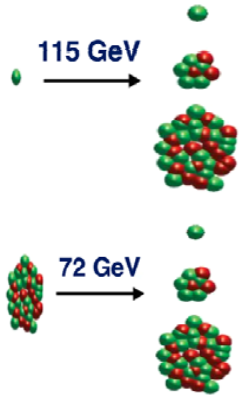

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Fixed-target collisions at the LHC: main kinematical features

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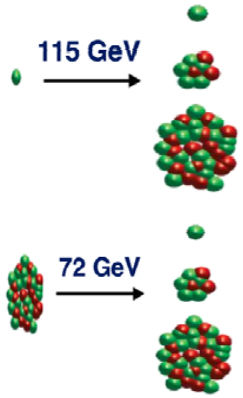

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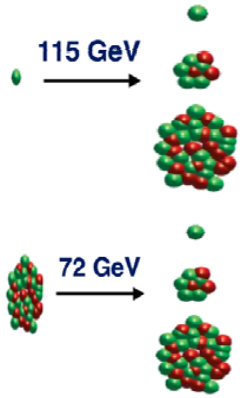

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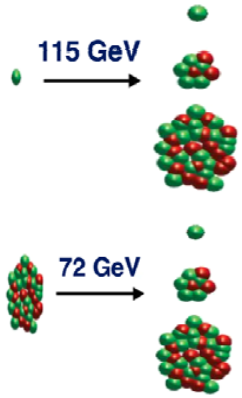

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- Allows for backward physics up to high x_{target} $(\equiv x_2)$ [uncharted for proton-nucleus; most relevant for p-p$^\uparrow$ with large $x^\uparrow$]

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

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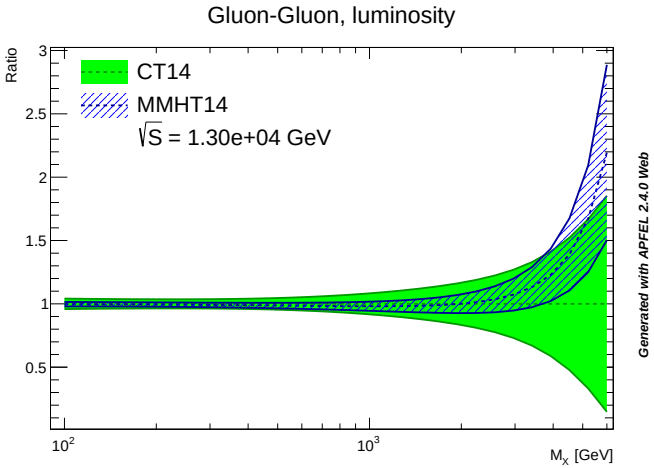

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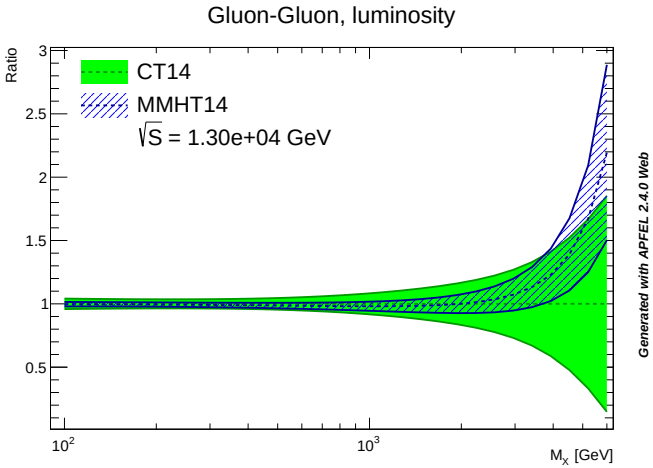

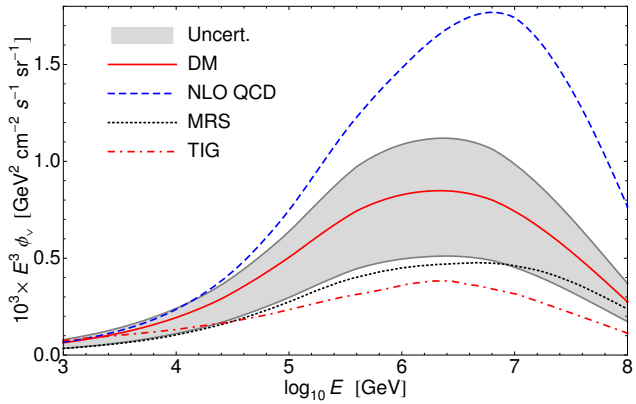

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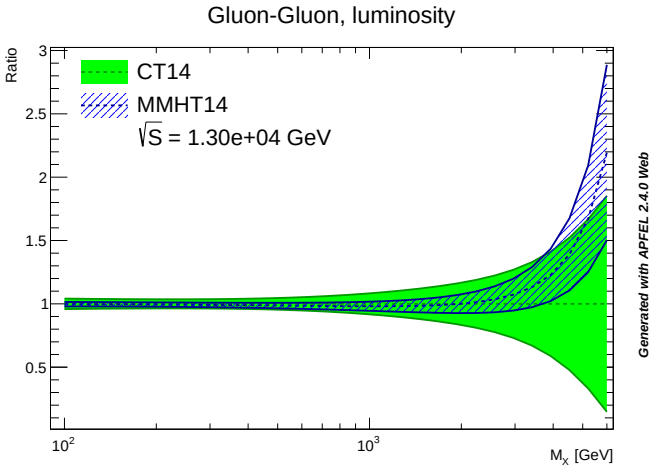

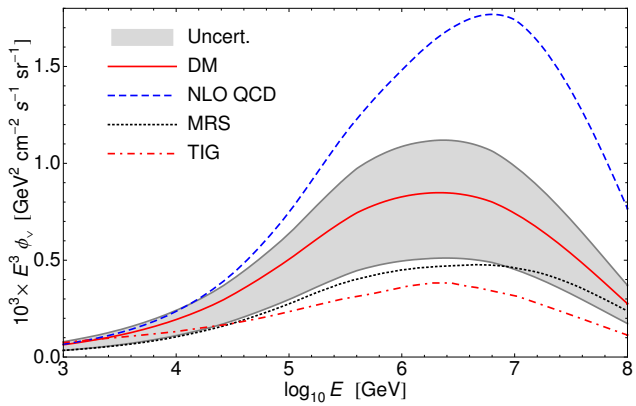

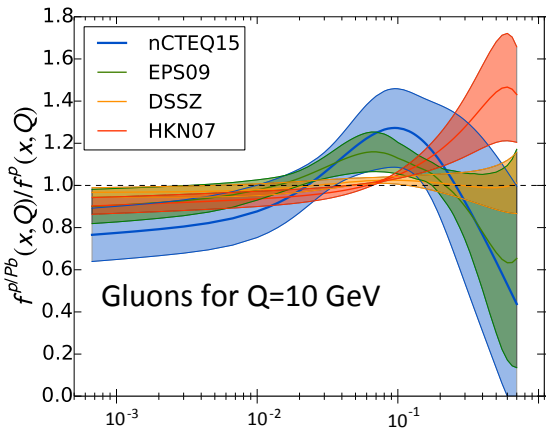

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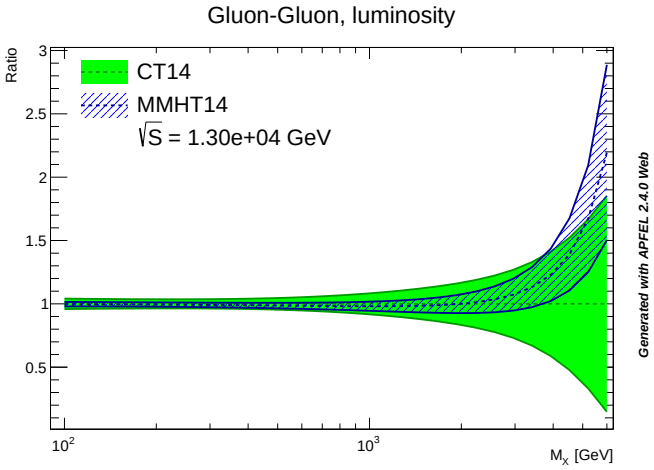

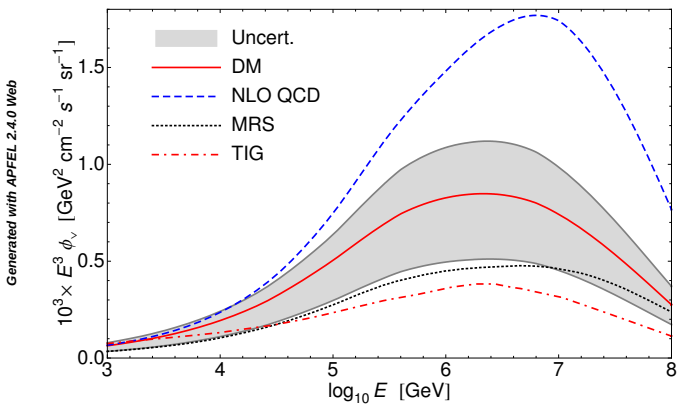

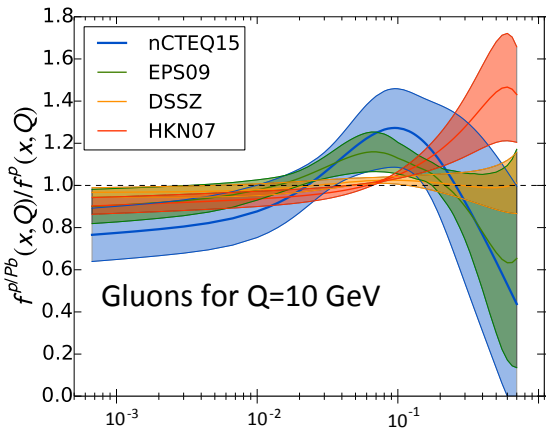

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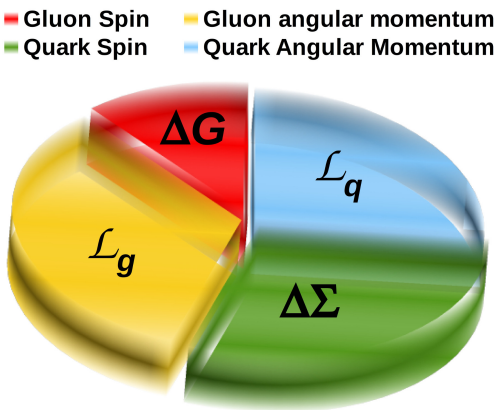

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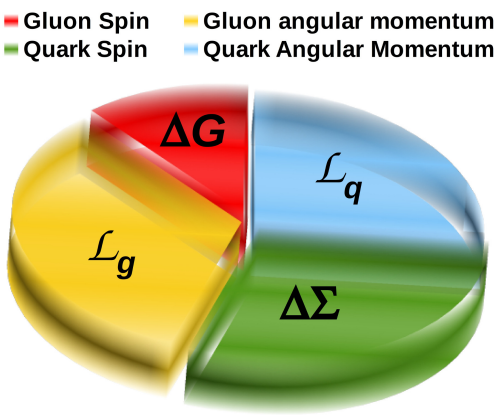

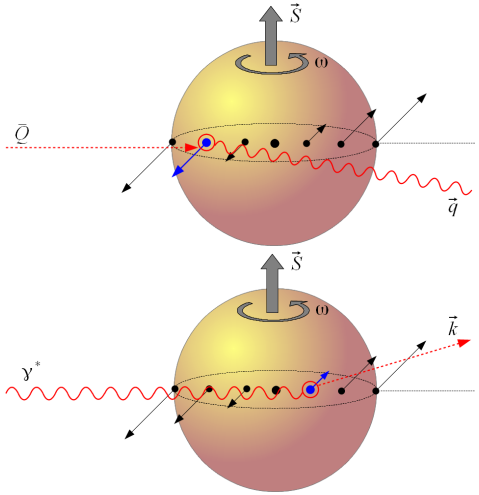

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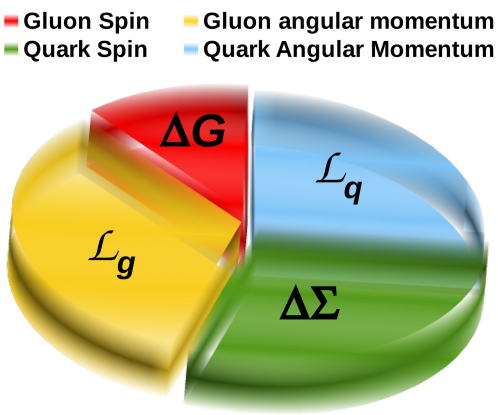
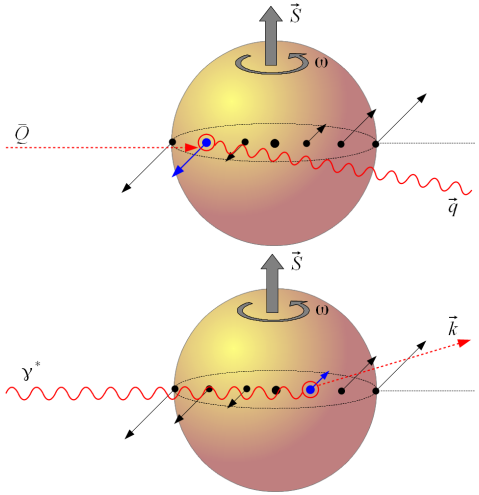
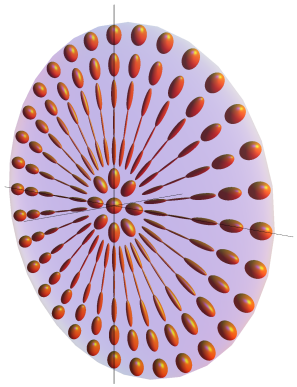
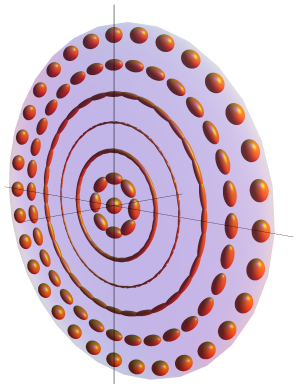
[once measured, allows for spin physics without polarised proton, e.g. at the LHC]









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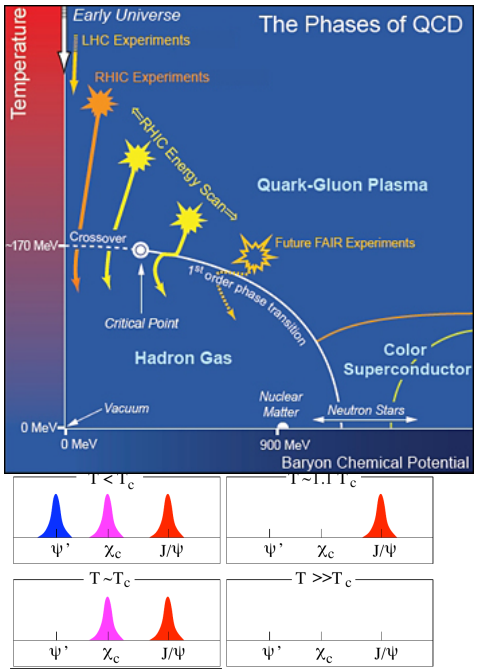

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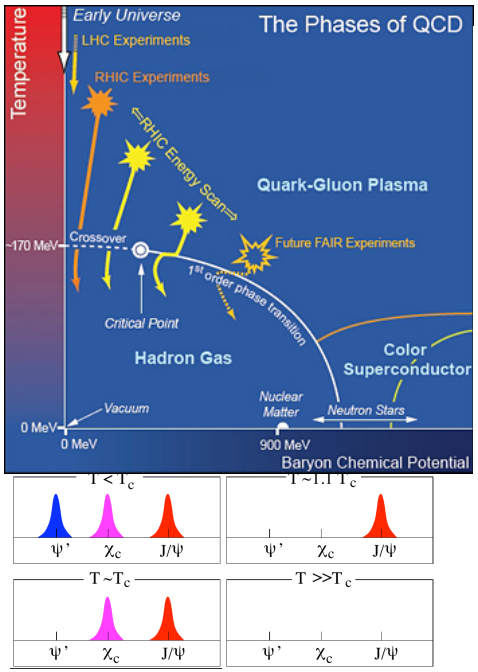

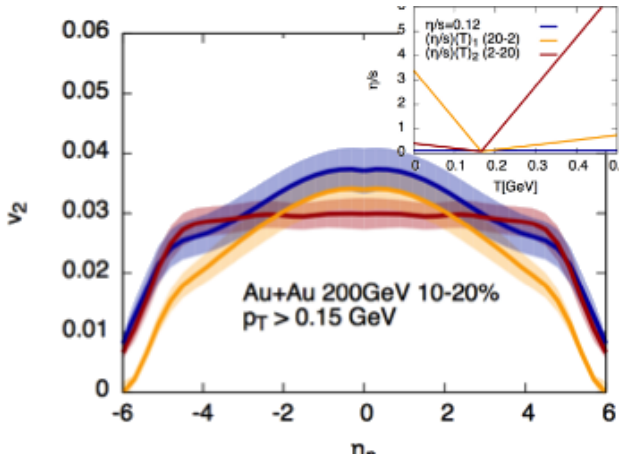

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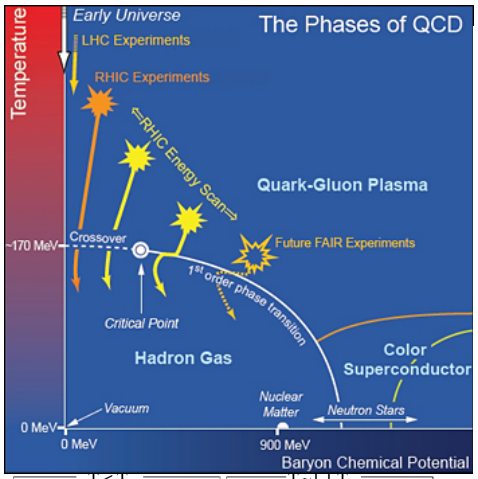

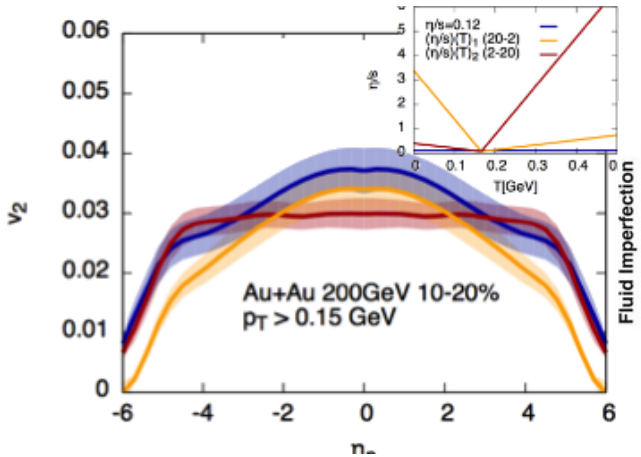

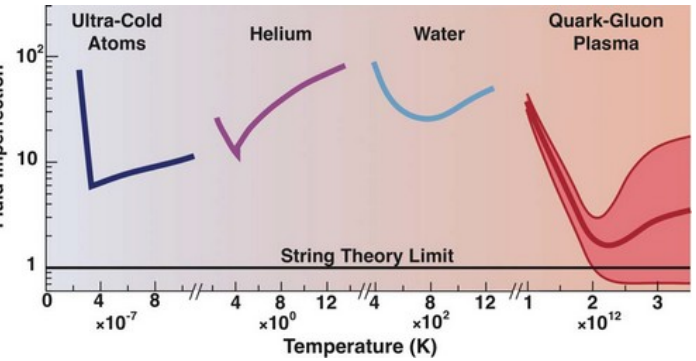

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