WG5 – Physics with Heavy Flavours

An attempt to summarize

Top researchers having **Charming** skills who presented **Beautiful** results

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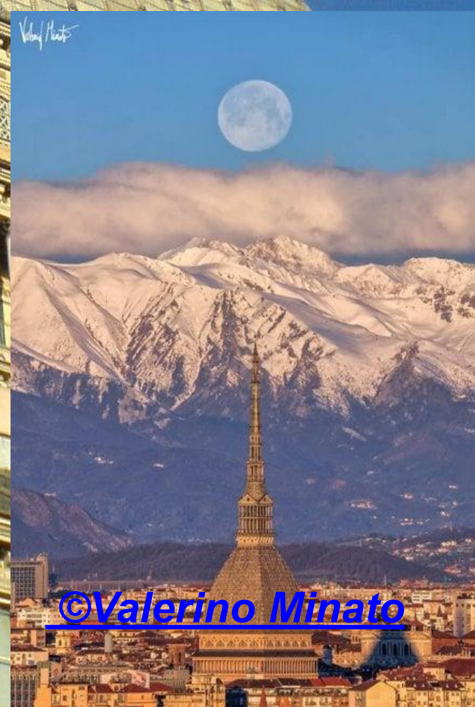
National Museum of Cinema (*Museo Nazionale del Cinema*), Turin

Top



Exotics

Charming

Bottom/Beauty

Top production at LHC (theory): Rene Poncelet
Top pairs at the LHC: Sergio Grancagnolo
Rare top production ttW, ttZ, ttgamma, tttt at the LHC: Joscha Knolle
Top properties at the LHC(theory): Markus Schulze
Top properties at the LHC : Baptiste Ravina
Single top production at the LHC : Achim Geiser
Direct determination of top quark width with bb4l : Tomas Jezo

8 sessions
21 Talks
30+5'

Spectroscopy of conventional hadrons at e+e- machines: Kiyoshi Tanida
Results of the XYZ states from experiments : Liang Yan
Heavy flavour spectroscopy and exotic states at the LHC : Roberta Cardinale
Quarkonium studies at Belle II : Yuji Kato
Quarkonium results in heavy-ion collisions: Roberta Arnaldi
Heavy flavor/quarkonium production at the LHC : Hee Sok Chung
Constraining gluon PDFs and TMDs with quarkonium production :Melih Arslan Ozcelik

Production of quarkonia and heavy flavour states in ATLAS: Paolo Lengo
Results from Charm baryon spectroscopy at LHCb, Belle and BESIII : Roberta Cardinal
Heavy-flavour hadron production at LHCb :Hans Dembinski
Heavy-flavor hadron production in heavy-ion collisions: Petr Chaloupka
Enhanced production of Λ_c in proton-proton collisions at LHC :Rafal Maciula

Radiative leptonic decay $B\to\gamma\ell\nu_\ell$ with subleading power corrections :Yao Ji
Measurement of beauty production from dimuon events at HERA : Achim Geiser

New Physics in joint session with WG3

**New Physics implications of the B-physics anomalies : ** Javier Fuentes-Martin
**B-flavour anomalies in b->sll and b->clnu transitions at LHCb : ** Alessandra Gioventu
**Heavy flavors at Belle II: status and plans : ** Akimasa Ishikawa
Search for NP in CP violation with beauty and charm decays at LHCb : Matteo Bartolini

8 sessions : **21 talks**
1 joint sessions with WG3 : **4 talks**

Each result is interesting and need attention by the community:
Not easy to summarize **855''** summary in **30''** summary

Discuss few results, which we think are interested (based on our biased NN weights)
Apologies for missing crucial result due to time constraint !

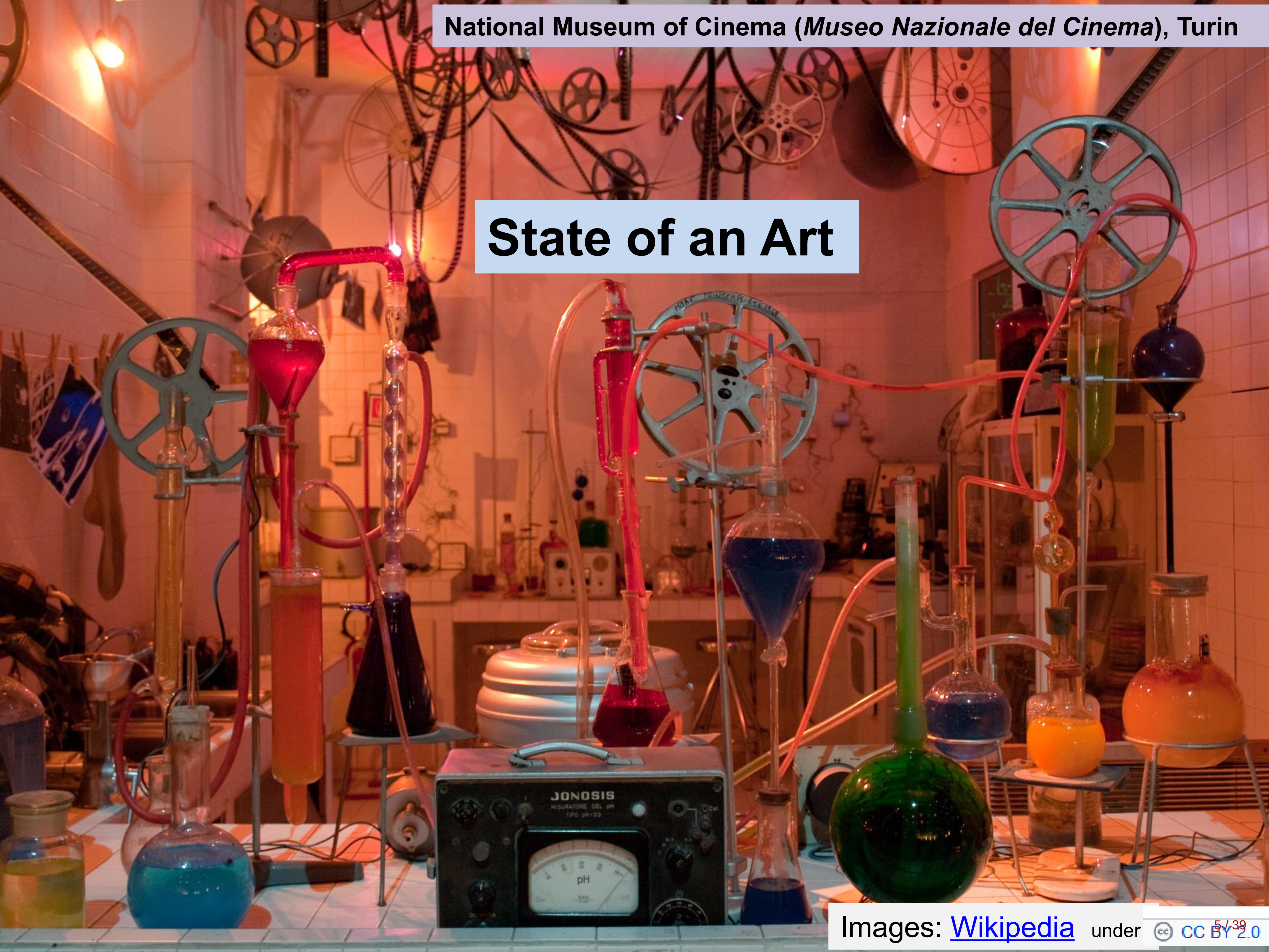
Divided into four main areas:
- Spectroscopy
- Production
- Top
- *B* decays

Summarized by Javier Virto (Top, *B* decays)

Instructions from Organizers :
Summary should be state of an art !

National Museum of Cinema (*Museo Nazionale del Cinema*), Turin

State of an Art

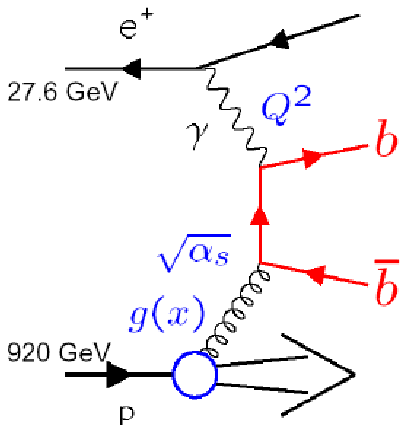


Images: Wikipedia under CC BY 2.0

Achim Geiser

DIS in ep @ 318 GeV

Boson-Gluon-Fusion



Total beauty cross section
HERA II preliminary :
$\sigma_{b\ total}\ ep \rightarrow bbX\ (318\ GeV) = 11.4 \pm 0.8(stat)^{+3.9}_{-2.9}(syst.)$nb

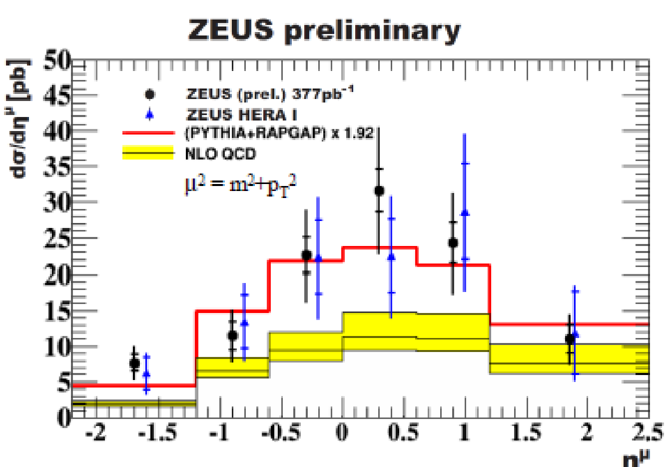
380 pb⁻¹

NLO QCD predictions
FMNR + HVQDIS = $7.5^{+4.5}_{-2.1}$ nb

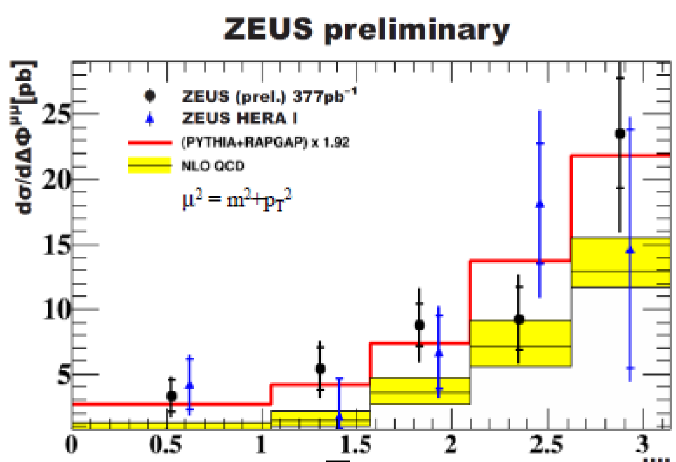
Agree within (large) uncertainties.
Interesting to get NNLO prediction [exists for pp]

Differential cross-section

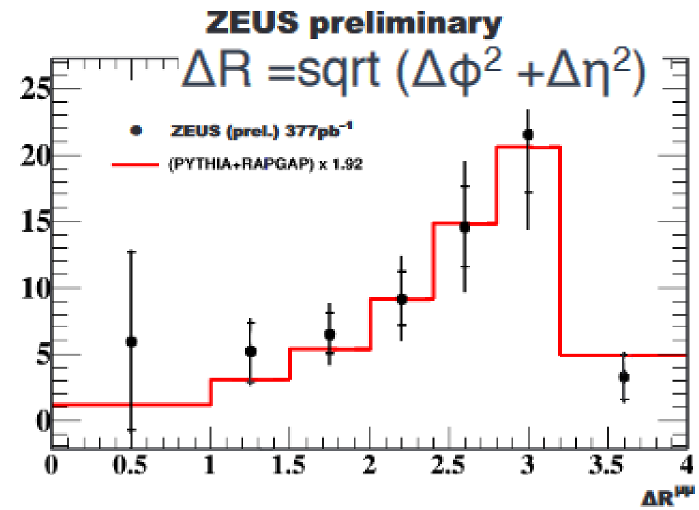
First time measurement



Muon pseudorapidity



Sensitive to $b\bar{b}$ correlation



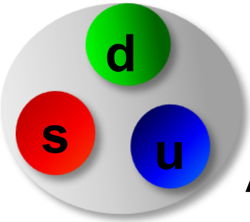
LO+PS describe better than NLO

Lower scale NLO prediction agree better

Agree with LO+PS, NLO not calculated yet

First time measurement of charm in charged current DIS ***(discussed more in WG1 by J. NAM)***

QCD : real particles are color singlet

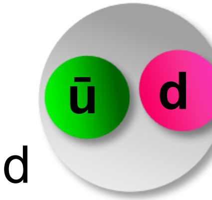


Baryons are red-blue-green triplets

Λ=usd

Mesons are color-anticolor pairs

π=ūd

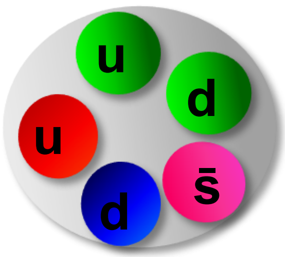


Other possible combinations of quarks and gluons :

artistic illustration

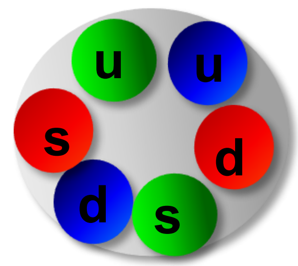
Pentaquark

S= +1 Baryon



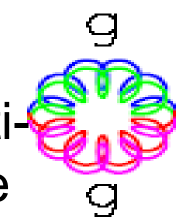
H di-Baryon

Tightly bound 6 quark state



Glueball

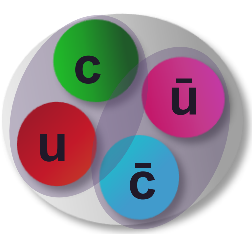
Color-singlet multi-gluon bound state



eXoTiC

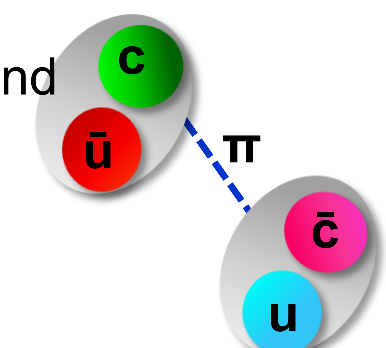
Tetraquark

Tightly bound diquark & anti-diquark

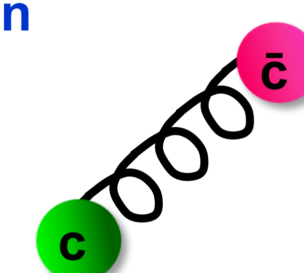


Molecule

loosely bound meson-antimeson “molecule”

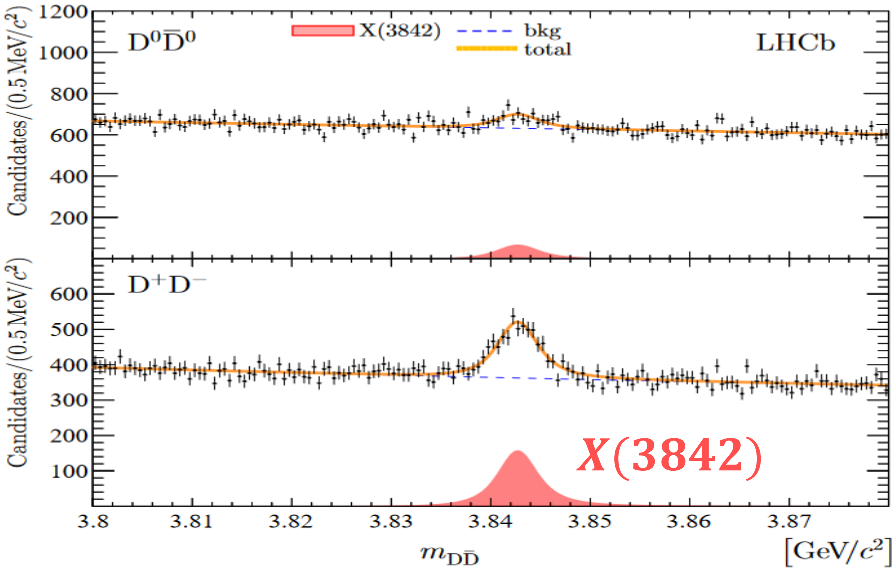


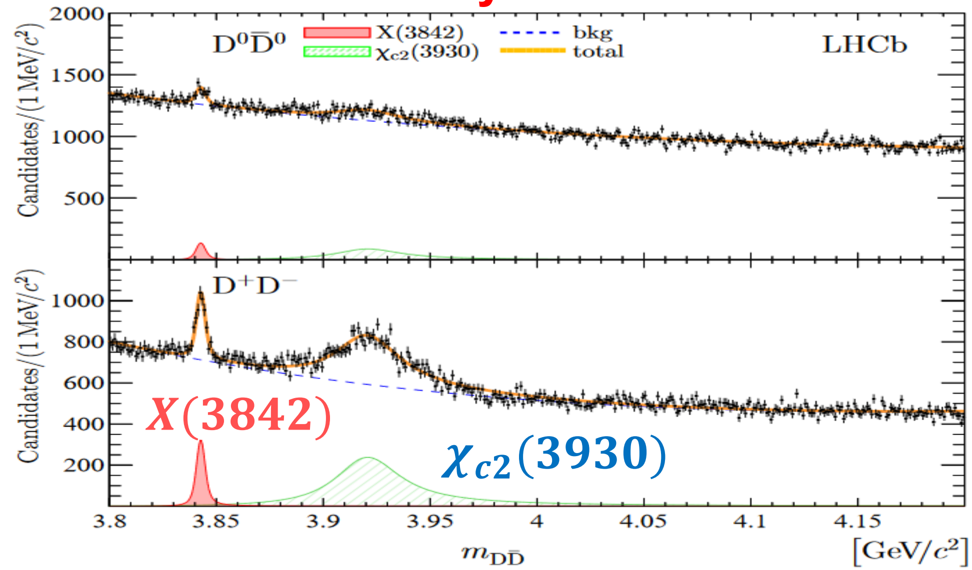
$q\bar{q}$ -gluon hybrid mesons



Conventional states

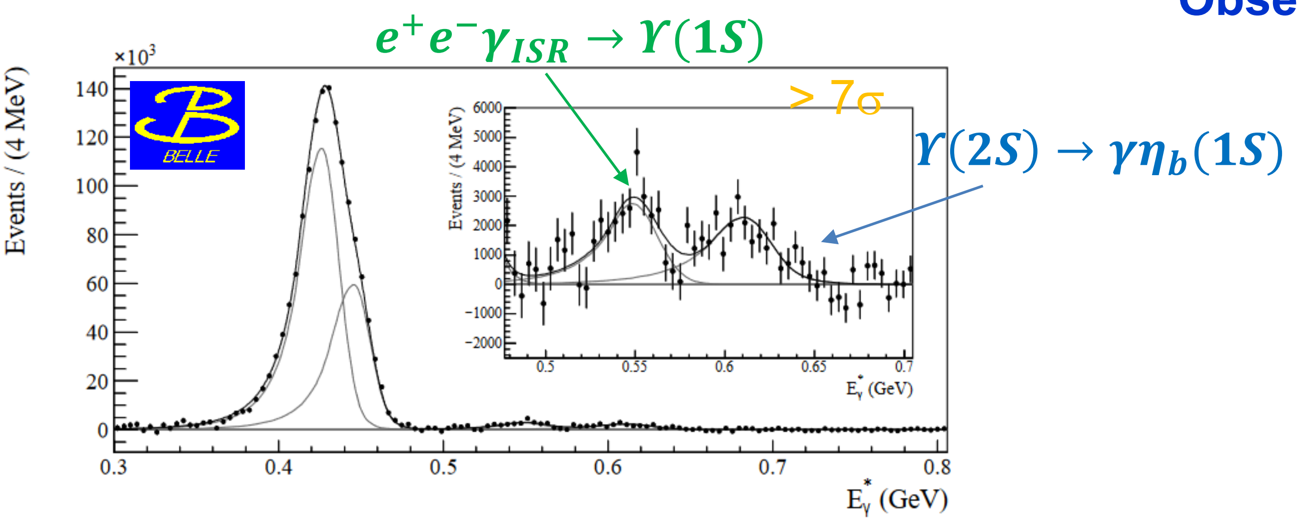
Roberta Cardinale,
Kiyoshi Tanida





New narrow charmonium state X(3842) : $\psi_3(1^3D_3)$ with $J^{PC} = 3^{--}$

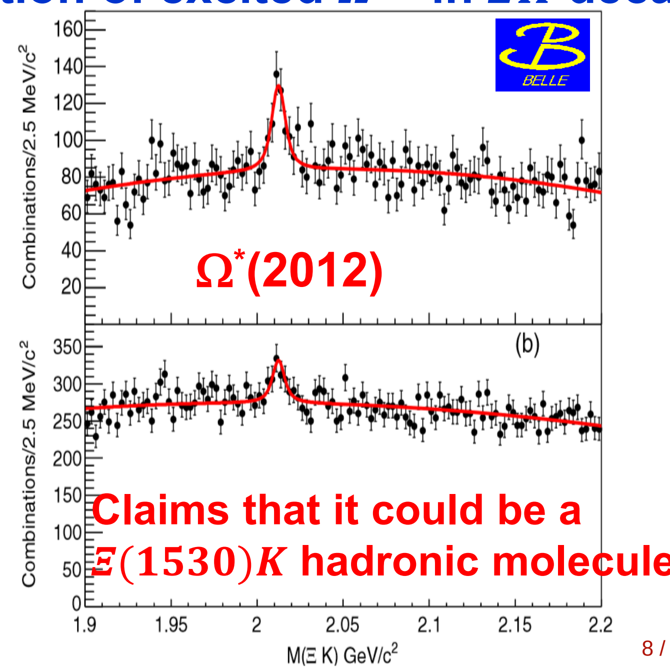
First observation of spin 3 charmonium !



- Heavy Quark spin flip transition

→ important inputs for theories

Observation of excited Ω^{*-} in ΞK decay



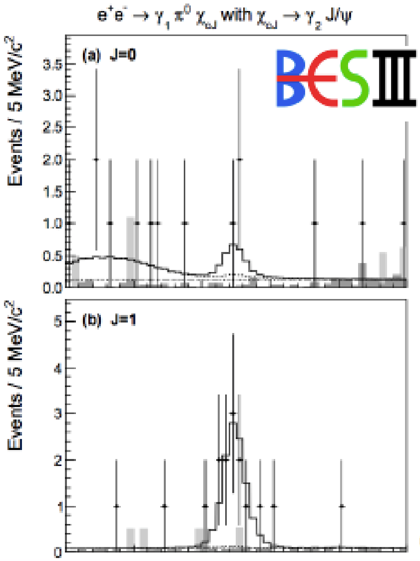
Claims that it could be a $\Xi(1530)K$ hadronic molecule

XYZ_c

Liang Yan,
Roberta Cardinale

X(3872) is still giving spectacular performance, don't want to loose poster boy image.

$X(3872) \rightarrow \chi_{cJ}\pi^0$



[arXiv:1901.03992]

$R_J = B(X \rightarrow \pi^0\chi_{cJ}) / B(X \rightarrow \pi^+\pi^- J/\psi)$:

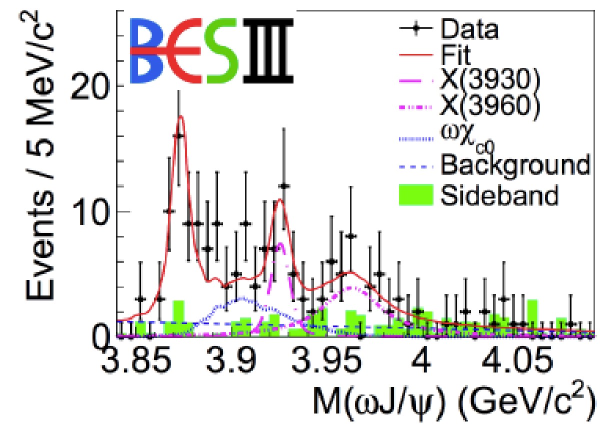
$R_0 < 19$ (90% U.L.)

$R_1 = 0.88^{+0.31}_{-0.26} \pm 0.14$

$R_2 < 1.0$ (90% U.L.)

Large R_1 suggest tetraquark nature of X(3872) ?

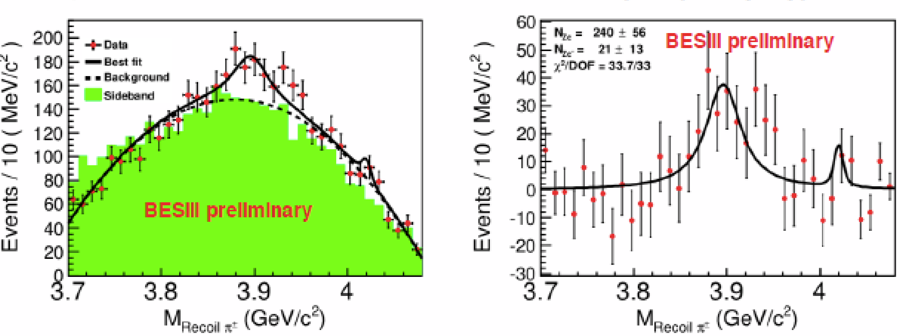
[arXiv:1903.04695]



$$\mathcal{R} = \frac{\mathcal{B}[X(3872)\rightarrow\omega J/\psi]}{\mathcal{B}[X(3872)\rightarrow\pi^+\pi^- J/\psi]} = 1.6^{+0.4}_{-0.3} \pm 0.2$$

Large Isospin violation (?)

$e^+e^- \rightarrow \pi Z_c, Z_c \rightarrow \rho\,\eta_c$

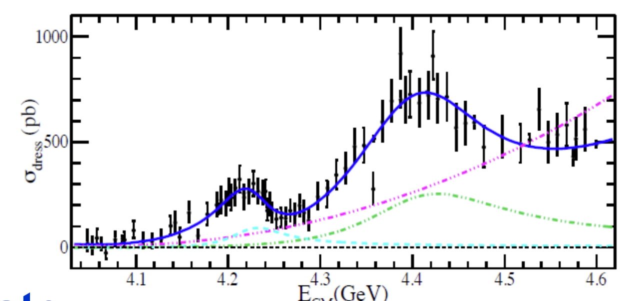


	$\sqrt{s} = 4.23$ GeV	$\sqrt{s} = 4.26$ GeV	$\sqrt{s} = 4.36$ GeV	Tetra-quarks-I	Tetra-quarks-II	Molecule
$Z_c(3900)$	2.1 ± 0.8	< 6.4	...	230^{+330}_{-140}	$0.27^{+0.40}_{-0.17}$	$0.046^{+0.025}_{-0.017}$
$Z_c(4020)$	< 1.9	< 1.2	< 1.0	$6.6^{+56.8}_{-5.8}$		$0.010^{+0.006}_{-0.004}$

Neutral partner of $Z_c(3900)^+$

[PRL122, 102002 (2019)]

$$e^+ e^- \rightarrow \pi^+ D^0 D^{*-} + c.c.$$



First observation of Y(4220) with an open charm final state.

M_1 = (4228.6 ± 4.1 ± 6.3) MeV/c²
Γ_1 = (77.0 ± 6.8 ± 6.3) MeV

Roberta Cardinale

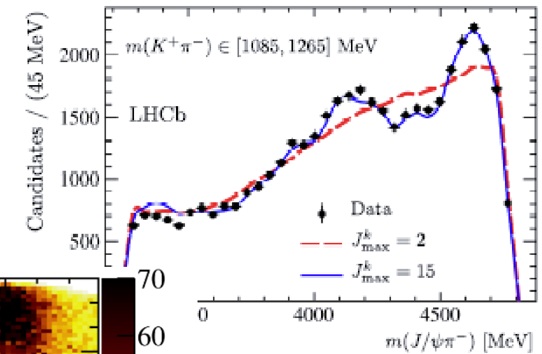
XYZ_c

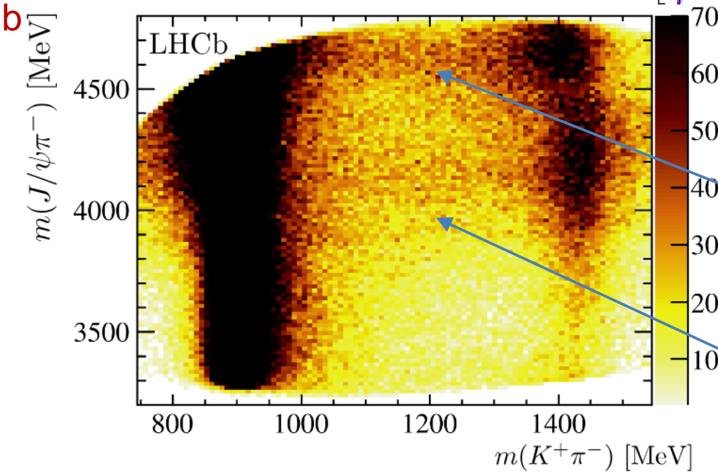
LHCb confirmed indirect existence of $Z_c(4200)^+ \to J/\psi\pi^+$ (by Belle).
They did very interesting model independent 4D analysis.

- Data divided in m(K+π-) bins,
- Check 3D angular distribution to check if described b conventional K* states (no need of exotic).
- Require only knowledge of highest spin J_{max}.

Reject only K_J^* hypothesis by 10σ

Amplitude analysis needed !

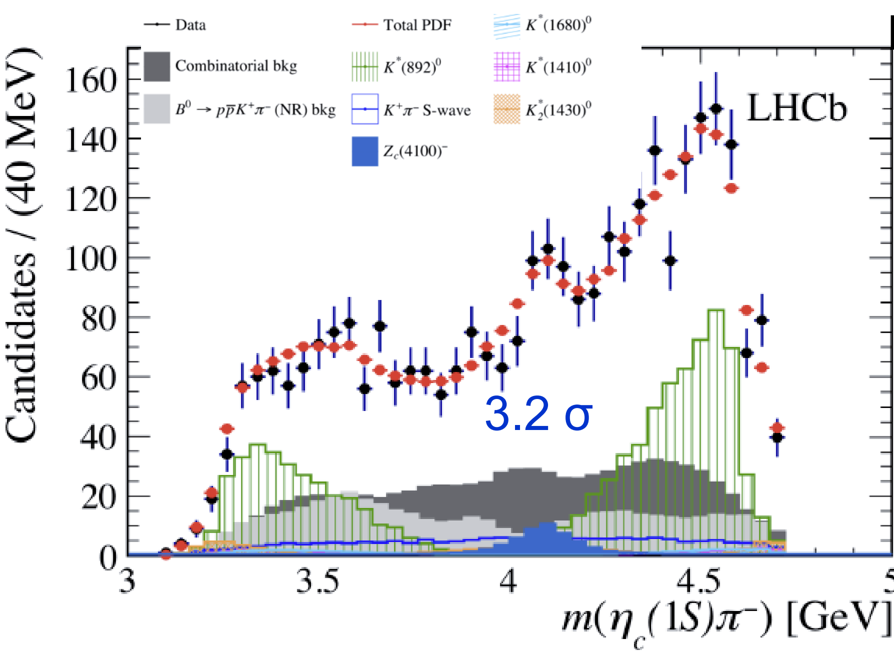




Second structure at 4600 ?

$Z_c(4200)^+$

$B^0 \to (\eta_c(1S)\pi^-)K^+$



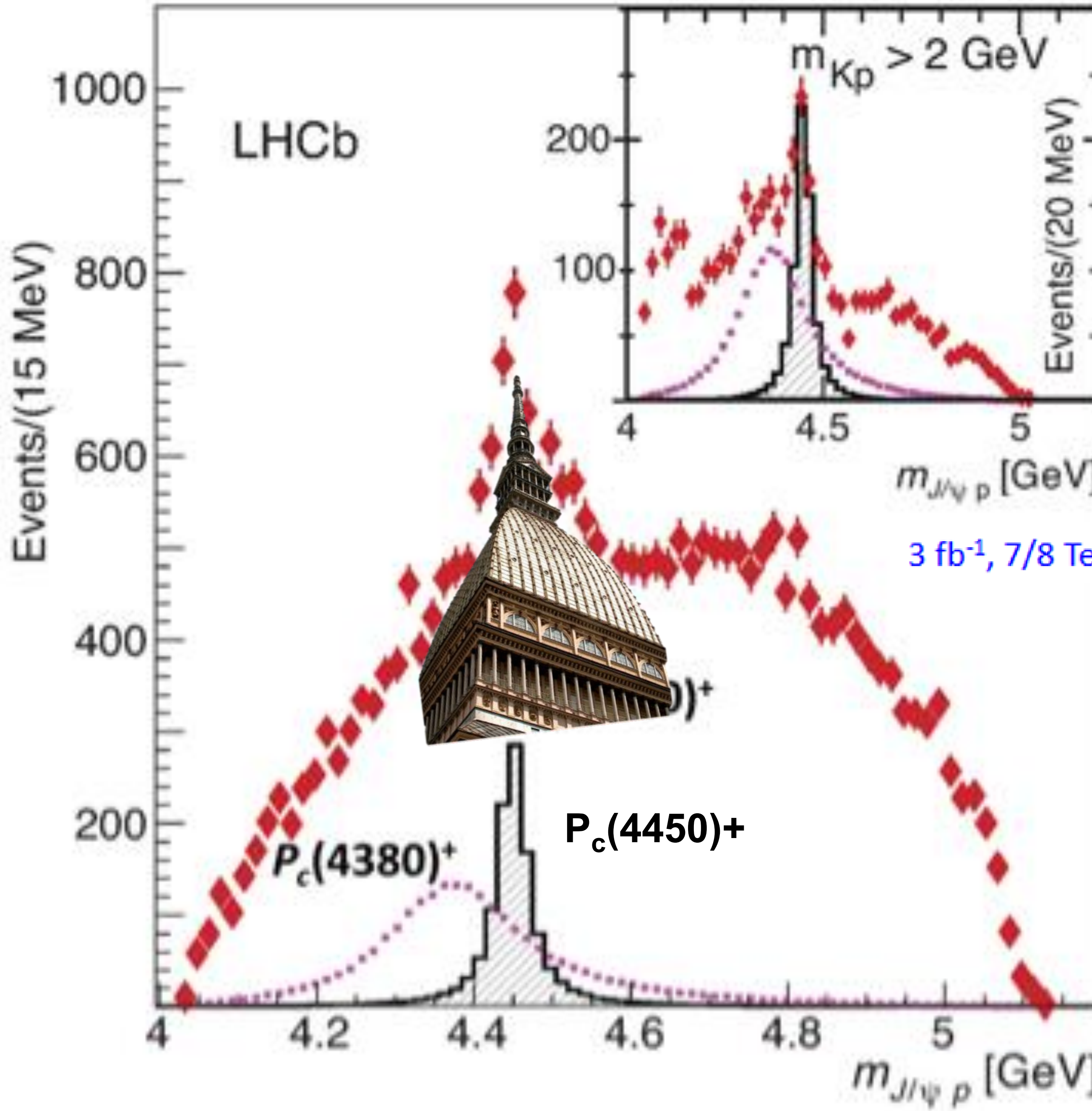
Dalitz Analysis done

Resonance	Mass [MeV]	Width [MeV]	J^P	Model
$K^*(892)^0$	895.55 ± 0.20	47.3 ± 0.5	1^-	RBW
$K^*(1410)^0$	1414 ± 15	232 ± 21	1^-	RBW
$K_0^*(1430)^0$	1425 ± 50	270 ± 80	0^+	LASS
$K_2^*(1430)^0$	1432.4 ± 1.3	109 ± 5	2^+	RBW
$K^*(1680)^0$	1717 ± 27	322 ± 110	1^-	RBW
$K_0^*(1950)^0$	1945 ± 22	201 ± 90	0^+	RBW

$$m_{Z_c^-} = 4096 \pm 20^{+18}_{-22}\ \text{MeV}$$
$$\Gamma_{Z_c^-} = 152 \pm 58^{+60}_{-35}\ \text{MeV}$$

The Pentaquark

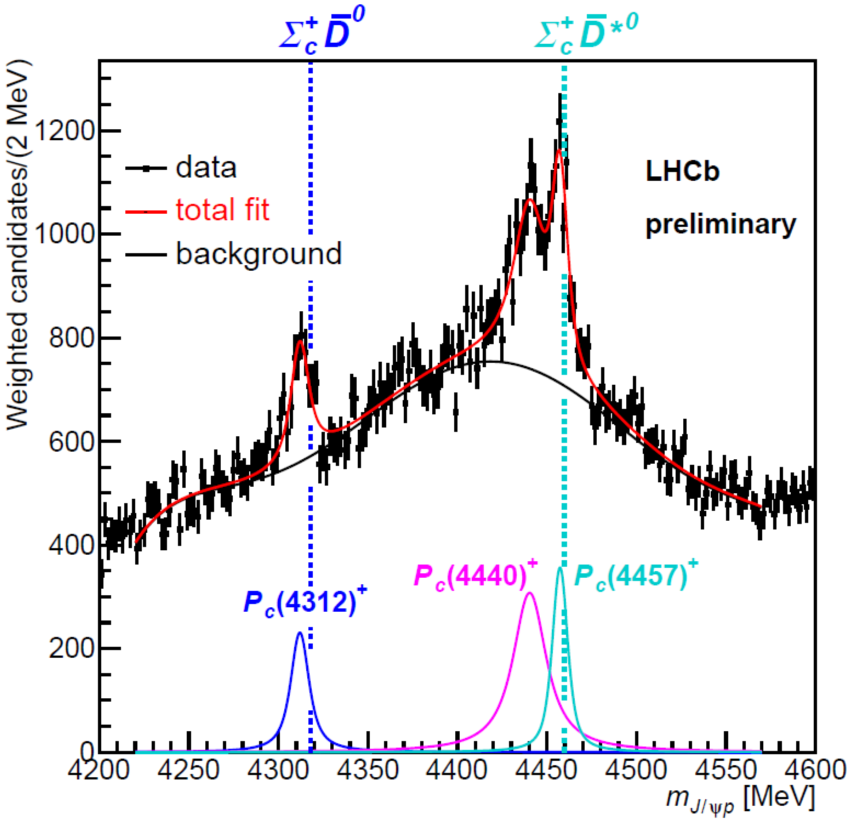
First pentaquark was found by LHCb around 4 years ago.



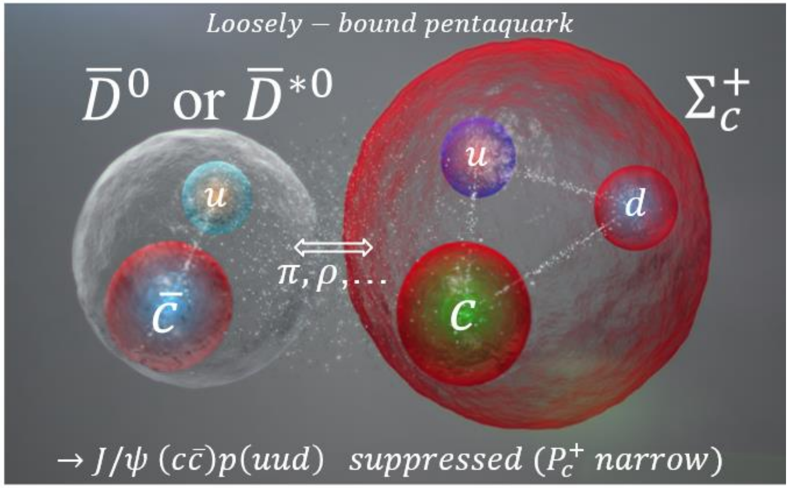
3 fb-1, 7/8 TeV [PRL 115 (2015) 072001]

Roberta Cardinale

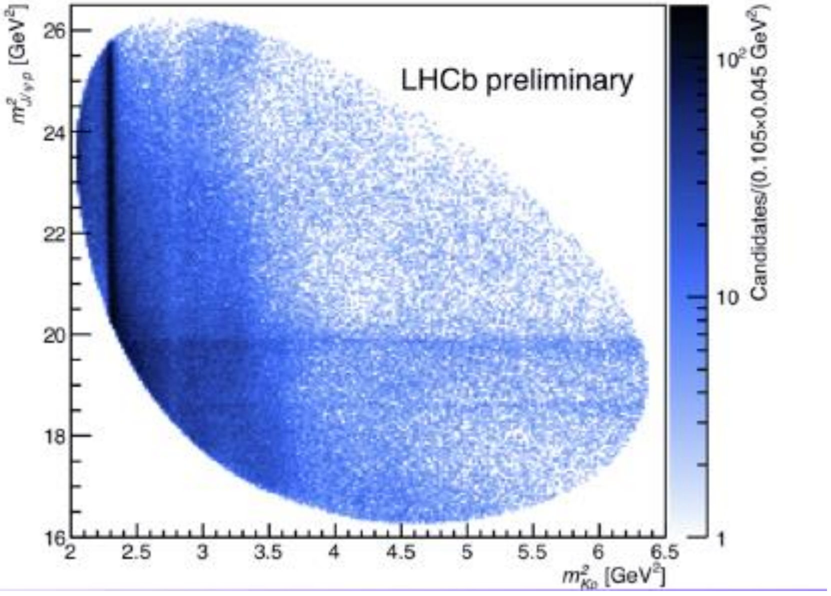
Pentaquarks (?)



Near threshold masses and narrow widths favour "molecular" pentaquarks



Tomasz Skwarnicki



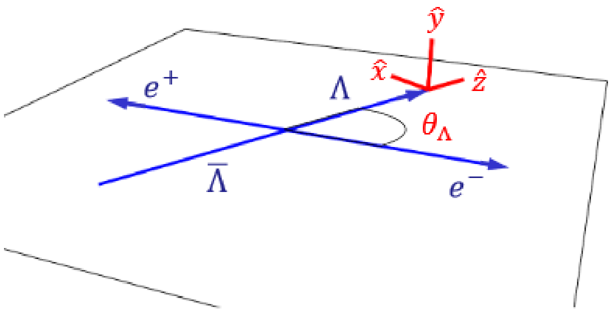
Need to measure J^Ps to confirm molecular hypothesis.
Should have isospin partners !

However, still the tightly bound-pentaquark picture can't be ruled out

Heavy Flavor Production

First observation of spin polarization of $\Lambda/\bar{\Lambda}$

Kiyoshi Tanida



Cross section

Spin Correlation

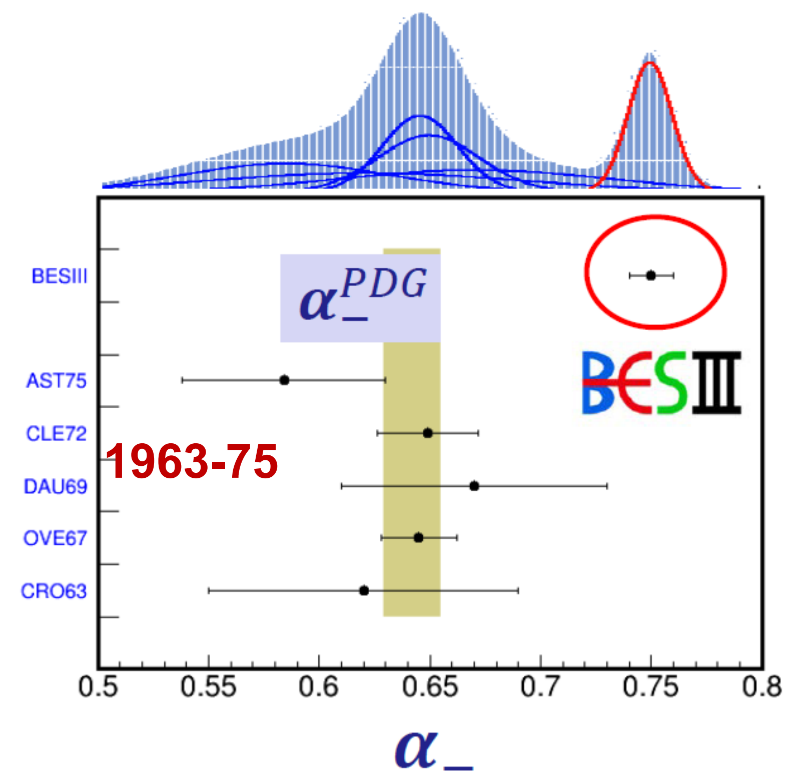
$$
\begin{aligned}
\mathcal{W}(\boldsymbol{\xi};\alpha_\psi,\Delta\Phi,\alpha_-,\alpha_+) =& 1+\alpha_\psi\cos^2\theta_\Lambda \\
&+\alpha_-\alpha_+\left[\sin^2\theta_\Lambda\left(n_{1,x}n_{2,x}-\alpha_\psi n_{1,y}n_{2,y}\right)+\left(\cos^2\theta_\Lambda+\alpha_\psi\right)n_{1,z}n_{2,z}\right] \\
&+\alpha_-\alpha_+\sqrt{1-\alpha_\psi{}^2}\cos(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda\left(n_{1,x}n_{2,z}+n_{1,z}n_{2,x}\right) \\
&+\sqrt{1-\alpha_\psi{}^2}\sin(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda\left(\alpha_-n_{1,y}+\alpha_+n_{2,y}\right),
\end{aligned}
$$

Polarization

Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [25]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [27]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [27]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [27]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

α_- and α_+ are decay asymmetries

$\Lambda \to p\pi^-$: $\alpha_-=0.750\pm0.009\pm0.004$



As one uses Λ information, other values are also affected e.g.:

$$\alpha(\Omega \to \Lambda K), \alpha(\Xi \to \Lambda K), \alpha(\Lambda_c \to \Lambda K)$$

Need for reinterpretation of all Λ polarization measurements !

17% larger than α_-^{PDG}

Quarkonium with Heavy Ions

Heavy-favour quarks are good probes for studying QGP

Quarkonium : binding energies of order of hundred MeV.

Interactions with QGP can overcome this threshold breaking the quarkonium system

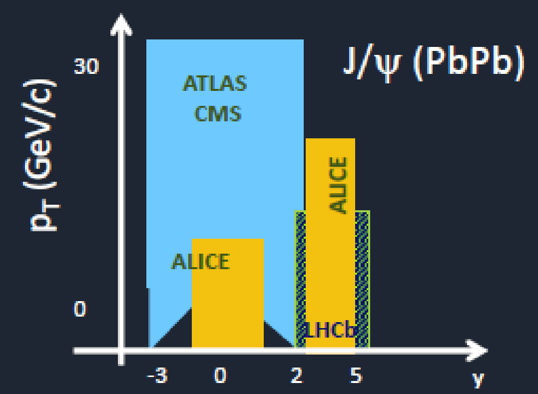
Heavy-ions program usually includes:

- **pp** – vacuum reference + pp physics
- **pA** – cold/(hot?) nuclear matter effects
- **AA** – hot matter effects

RHIC: various collision systems are explored, scanning in energy

Exp.	System	$\sqrt{s_{NN}}$ (TeV)
PHENIX STAR	AuAu, CuCu, CuAu, UU	0.039 – 0.2
	p-A, d-Au, p-Al, ^{3}He-Al	0.2
	pp	0.2-0.5

LHC: results are complementary, due to different kinematic coverages



Exp.	System	$\sqrt{s_{NN}}$ (TeV)
ALICE ATLAS CMS LHCb (*)	PbPb, XeXe	2.76, 5.02, 5.44
	pPb	5.02, 8.16
	pp	2.76, 5, 7, 8, 13

(*) only recently joined the study of AA collisions

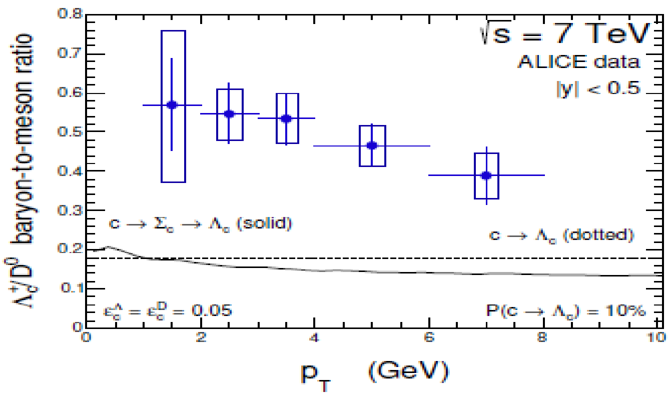
Roberta Arnaldi   XXVII DIS Conference   April 10th 2019   4

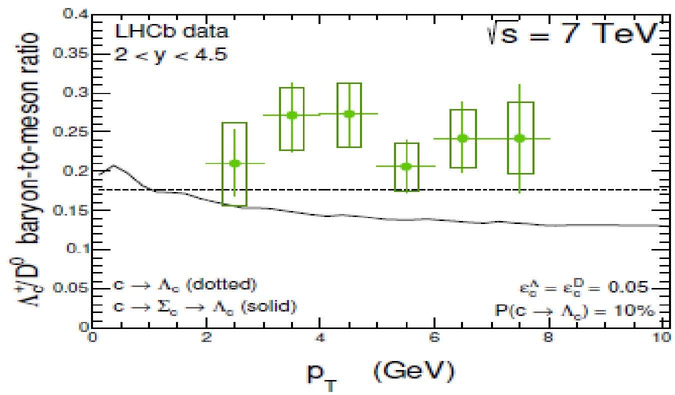
Main observables are :

- ❖ Nuclear modification factor R_{AA}, $R_{AA} \neq 1$ suggest presence of hot/cold matter effect.
- ❖ Elliptic flow v_2 : Quarkonium produced through re(generation) should inherit quark flow in QGP ($v_2>0$)

Hans Dembinski, Paolo Iengo

Very nice pp results were discussed: crucial to test production and different models.





Rafal Maciula

Enhanced production of Λ_c at ALICE and LHCb

k_T-factorization: $g^* g^* \to c\bar{c}$ + KMR uPDF + Peterson FF for $c \to \Lambda$ transition

Able to describe ALICE, but can't describe ALICE and LHCb data simultaneously as well D-meson production with same parameters.

Interpretation of increase fragmentation fraction $f_c \to \Lambda_c$ needed

Hee Sok Chung

Quarkonium production and Improved Color Evaporation Model

Melih A. Ozcelik

Attempt to resolve negative cross-section with η_c

More details in backUP

Hanni Paukkunen

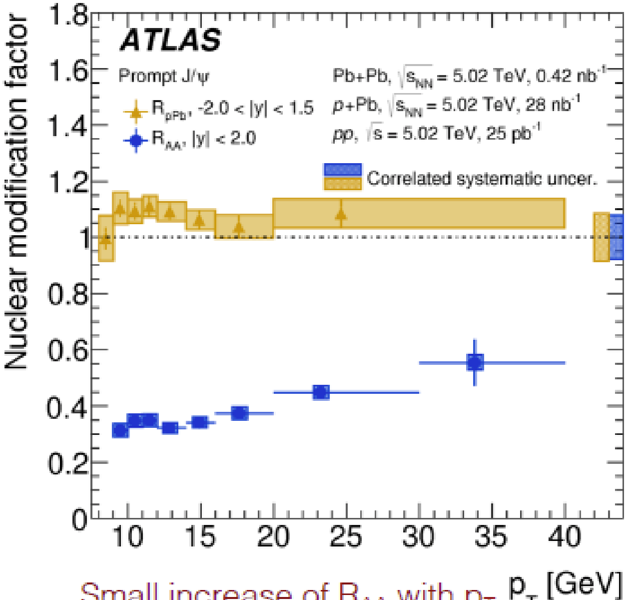
GM-VFNS scheme – SACOT-mT introduced for heavy-flavoured meson production

Not able to discuss here due to time constraint, recommend to look at their slides.

Charmonium with Heavy Ions

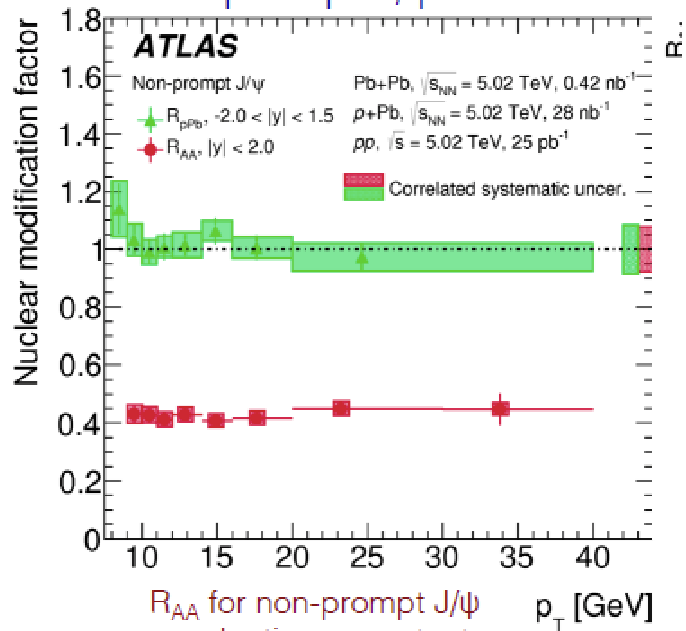
Paolo Iengo,
Roberta Arnaldi

- Prompt J/ψ

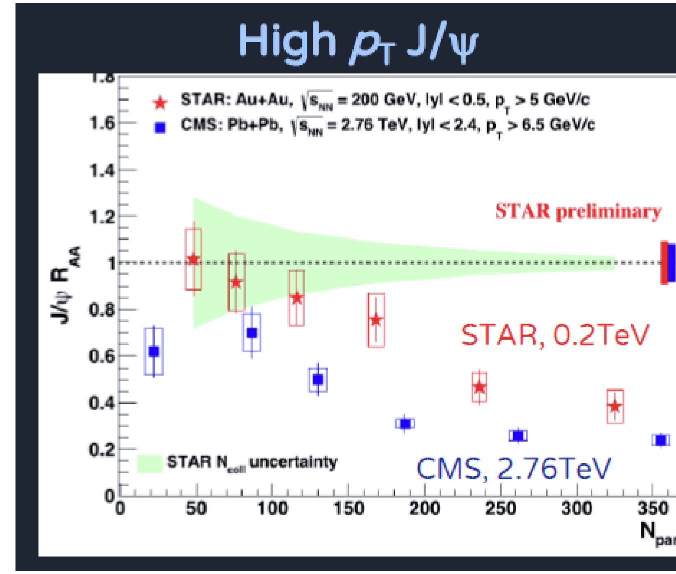


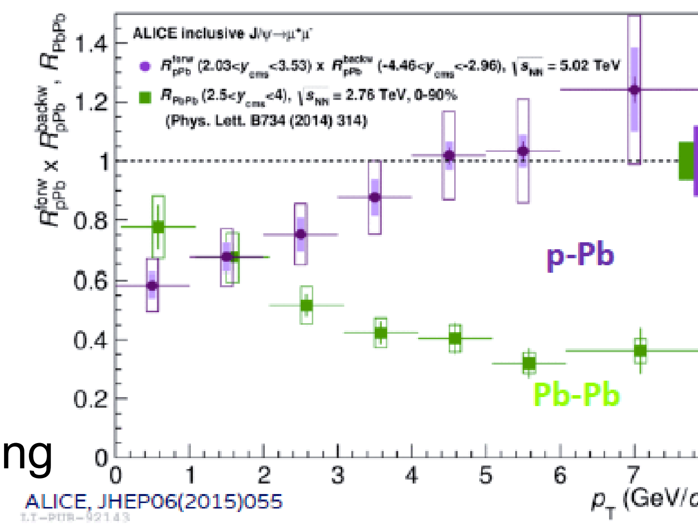
Small increase of R_{AA} with p_T in prompt J/ψ production

- Non-prompt J/ψ



R_{AA} for non-prompt J/ψ production ~constant





Cold Nuclear Matter (CNM) effects are small for prompt and non-prompt J/ψ production

Strong suppression of charmonia production in AA collisions

Suppression in AA due to CNM effects ?
Alice shows result assuming $R_{AA} = R_{pA} \times R_{Ap}$ (as for shadowing dominance)

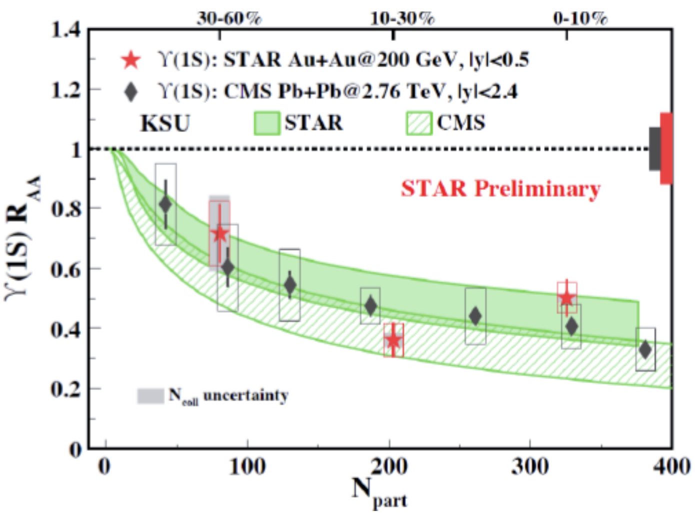
Comparison of pA and AA results indicates that CNM effects can not account for the observed R_{AA} at high p_T

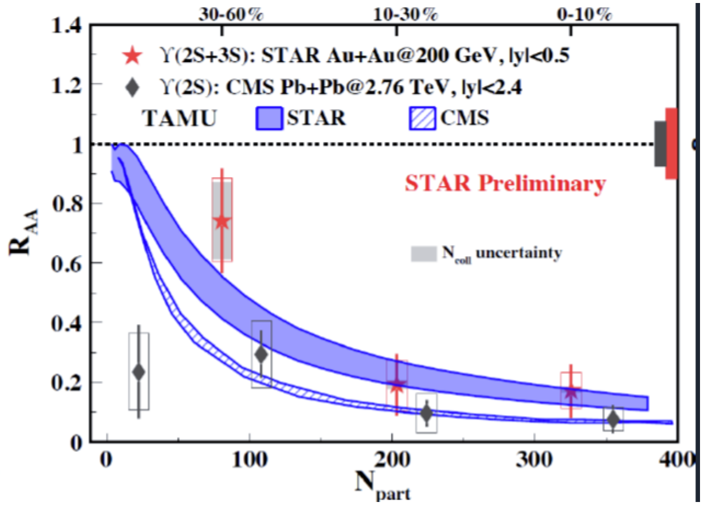
Ψ(2S) suppression is stronger than the J/ψ at high pT by CMS (as expected in sequential suppression scenario)

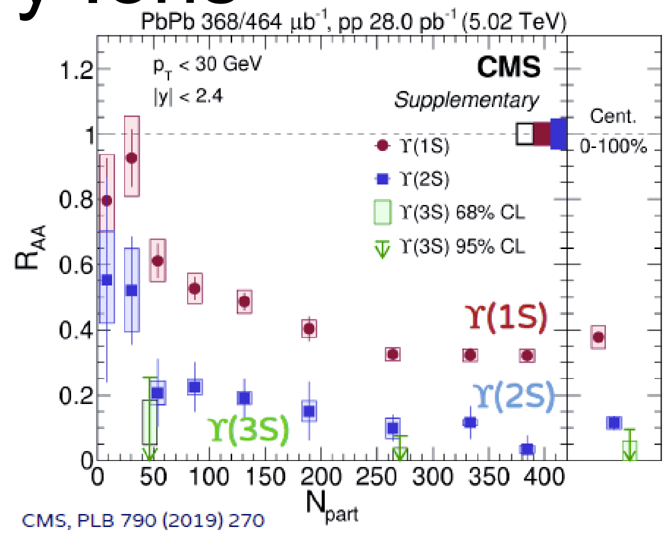
Similar results in backUP

Roberta Arnaldi
Hans Dembinski

Bottomonium with Heavy Ions



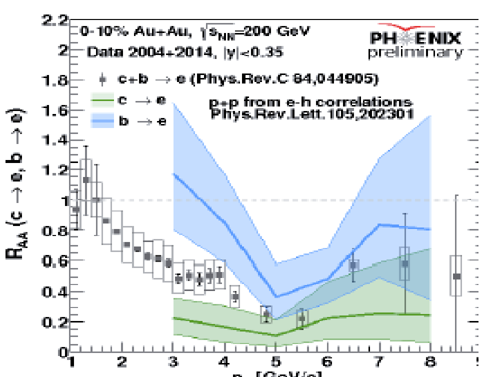


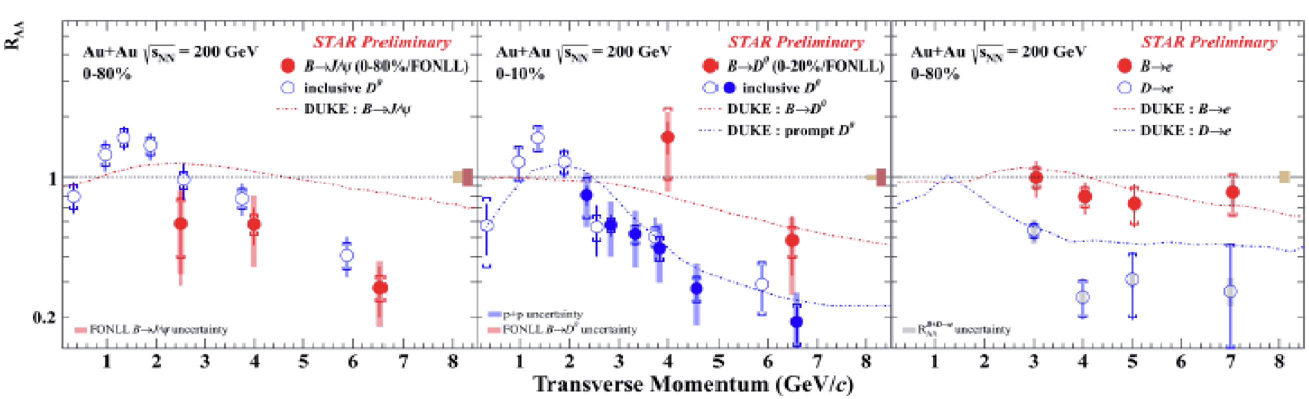


Lower R_{AA} value for excited states compatible with sequential suppression
Excited states suppression stronger at LHC (?)

LHCb also saw stronger suppression for Y(2S) at low pT
Enhanced suppression of $\Upsilon(3S)$ in pPb compare to pp at negative rapidity

Similar results were seen for open charm/beauty **Petr Chaloupka**



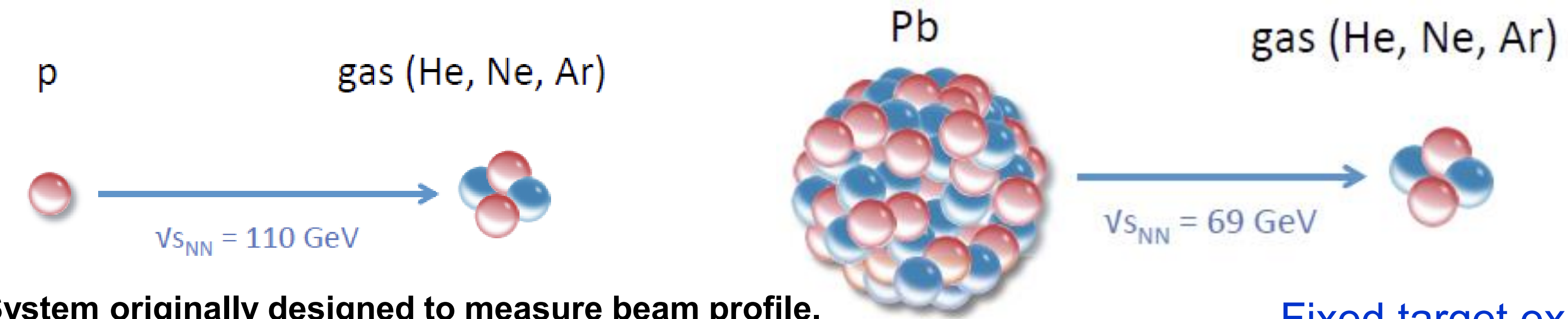


Consistent with mass hierarchy of energy loss

More in backUP

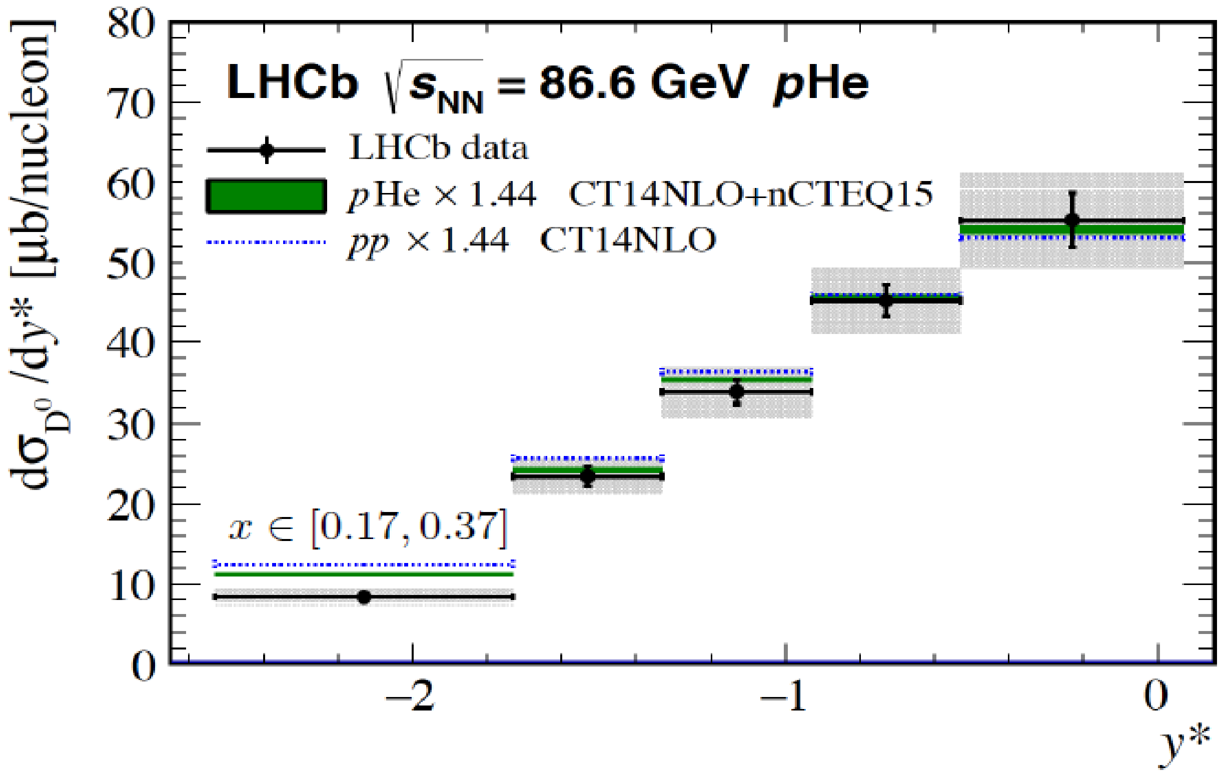
Hans Dembinski

Innovative (p, Gas) collisions



System originally designed to measure beam profile.
Inject He,Ne, Ar into VELO at ~ 2 x 10^-7 mbar.

Fixed target experiment !



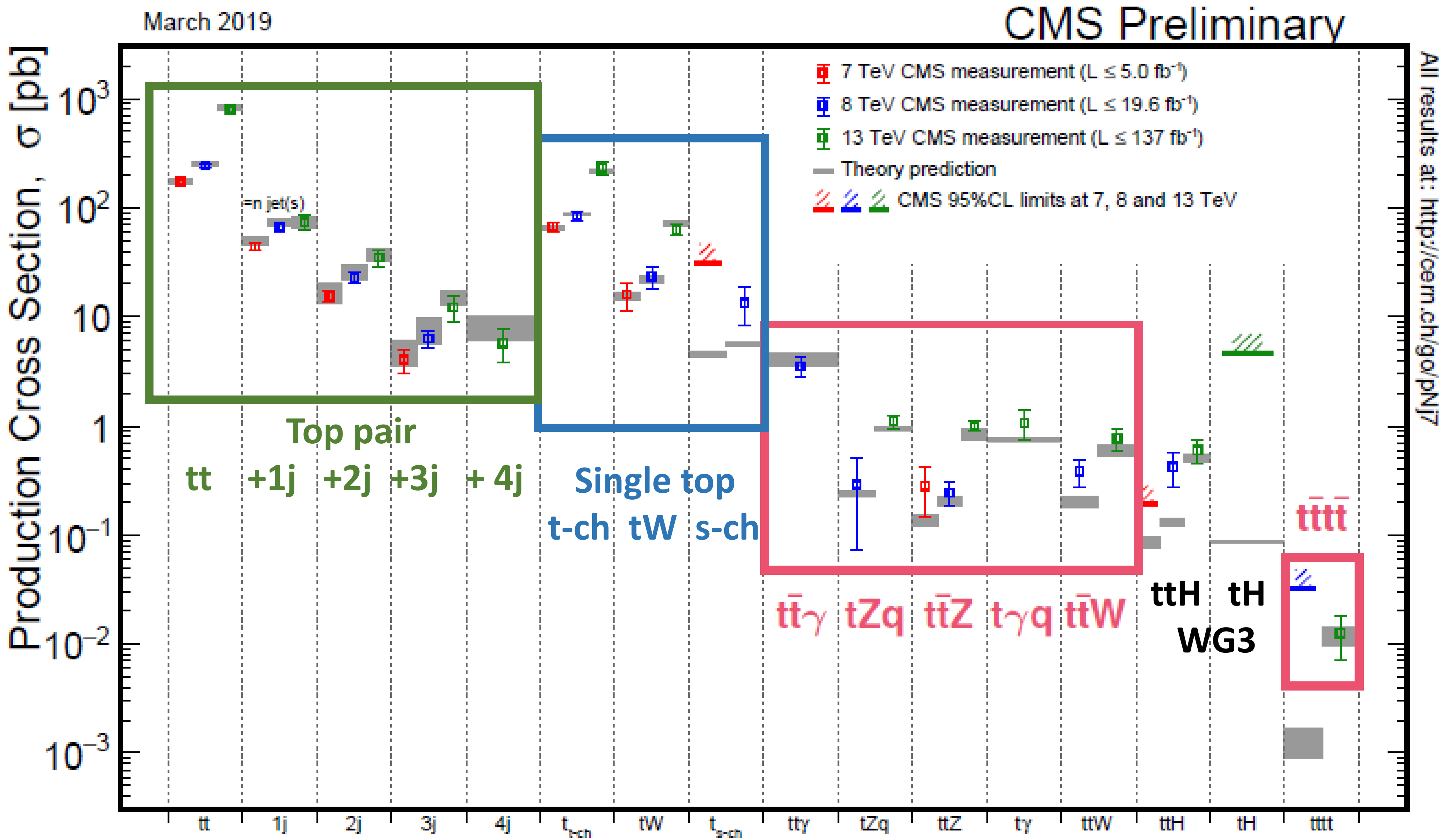
- Substantial intrinstic valence-like charm content of nucleon expected in some theories.
- Would be visible in most backward bin of pHe data.
- No evidence of substantial instrinsic charm content of nucleon observed (?).
- Might be interesting to study other variables (?)

Top production and properties

- LHC is a top factory:
  - $t\bar{t}$ produced at a rate of 8 Hz at the L with L=10^{34} $cm^{-2}s^{-1}$ and $\sqrt{s}$=13 TeV
- Heaviest particle means it has a special place within the SM with many connections to different areas
  - Higgs/electroweak, BSM and QCD
  - $\Lambda_{QCD} << \Gamma_t << m_t$
- Two broad areas to cover
  - single, pair and associated production
    - Talks by Poncelet, Grancagnolo, Knolle and Geiser
  - properties: mass, width, spin correlations, couplings
    - Talks by Schulze, Ravina and Jezo

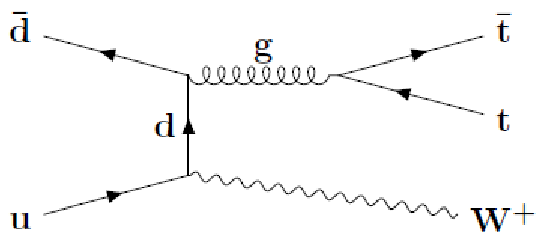
Top cross sections measured at LHC
Knolle, Geiser and Grancagnolo

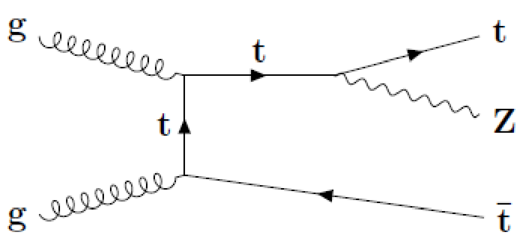
NB: measurements have been used for PDF constraints, see talk Beneke in WG1



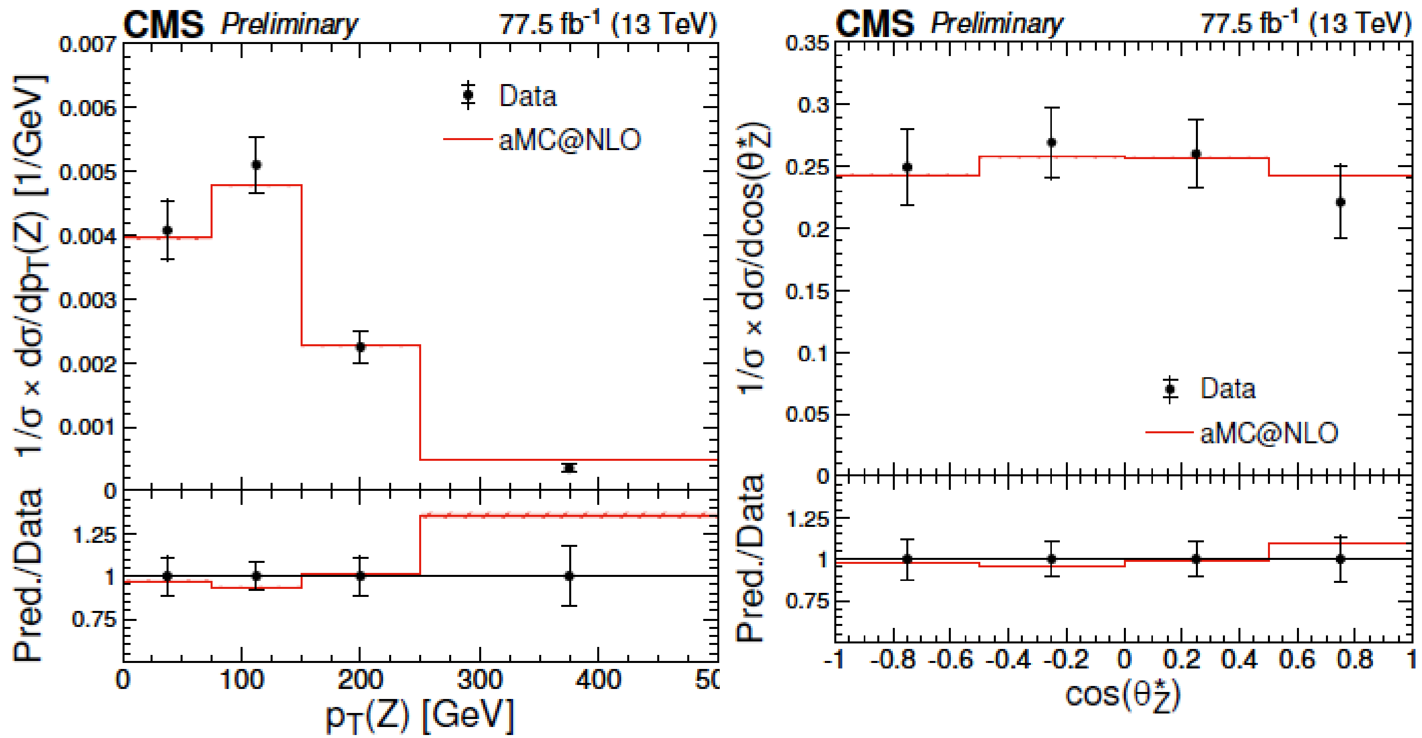
ttZ and ttW production

Knolle, Schultze





- Sensitive to $Z^0 \to t\bar{t}$ coupling and background to final states with top and leptons *i.e.* ttH

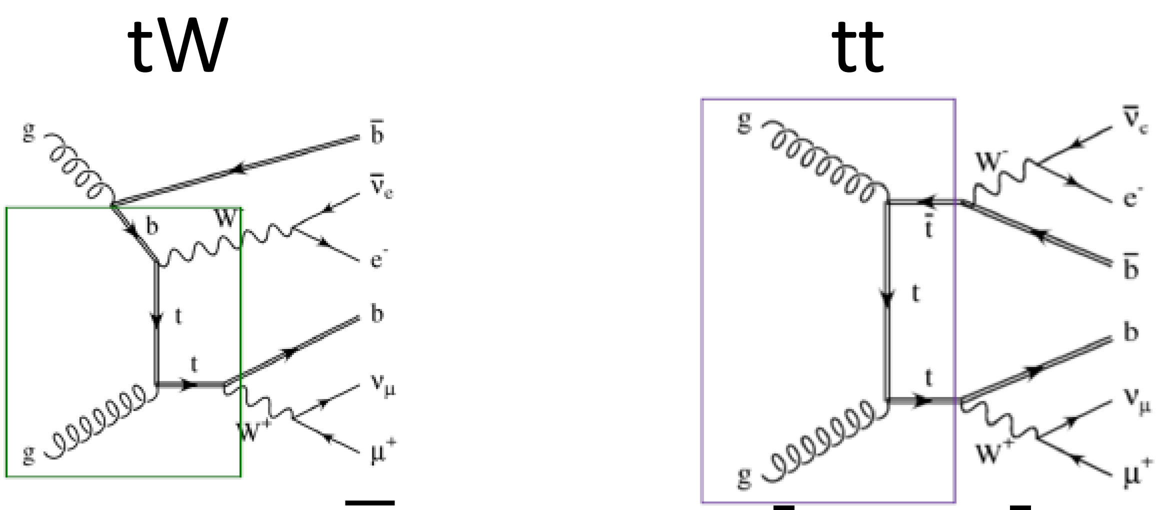


CMS-PAS-TOP-18-009

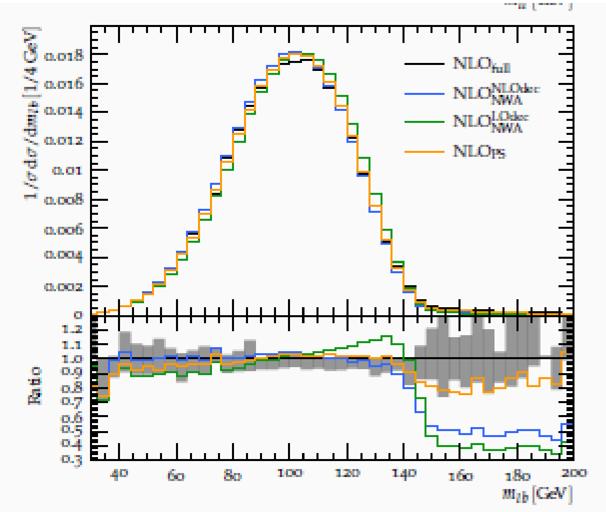
- Differential ttZ distributions
- Interpretation in terms of SM effective field theory (EFT)
  - $L = L_{SM} + (c/\Lambda^2)\, O_{dim\text{-}6} + \ldots$
  - Fit data to constrain c/Λ^2
  - Talk by B. Francois in WG3 on the interpretation
- Great potential to add many more observables i.e. ttW, tqW

Interference in associated tW production:

Geiser, Poncelet, Jezo

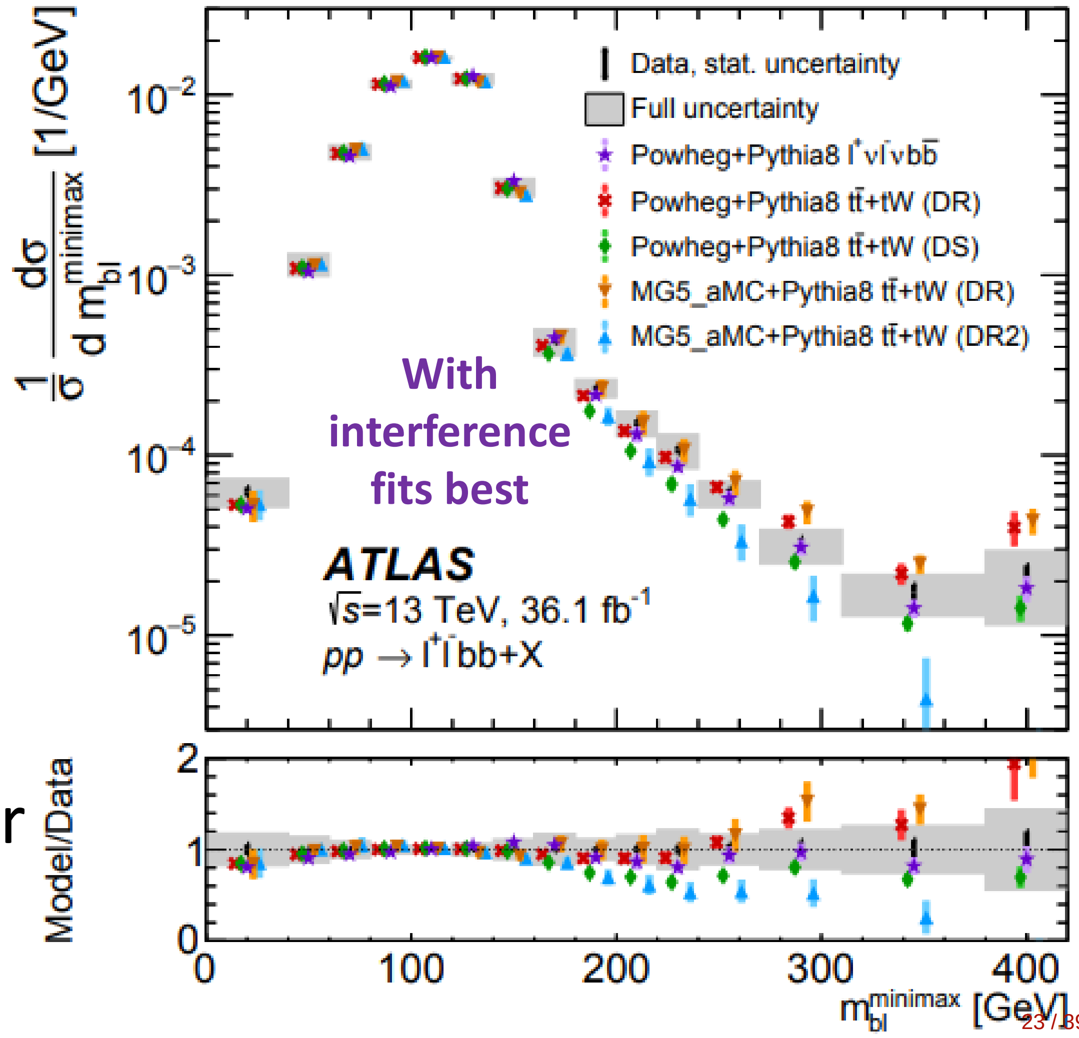


$$gg \to b\bar{b}e^{-}\bar{\nu}_e\mu^{+}\nu_\mu \; [\mathrm{bb\,4l}]$$



Related: full NLO theory without narrow width approx. for top gives better description in tails of kinematic distribution

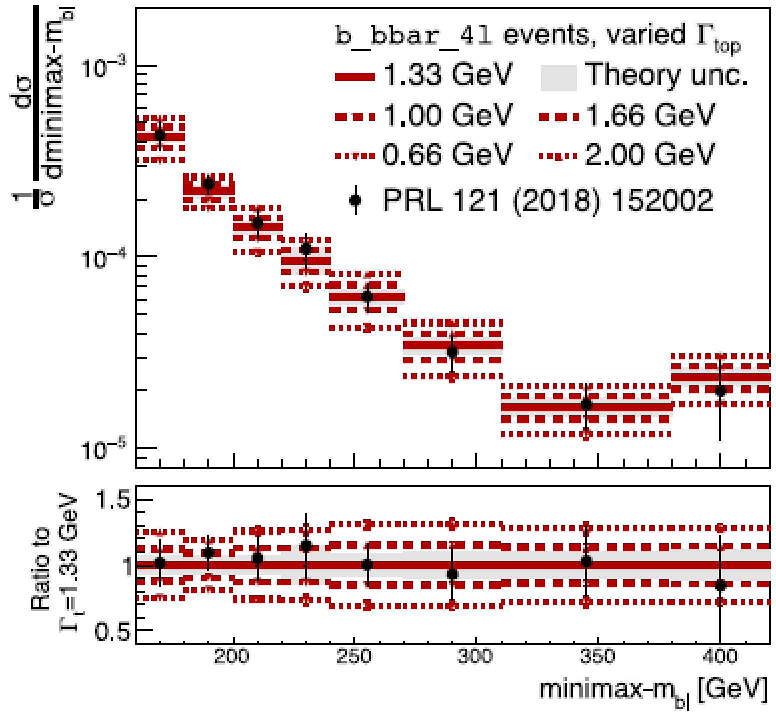
Phys. Rev. Lett. **121**, 152002 (2018)

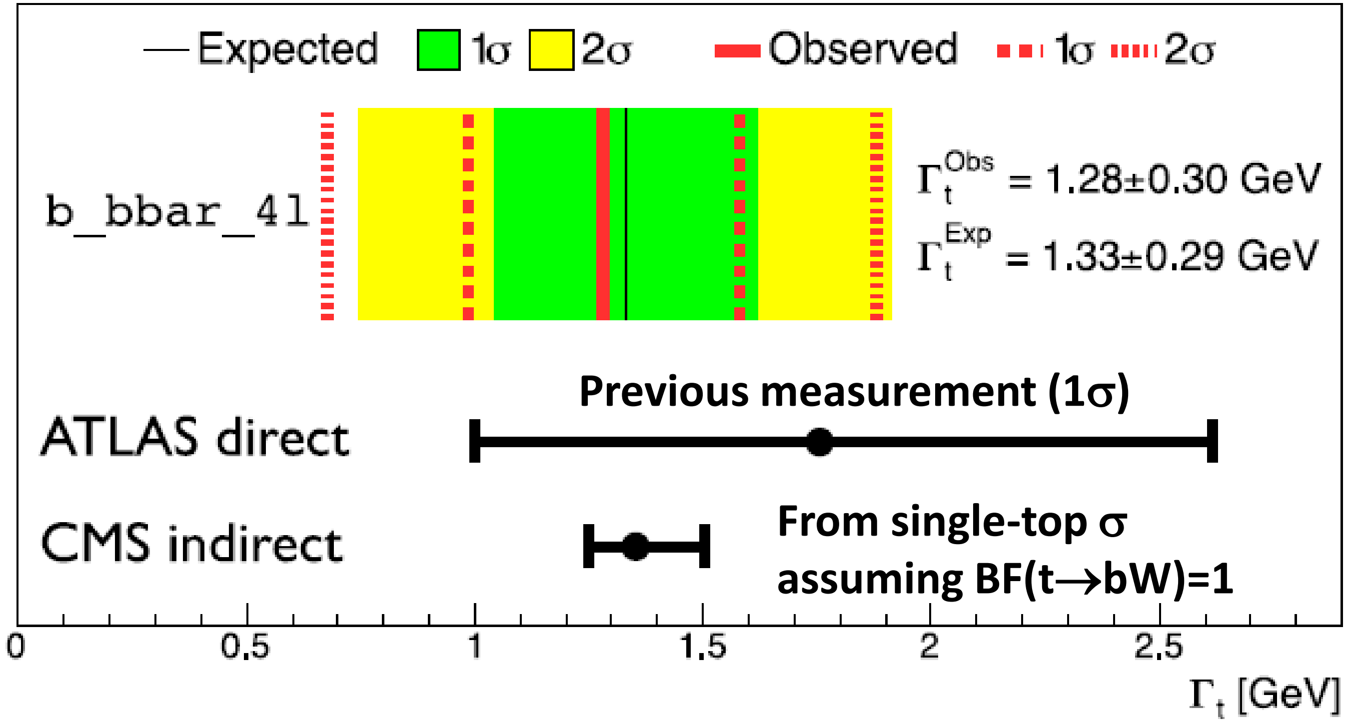


Direct measurement of Γ_t

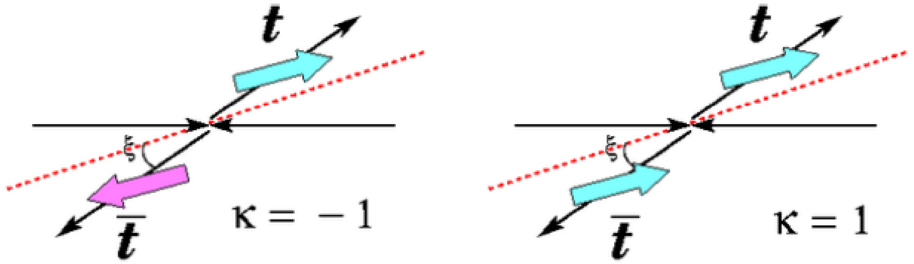
Jezo

- Turn the full bb4l calculation around to find sensitivity to Γ_t in the region sensitive to interference – arXiv:1903.10519

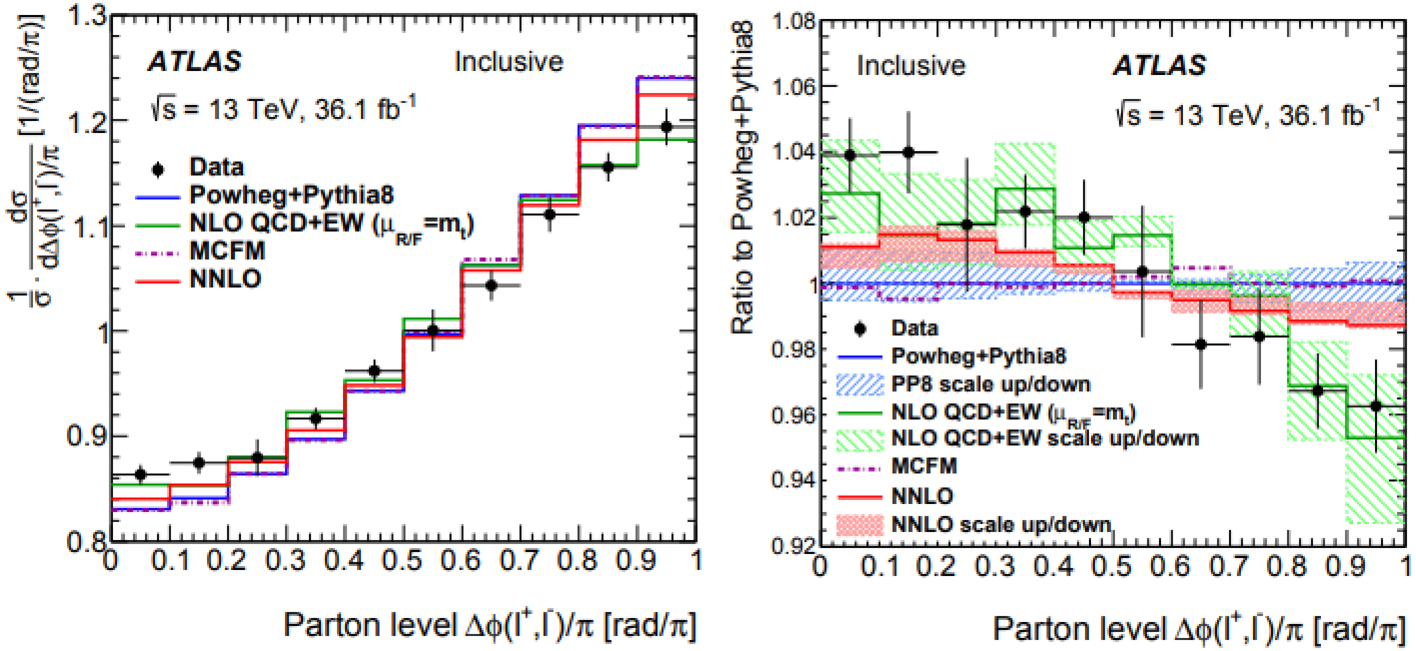




Spin correlations:
Ravina, Poncelet, Schultze



$$C_{\rm LO}^{\rm SM} = \frac{\#(\uparrow\uparrow + \downarrow\downarrow) - \#(\uparrow\downarrow + \downarrow\uparrow)}{\#\text{total}} = \begin{cases} -46\% \text{ at Tevatron,} \\ +31\% \text{ at LHC.} \end{cases}$$

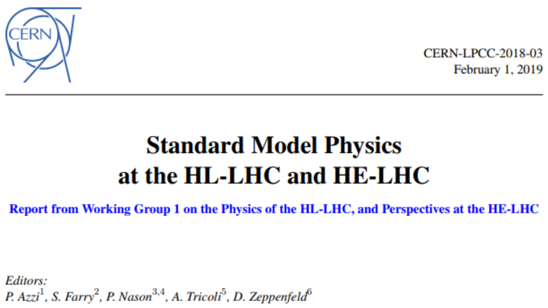


arXiv:1903.07570 [hep-ex]

- Spin correlation preserved by the two leptons
- Azimuthal separation $\Delta\phi$ is the sensitive observable
- Unfolding performed to full phase space and the parton level
- Generators do not match data!
- Improved agreement with NNLO calculation
- NLO with $\mu_F = \mu_R = m_t$ for QCD and EW (Bernreuther, Heisler, Zi) agrees but with large scale uncertainties – more work to see if this a BSM effect

Top and CKM

Schultze


CERN-LPCC-2018-03
February 1, 2019

Standard Model Physics
at the HL-LHC and HE-LHC

Report from Working Group 1 on the Physics of the HL-LHC, and Perspectives at the HE-LHC

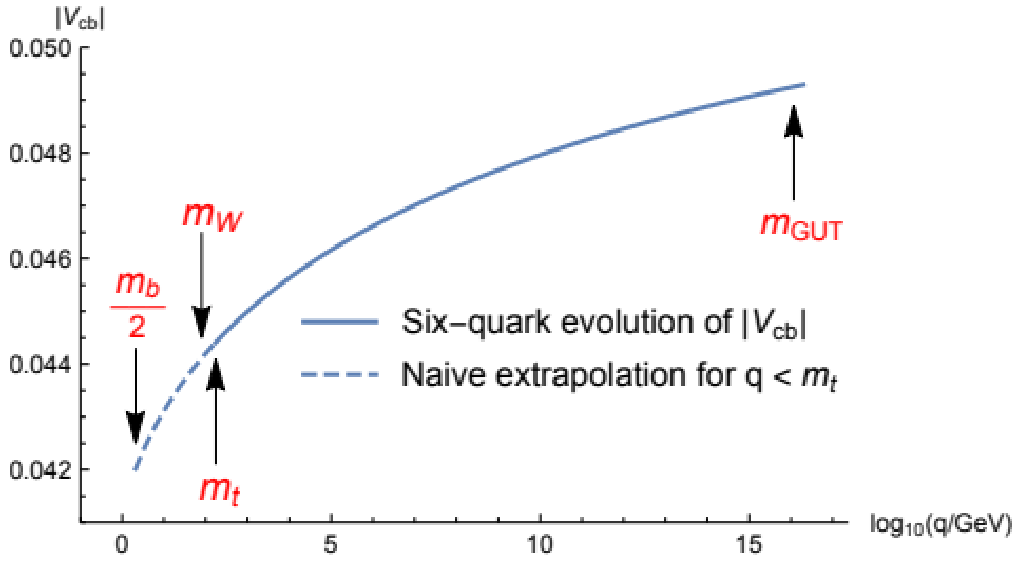
Editors:
P. Azzi[1], S. Farry[2], P. Nason[3,4], A. Tricoli[5], D. Zeppenfeld[6]

- $V_{cb}=(42.2\pm0.8)\times10^{-3}$ [PDG] – 2% relative and systematically limited
- Also only at the $m_b/2$ scale
- New method at EW scale with $t\bar{t}$

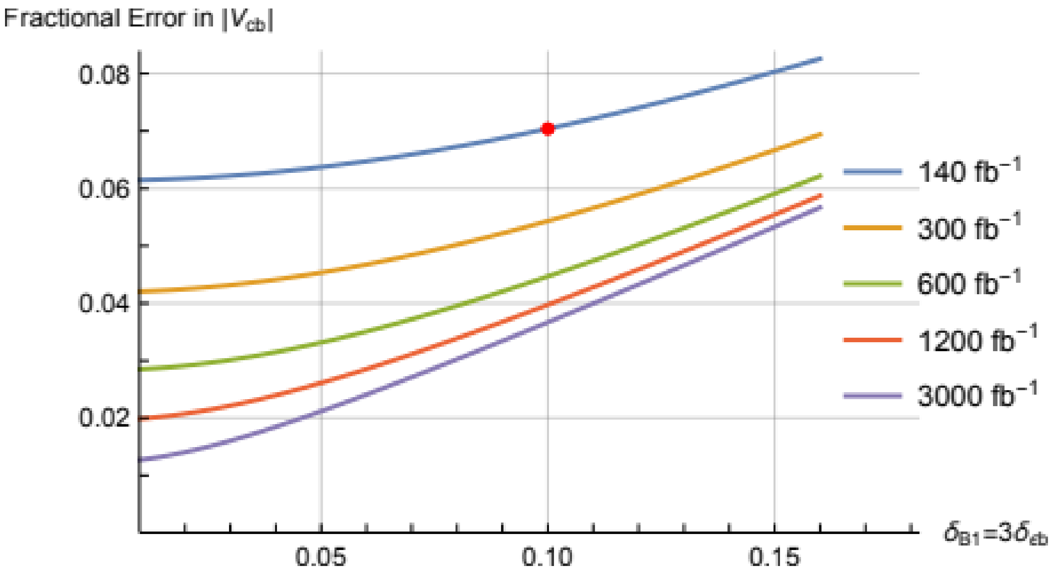
$$\bar{t} \to \bar{b}W^- \to \bar{b}l^-\bar{\nu}_l \qquad t \to bW^+ \to b\bar{q}c$$

fraction with q=b $\propto |V_{cb}|^2$

- Lepton + 3 b jets + 1 c jet
- HL-LHC potential to measure to 2% if systematics can be controlled



Harrison and Vladimirov JHEP (2019) 2019: 191



Assumption about light → b jet mis-ID and b-jet efficiency

Flavor with Beauty and Charm

CPV

M. Bartolini

B-Anomalies

J. Fuentes-Martín
A. Gioventú
F. Saturnino

B-meson LCDAs

Yao Ji

Belle-II

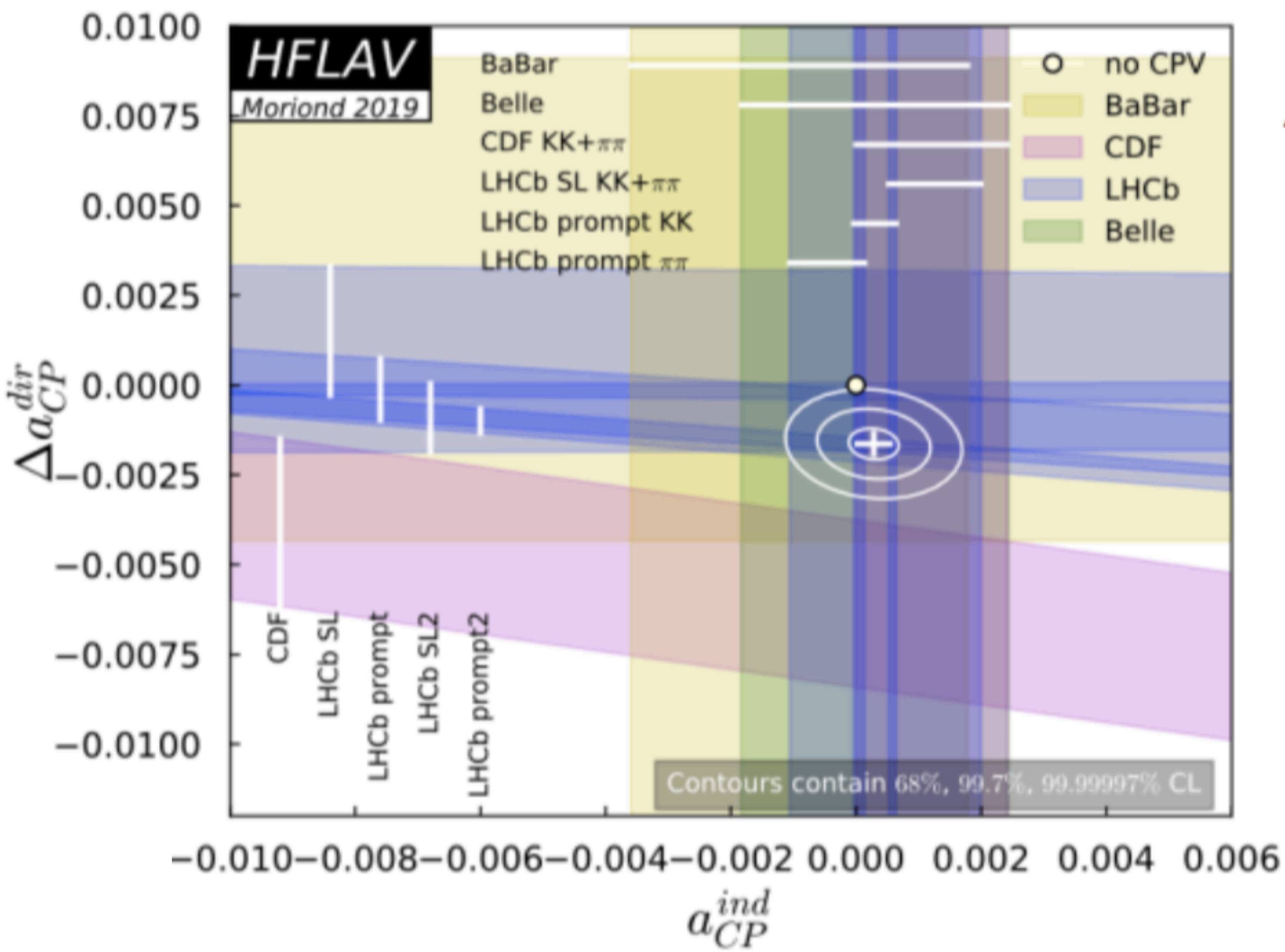
A. Ishikawa

Charming CPV

M. Bartolini

- Recent observation of CPV: $\Delta A_{CP} \equiv A_{CP}(D \to K^+K^-) - A_{CP}(D \to \pi^+\pi^-)$

LHCB PAPER-2019-006 arXiv:1903.08726



$$\Delta A_{CP} = \Delta a_{CP}^{dir}\left(1 + \frac{\langle \bar{t} \rangle}{\tau(D^0)} y_{CP}\right) + \frac{\Delta \langle t \rangle}{\tau(D^0)} a_{CP}^{ind}$$

2019: $\Delta a_{CP}^{dir} = (-15.6 \pm 2.9) \times 10^{-4}$

New WA: $\Delta a_{CP}^{dir} = (-16.4 \pm 2.8) \times 10^{-4}$

Theory? $\Delta a_{CP}^{dir} = 0.020 \pm 0.003\%$

Khodjamirian, Petrov 2017

- CPV in other modes

arXiv:1903.01150

$$\mathcal{A}(D_s^+ \to K_S^0 \pi^+) = (1.3 \pm 1.9(stat) \pm 0.5(syst)) \times 10^{-3}$$

$$\mathcal{A}(D^+ \to K_S^0 K^+) = (-0.09 \pm 0.65(stat) \pm 0.48(syst)) \times 10^{-3}$$

$$\mathcal{A}(D^+ \to \phi \pi^+) = (0.05 \pm 0.42(stat) \pm 0.29(syst)) \times 10^{-3}$$

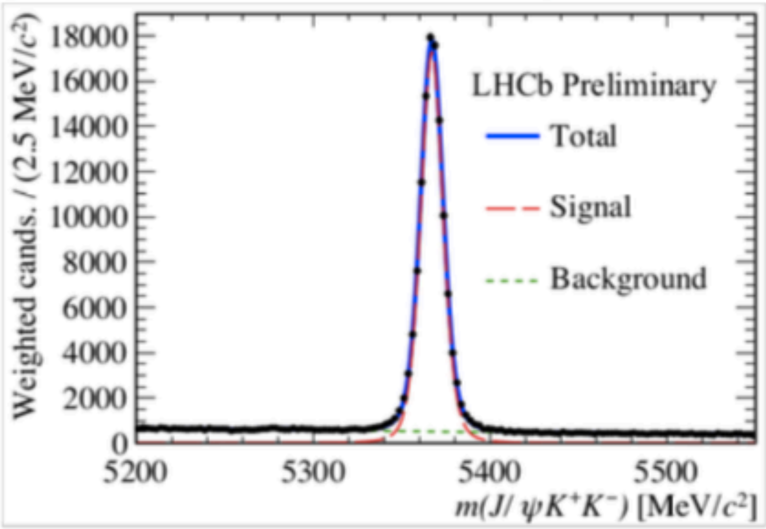
- **Most precise determination of these quantities to date!**
- No evidence for CP violation is found

CPV in Bs

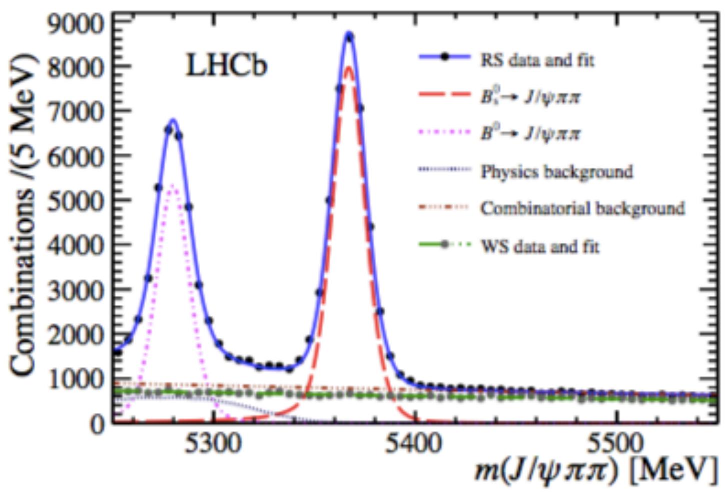
M. Bartolini

- Multidimensional fit to $J/\psi K^+K^-,\ J/\psi\pi^+\pi^-$

$B_s^0 \to J/\psi K^+K^-$
[LHCB-PAPER-2019-013]

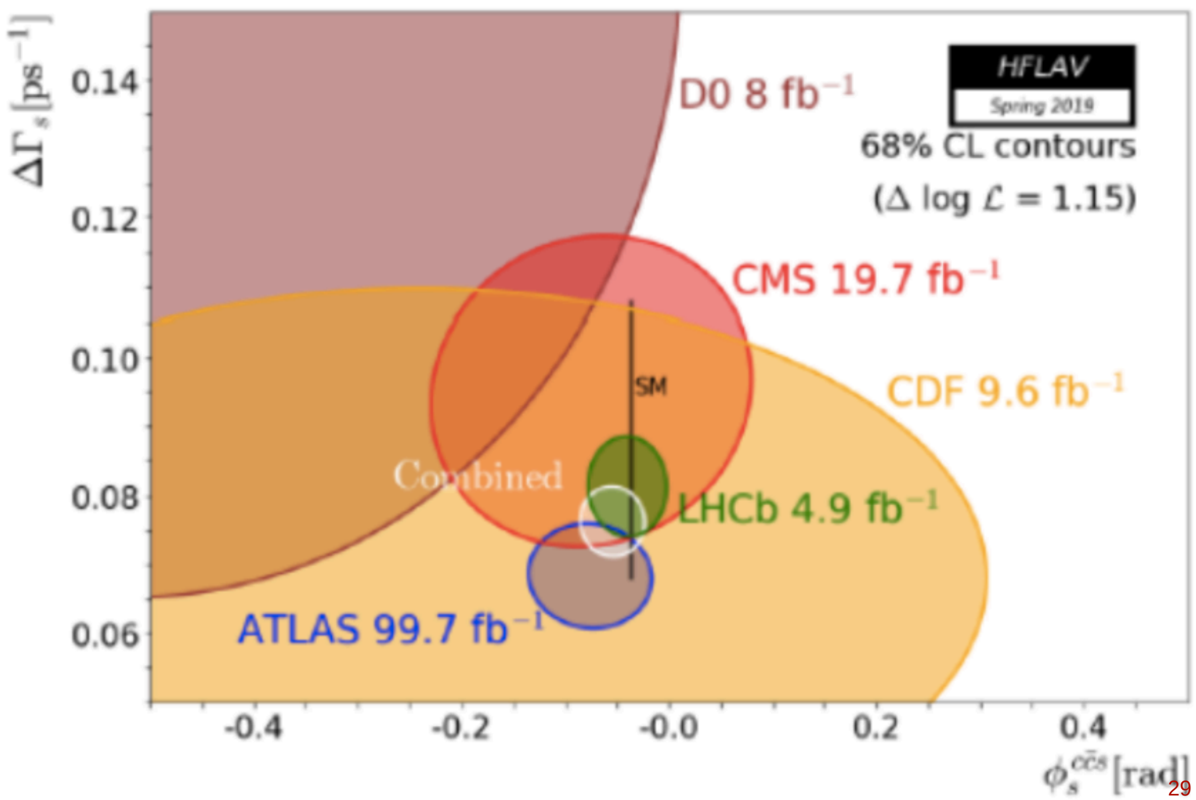


$B_s^0 \to J/\psi\pi^+\pi^-$
[arXiv:1903.05530, Submitted to JHEP]



- Combination of LHCb Run1 + Run2

Preliminary



$$\phi_s = -0.040 \pm 0.025[rad]$$

$$\Delta\Gamma_s = 0.0813 \pm 0.0048[ps^{-1}]$$

Preliminary

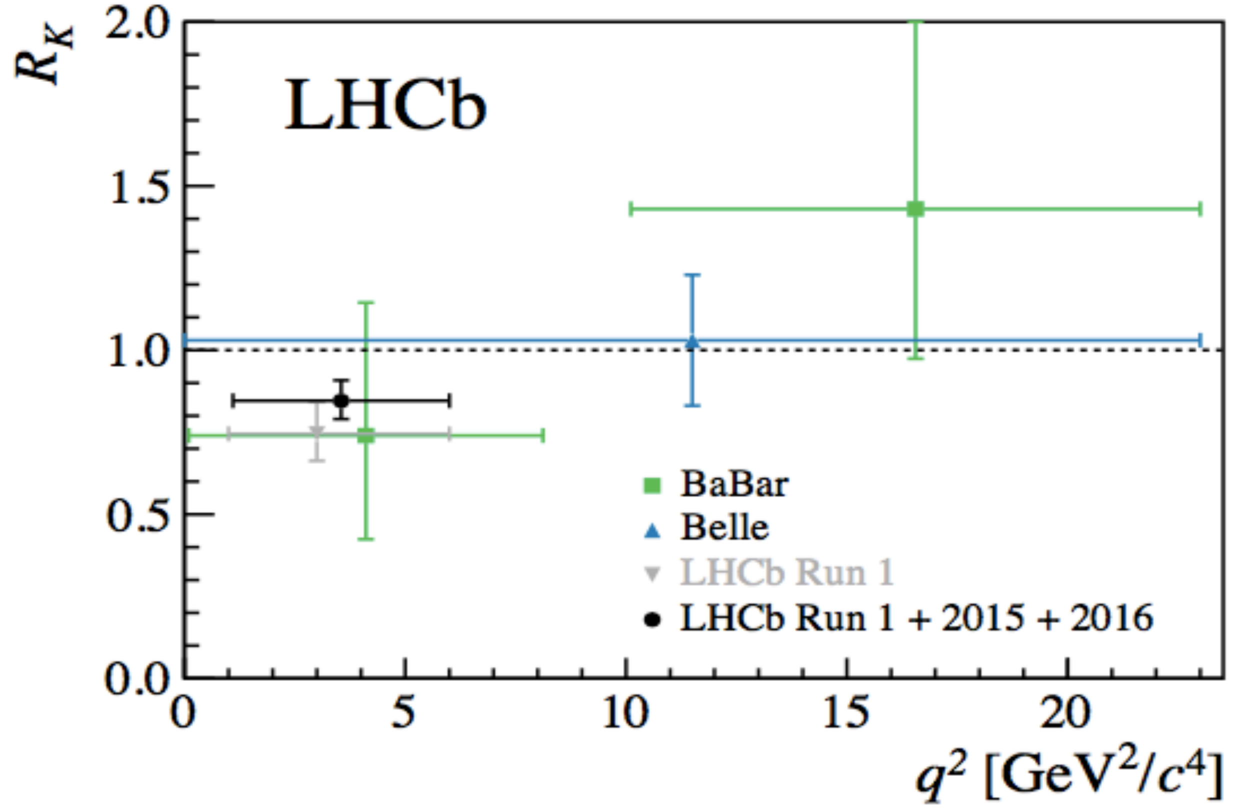
New world average:

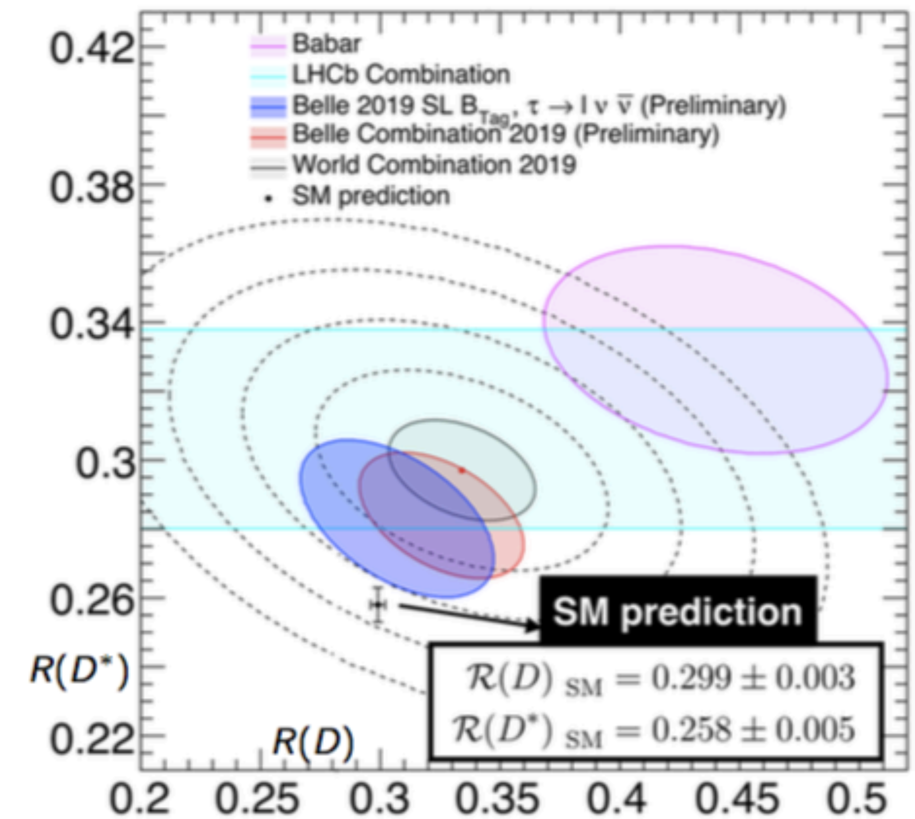
$$\phi_s = (-\mathbf{0.0544} \pm \mathbf{0.0205})$$

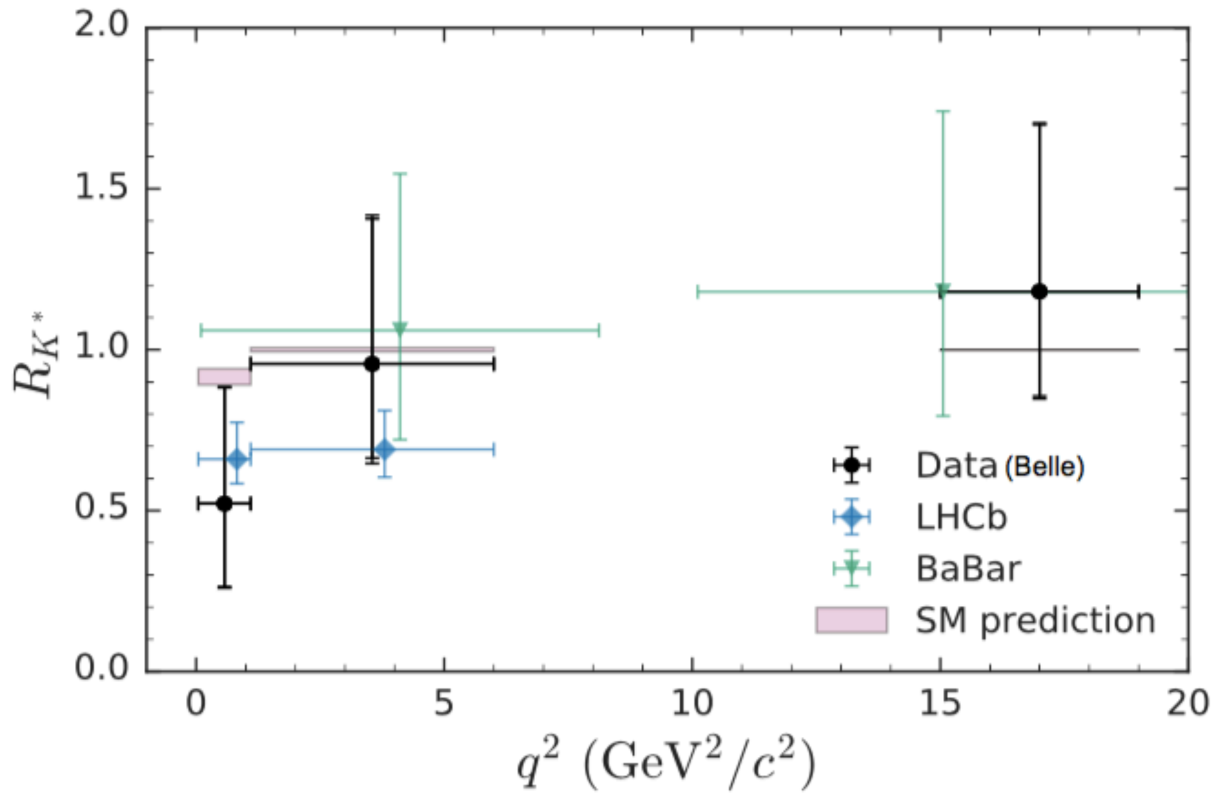
B - Anomalies *(w/ news 2019!)*

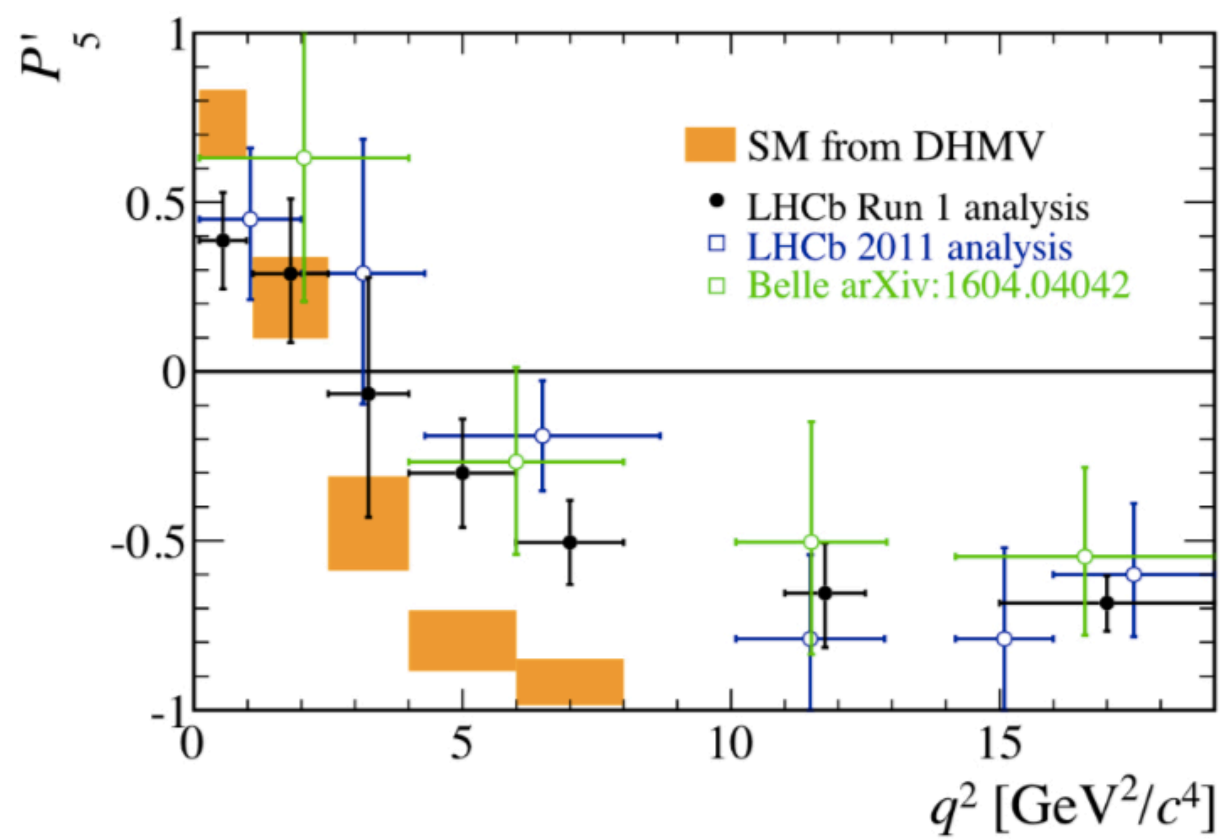
Fuentes, Gioventu', Saturnino

$$R(D^{(*)}) = \frac{\text{Br}[B \to D^{(*)}\tau\nu]}{\text{Br}[B \to D^{(*)}\ell\nu]} \quad \ell = \{\mu, e\}$$





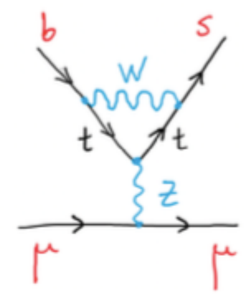




B - Anomalies *Interpretations*

Fuentes, Saturnino

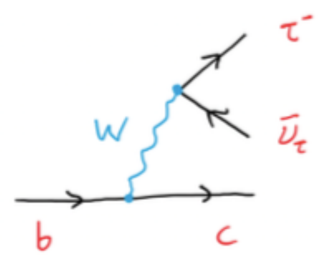
- Flavor!



$3_Q \to 2_Q 2_L 2_L$

~25% of a SM **loop** effect

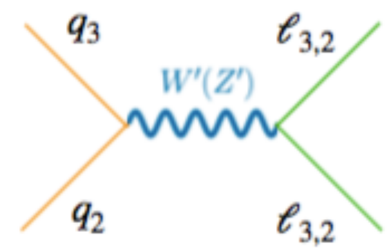
≪



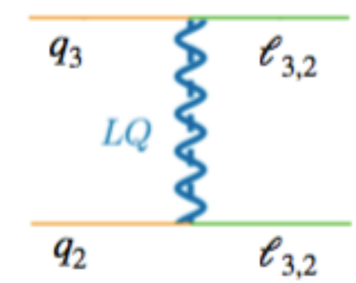
$3_Q \to 2_Q 3_L 3_L$

~15% of a SM **tree-level** effect

- Vector LQ $U_1 = (\mathbf{3}, \mathbf{1})_{2/3}$

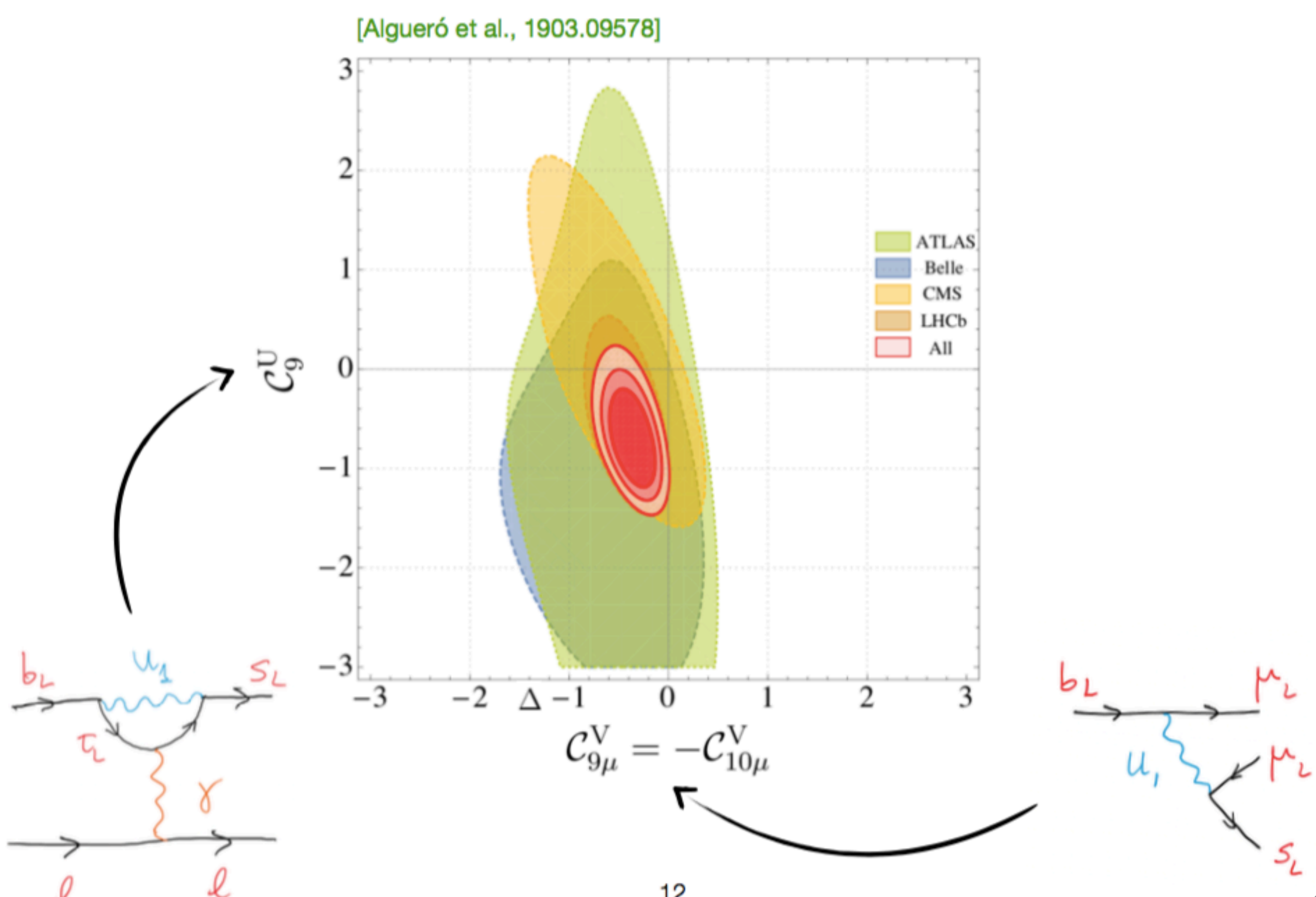


No

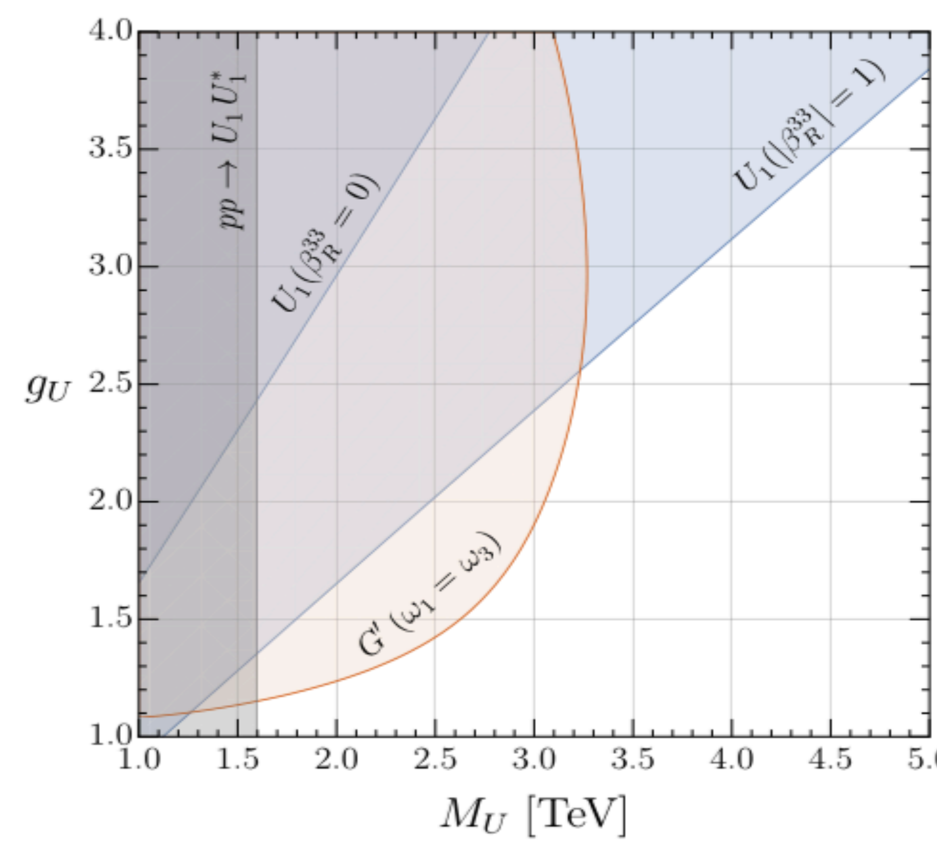


Yes

- Loop Effects & correlations



- UV completions (eg.“4321”)



[Baker, JFM, Isidori, König, 1901.10480]

B-meson LCDAs

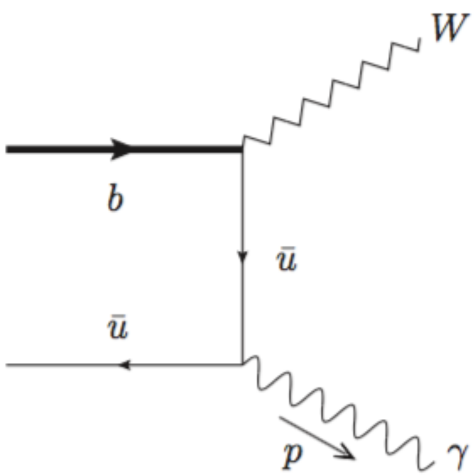
Yao Ji

- Non-perturbative quantities of maximal interest (fact theorems)

$$\langle 0|\bar{q}(nz)\Gamma W(nz,0)h_v(0)|\bar{B}(v)\rangle = f_B \mathrm{Tr}\left\{\gamma_5 \Gamma P_+ \left[\phi_+(z,\mu) - \frac{\not{n}}{2}\phi_\pm(z,\mu)\right]\right\}$$

$$\lambda_B^{-1}(\mu) \equiv \int_0^\infty \frac{d\omega}{\omega}\phi_B^+(\omega,\mu)$$

- Best mode to extract λ_B: $B \to \gamma\ell\bar{\nu}$ for $E_\gamma \sim m_b$



$$\frac{d\Gamma}{dE_\gamma} = \frac{\alpha_{\rm em} G_F^2 |V_{ub}|^2}{6\pi^2} m_B E_\gamma^3 \left(1 - \frac{2E_\gamma}{m_B}\right)\left(|F_V|^2 + |F_A + \frac{e_\ell f_B}{E_\gamma}|^2\right)$$

$$F_{V,A}(E_\gamma) = \underbrace{\frac{e_u f_B m_B}{2E_\gamma \lambda_B(\mu)} R(E_\gamma,\mu)}_{\text{leading power contribution } F_{V/A}^{\mathrm{tw}-2}} + \underbrace{\xi(E_\gamma) \pm \Delta\xi(E_\gamma)}_{\text{power suppressed \& } \gamma \text{ from b-quark vertex}}$$

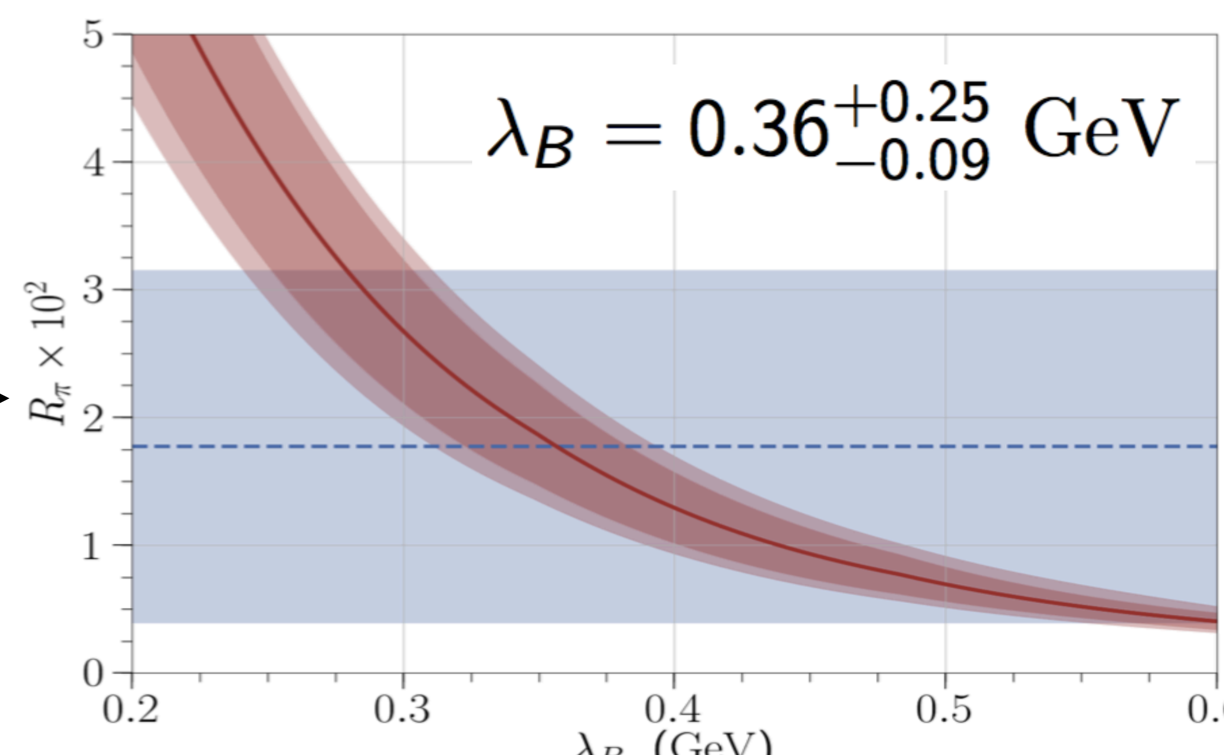
- Belle extraction:

[M. Gelb *et al.* [Belle Collaboration] (2018)

(Result compatible w/ QCD sum rules)

$$\frac{\Gamma(B \to \gamma\ell\bar{\nu})}{\Gamma(B \to \pi\ell\bar{\nu})} \longrightarrow$$

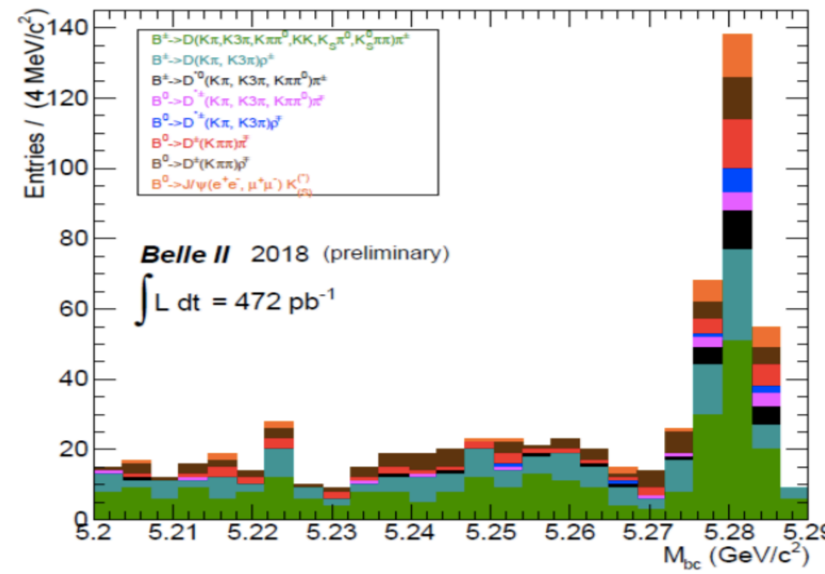
(Belle-II prospects)



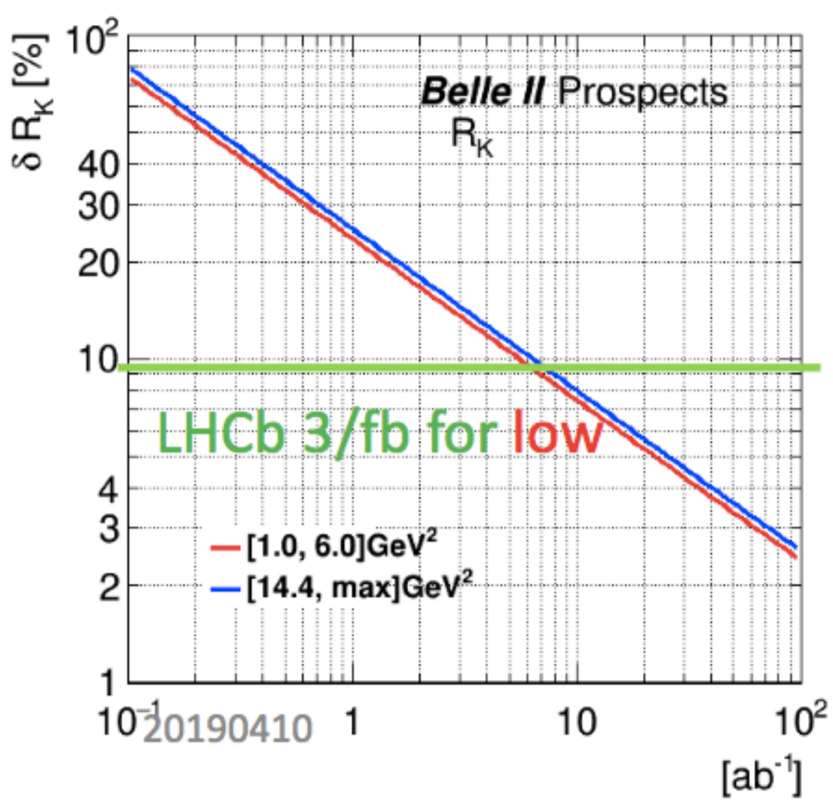
Future: Belle-II

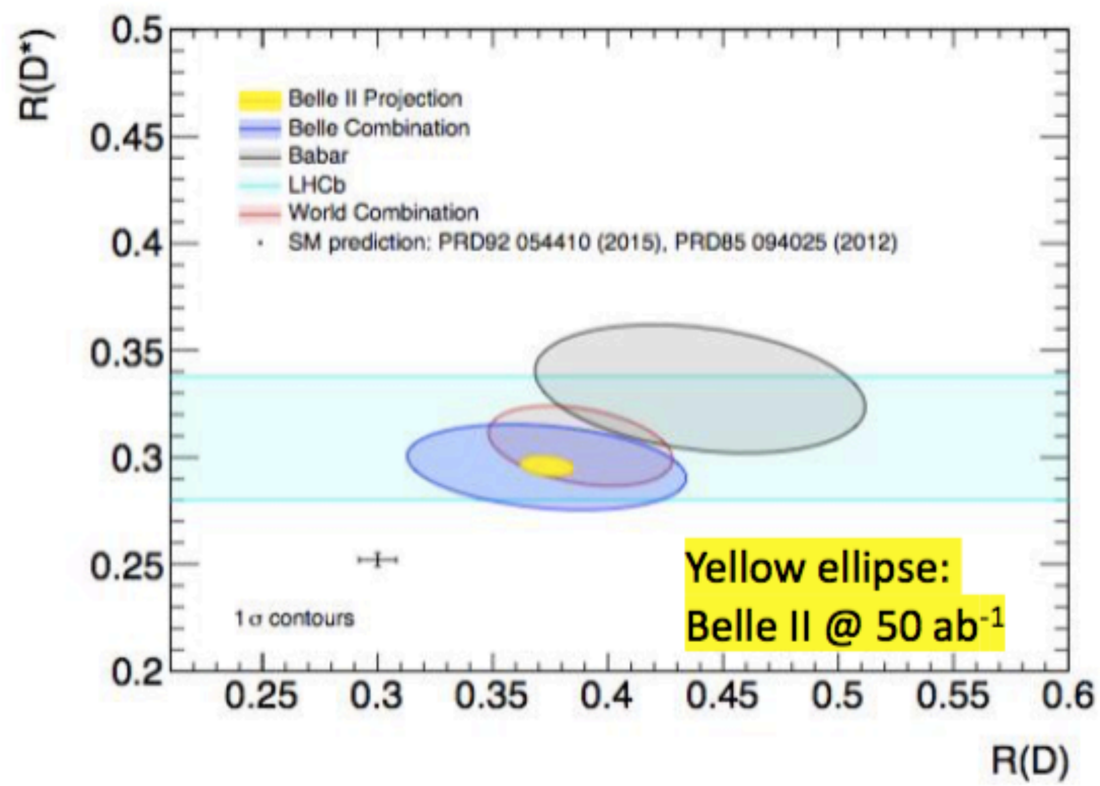
Ishikawa, Kato

- Target: *50/ab by 2027* — (x40 KEKB lumi) — Supersede B-fact 2021
- Rediscovery of *B* mesons! (Phase 2 commissioning Run)
- First collision in Phase 3 in
  March 25th 2019
- B, D and tau physics
  + dark "photon", EW, spectroscopy …



- Anomalies: $R_{K^{(*)}}, R_{X_s}, R(D^{(*)}),\ B \to X_s \ell\ell,\ B \to \gamma \ell \bar{\nu}, \ldots$





Thanks to all the speakers in WG5

Thanks to the organizers

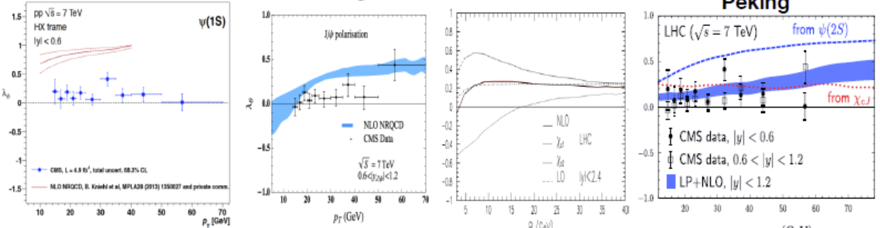
Expect more exciting **Heavy Flavor** results at DIS 202x

BACK UP

Back UP

J/ψ polarization in hadro-production

Hamburg | Peking | IHEP | ANL/KU/ Peking



CMS, PLB727, 381 (2013)
Butenschoen and Kniehl, PRL108, 172002 (2012)

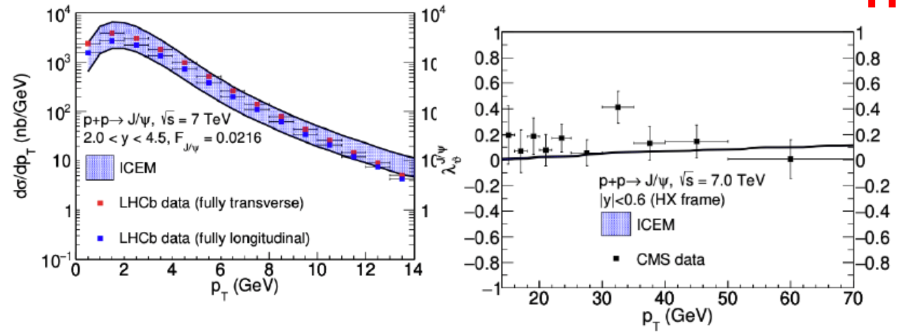
Shao, Han, Ma, Meng, Zhang, Chao, JHEP 1505 (2015) 103

Gong, Wan, Wang, Zhang, PRL110, 042002 (2013)

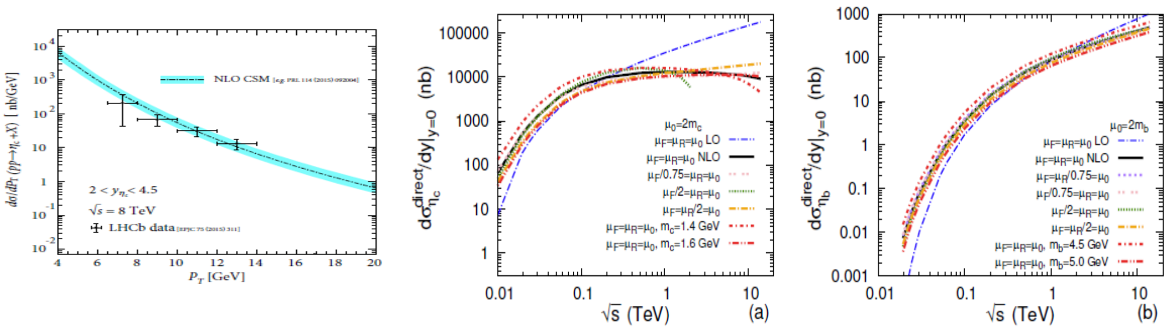
Bodwin, Chao, Chung, Kim, Lee, Ma, PRD93, 034041 (2016)

Improved Color Evaporation Model

Hee Sok Chung



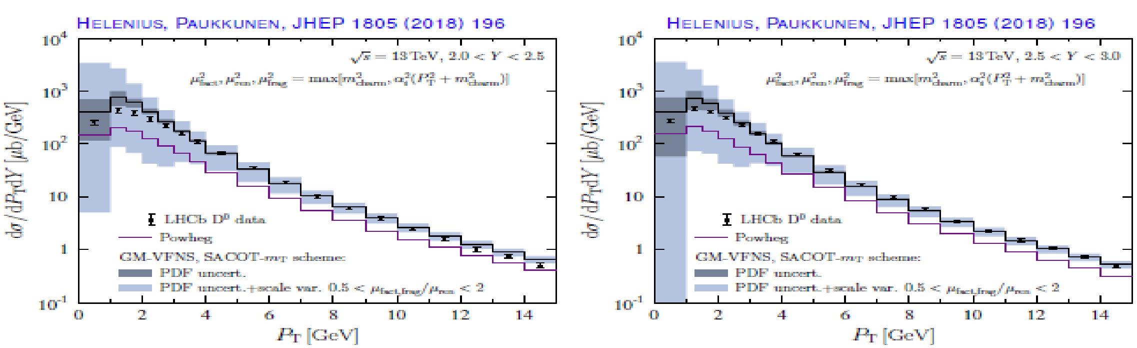
Heavy quarkonium production can be more sensitive to TMD PDFs, DPS and QFG effects, but production mechanism of heavy quarkonia is still a challenge for theory



Melih A. Ozcelik

Attempt to re-solve negative cross-section with η_c

TMD vs collinear factorization



Hanni Paukkunen

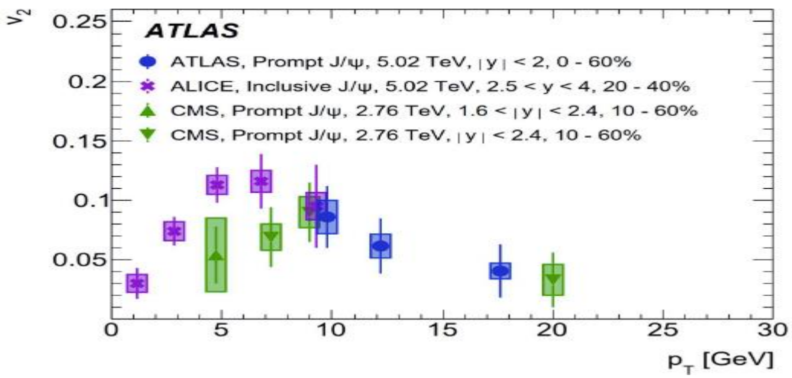
GM-VFNS scheme – SACOT-mT introduced for heavy-flavoured meson production: Agreement with LHCb p-p data.

Full NLO level, parts of NNLO known

Back UP Charmonium at Heavy Ions

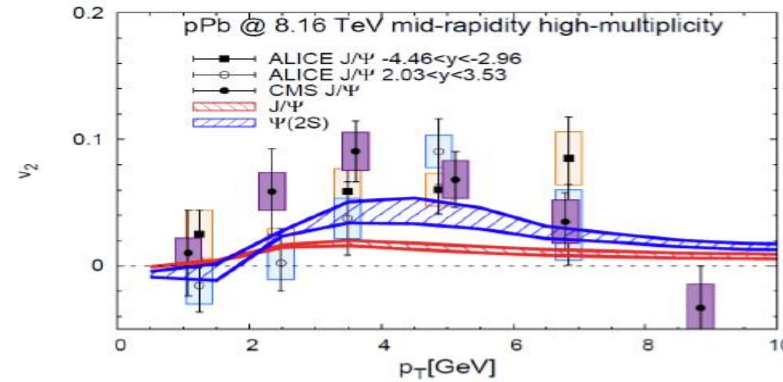
Roberta Arnaldi

J/ψ v2 measurement over broad p_T range

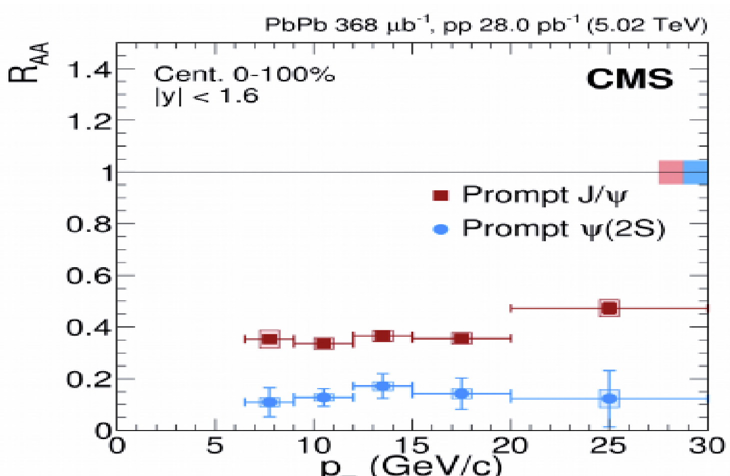


Low pT : Evidence for non-zero flow
(ALICE, 7σ effect in 4< pT < 6 GeV)
High pT : v2≠0 (ATLAS and CMS)

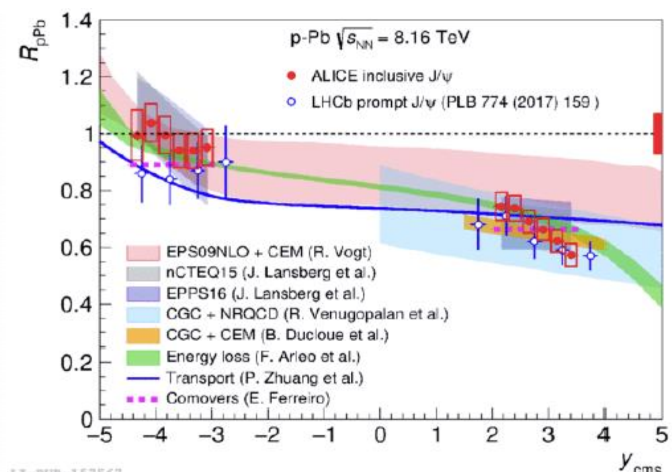
Significant non-zero v2 is observed in high-multiplicity p-Pb



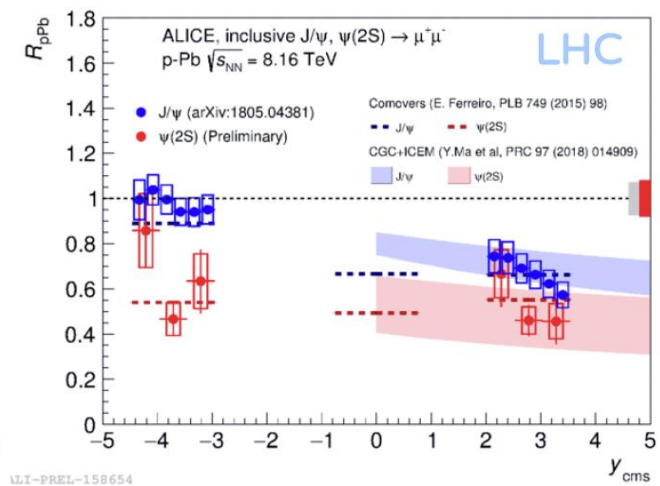
Models where the v2 originates from final-state interactions in the fireball + regeneration underestimate in data



Ψ(2S) suppression is stronger than the J/ψ at high pT
(as expected in sequential suppression scenario)



Good agreement b/w data and models (based on shadowing, CGC, energy Loss)
Size of theory uncertainty (mainly shadowing) still limits quantitative comparison



Different behaviour for J/ψ and ψ(2S) not expected.
Shadowing/energy loss not enough to describe ψ(2S) suppression at backward y.

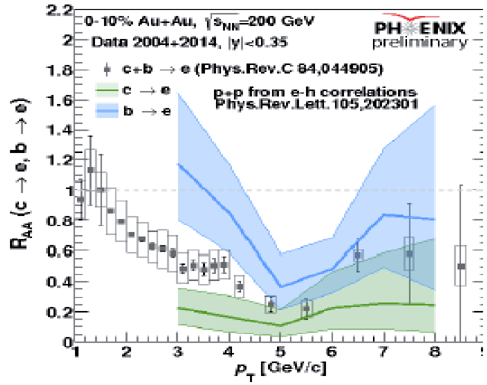
Back UP

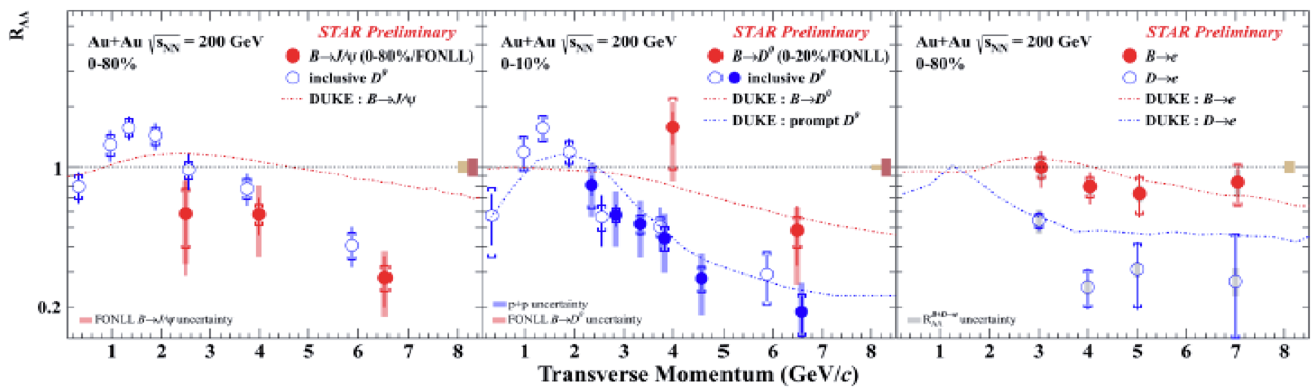
B/D suppression

Petr Chaloupka

Bottom suppression @ RHIC

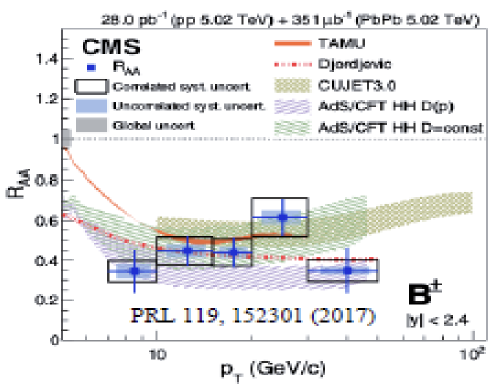
b→e
c→ e

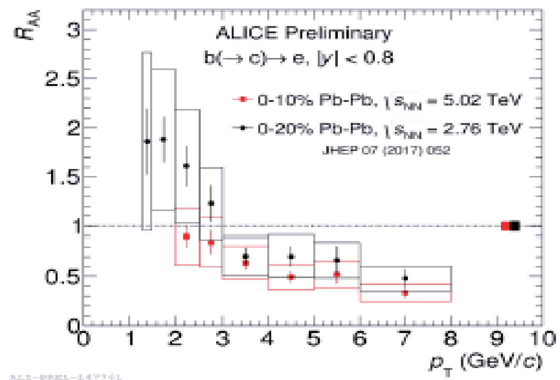


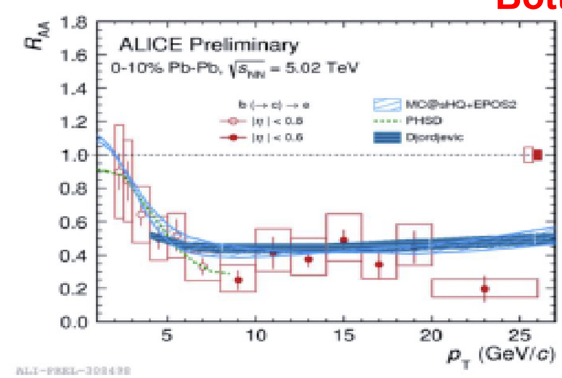


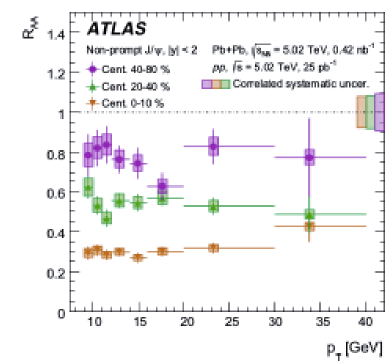
Consistent with mass hierarchy of energy loss

Bottom suppression @ LHC





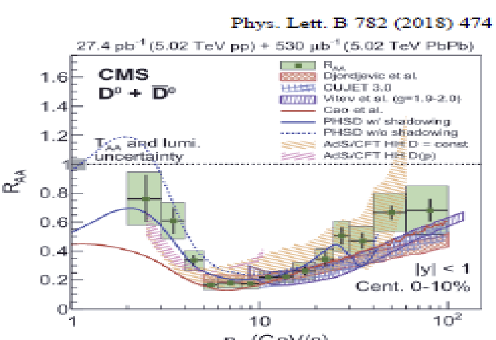


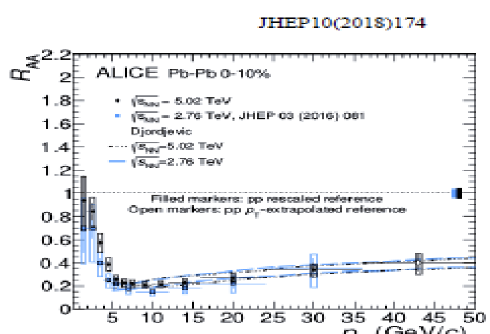


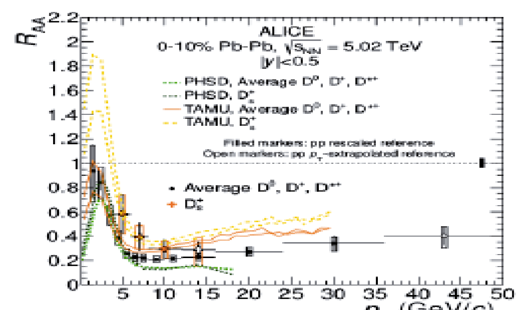
Strong suppression for p_T > 7 GeV

Observed suppression described by models with mass-dependent energy loss

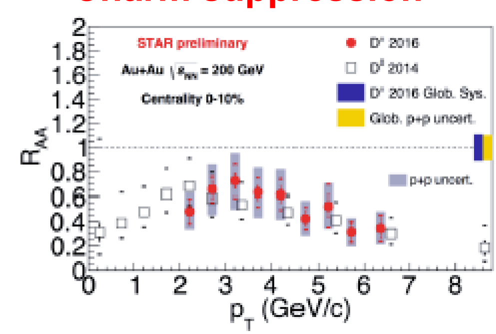
Flat suppression up to high pT







Charm suppression

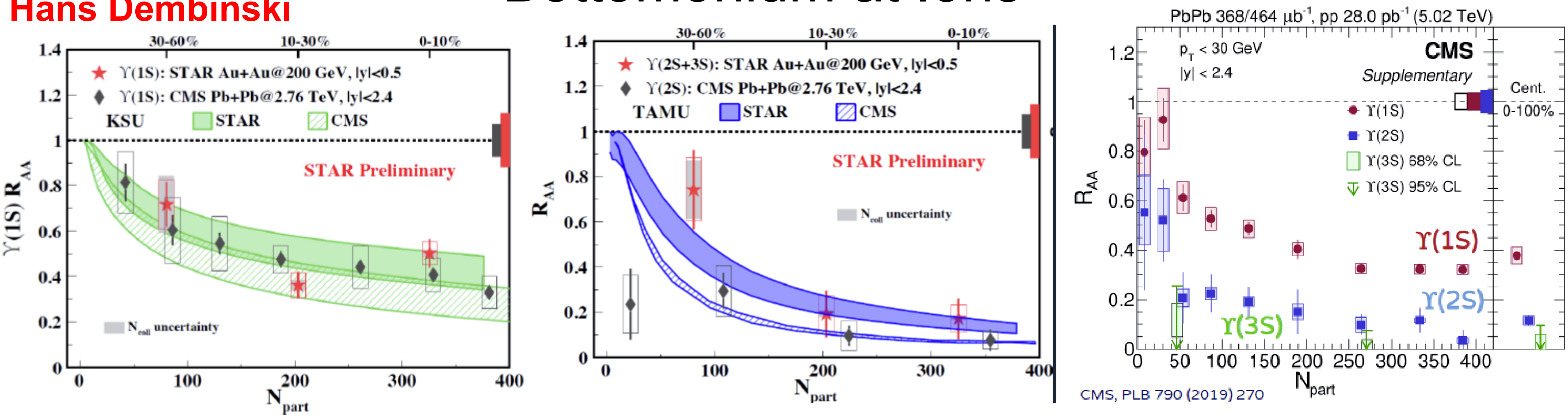


High pT: Need to include radiative energy loss
Low pT: Non negligible collisional energy loss and shadowing improves description

Similar suppression for charged D also

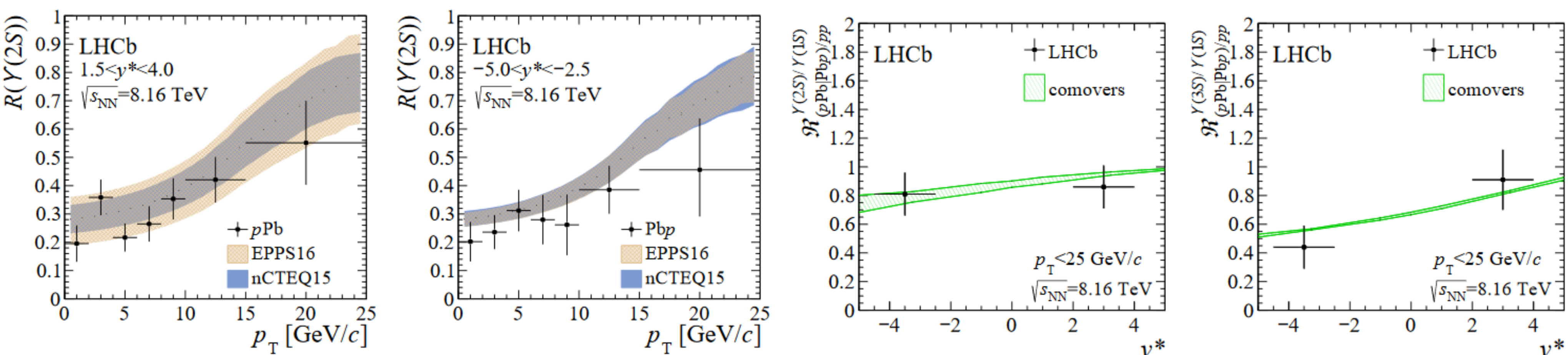
Roberta Arnaldi
Hans Dembinski

Bottomonium at Ions



Lower R_{AA} value for excited states compatible with sequential suppression

Excited states suppression stronger at LHC (?)



$$R(\Upsilon(nS)) = \frac{[\mathrm{d}^2\sigma/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*]\,(\Upsilon(nS))}{[\mathrm{d}^2\sigma/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*]\,(\Upsilon(1S))} \qquad \mathfrak{R}^{\Upsilon(nS)/\Upsilon(1S)}_{(p\mathrm{Pb}|\mathrm{Pb}p)/pp} = \frac{R(\Upsilon(nS))_{p\mathrm{Pb}|\mathrm{Pb}p}}{R(\Upsilon(nS))_{pp}}$$

LHCb saw stronger suppression for Y(2S) at low pT

Enhanced suppression of $\Upsilon(3S)$ in pPb compare to pp at negative rapidity