WG 4 @ DIS2016: Heavy Flavours (Charm, Beauty and Top)

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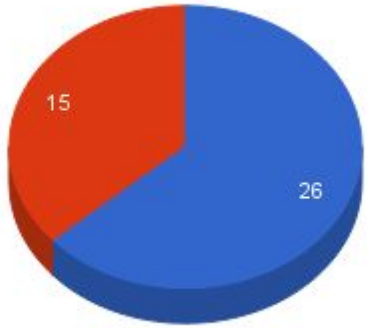
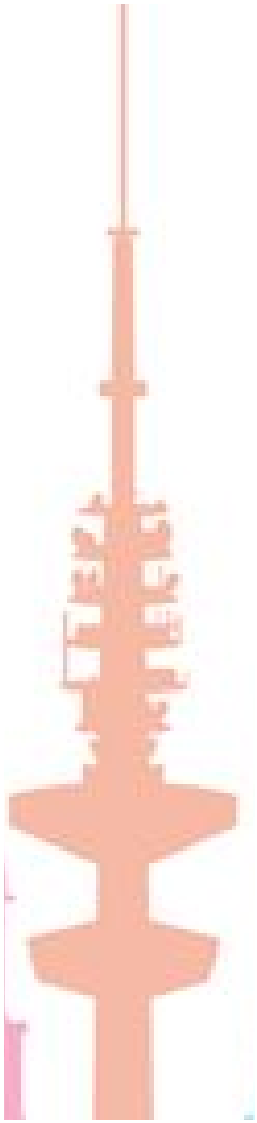
Overview of HF session

- 41 talks
- 2 talks with “DIS” in the title
- This talk: 40 x 15 min → 20 min (compression factor of 30).
- Disclaimer: only a biased selection of some results. ⇒ Apologies, if your results are included in the summary
- See also the Top plenary talk by O. Iorio.



Theo
Exp

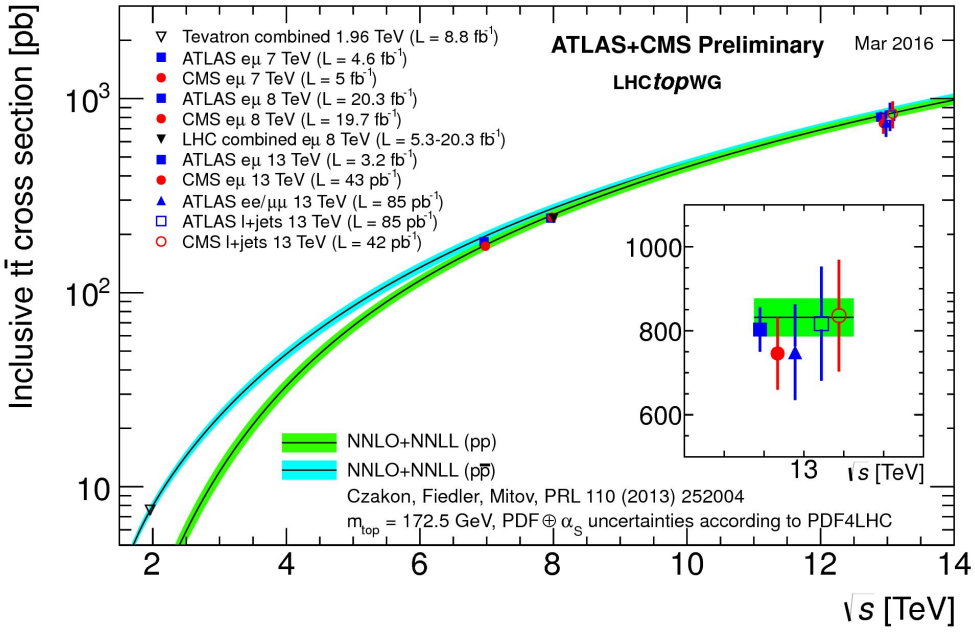


Top Physics

Top quark production at 13 TeV

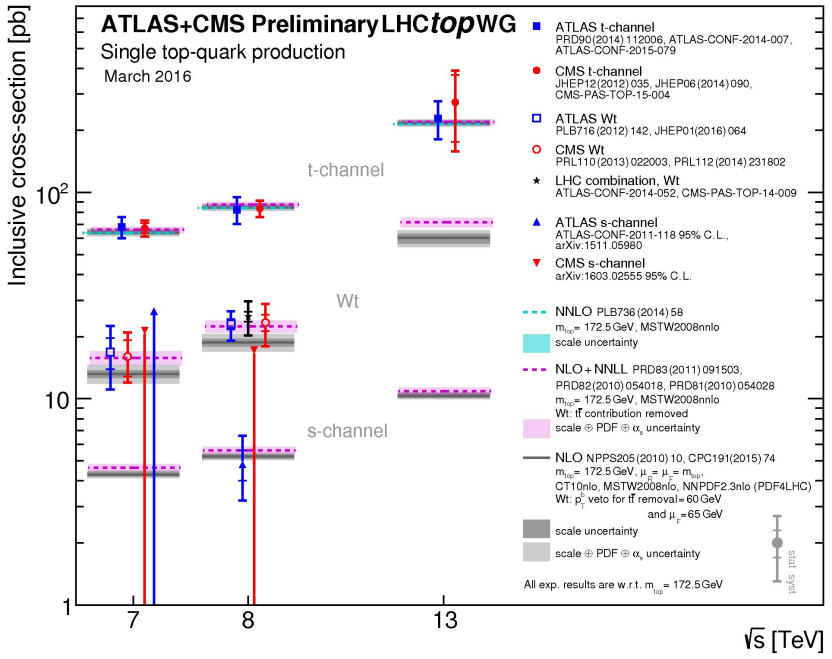
→ Bartosik
→ Ahmed

Top pairs



Single top

→ Mitra
→ Rieck



- Evolution with centre-of-mass energy well understood (at NNLO precision)
- ttbar measurements approach theoretical uncertainty

Latest results at 13 TeV, not yet included in plots:

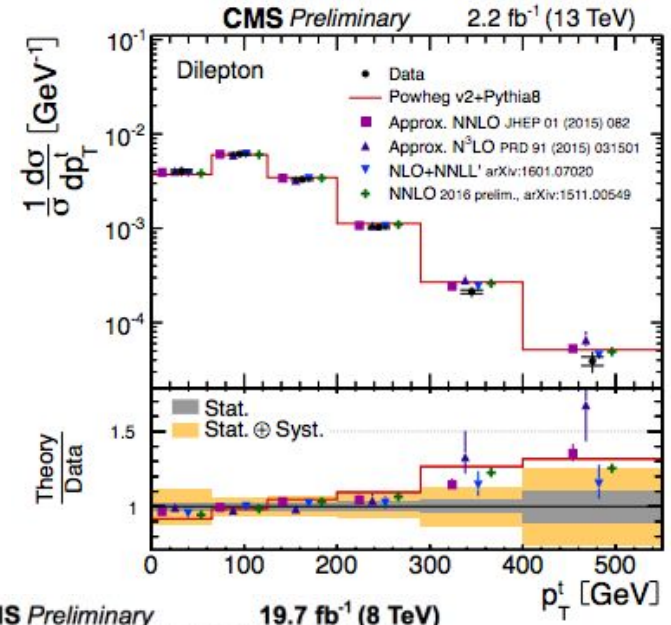
t-channel:
Brucherseifer, Caola, Melnikov

cms-top-16-003 $\sigma_{tt} = 793 \pm 8^{stat} \pm 38^{syst} \pm 21^{lumi}$ pb | 5.6% total most precise yet at 13 TeV

cms-top-16-005 $\sigma_{t\text{-ch}}$ (13 TeV) = 227.8 ± 9.1 (stat.) ± 14.0 (exp) +28.7 / -27.7(th.) ± 6.2 (Lumi) pb

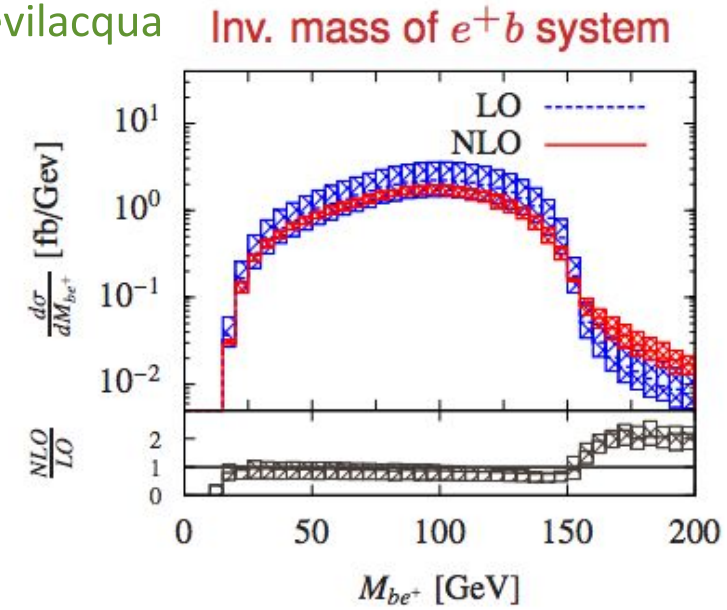
Top theory predictions : state of the art

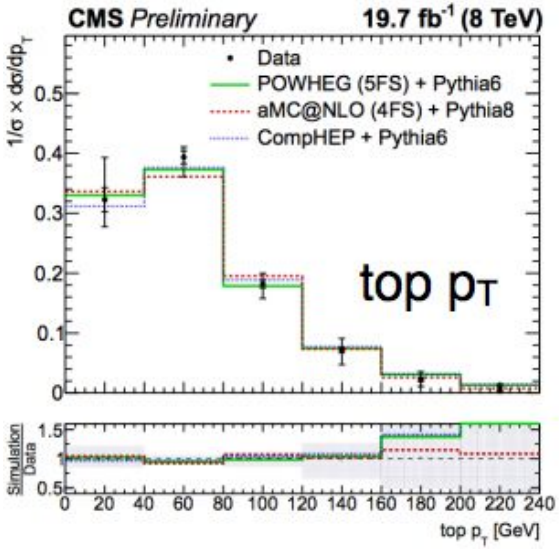
- Full NNLO, inclusive & differential
  - For stable top quarks
- NLO+PS MC models
  - Now widely adopted
- NLO incl. off-shell + top decay for ttbar+jet



ttbar
→ Bilin

→ Bevilacqua



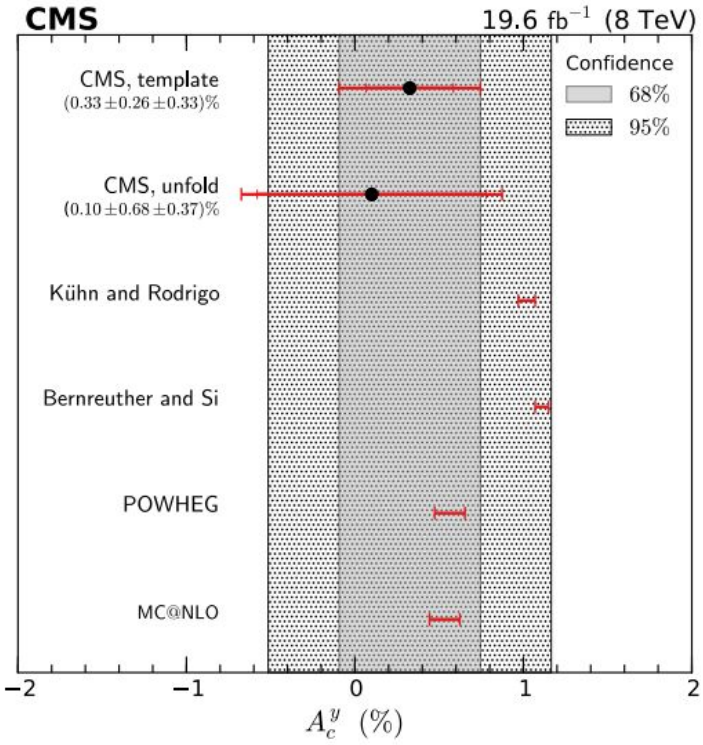


t-channel
→ Mitra

ttbar Charge Asymmetry (cf A_{FB})

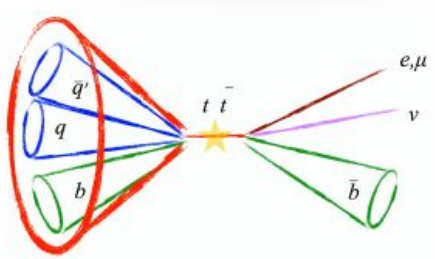
→ Poyraz (CMS) , Kareem (ATLAS)

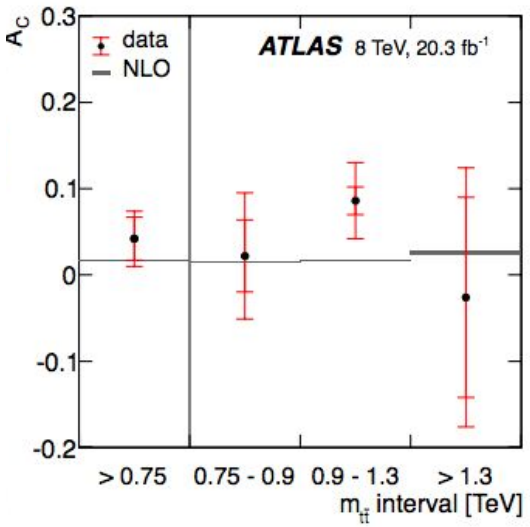
Achieving sub-1% precision



extending to boosted regime (right)

Physics Letters B (2016), Vol. 756, pp. 52-71

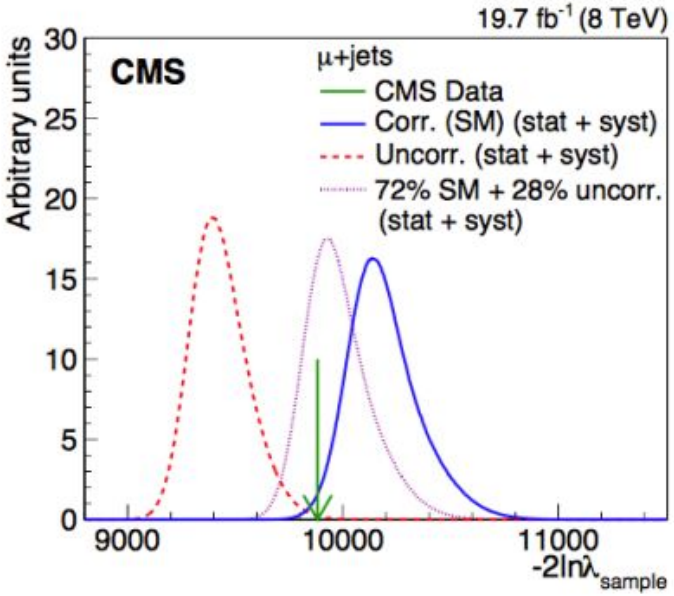


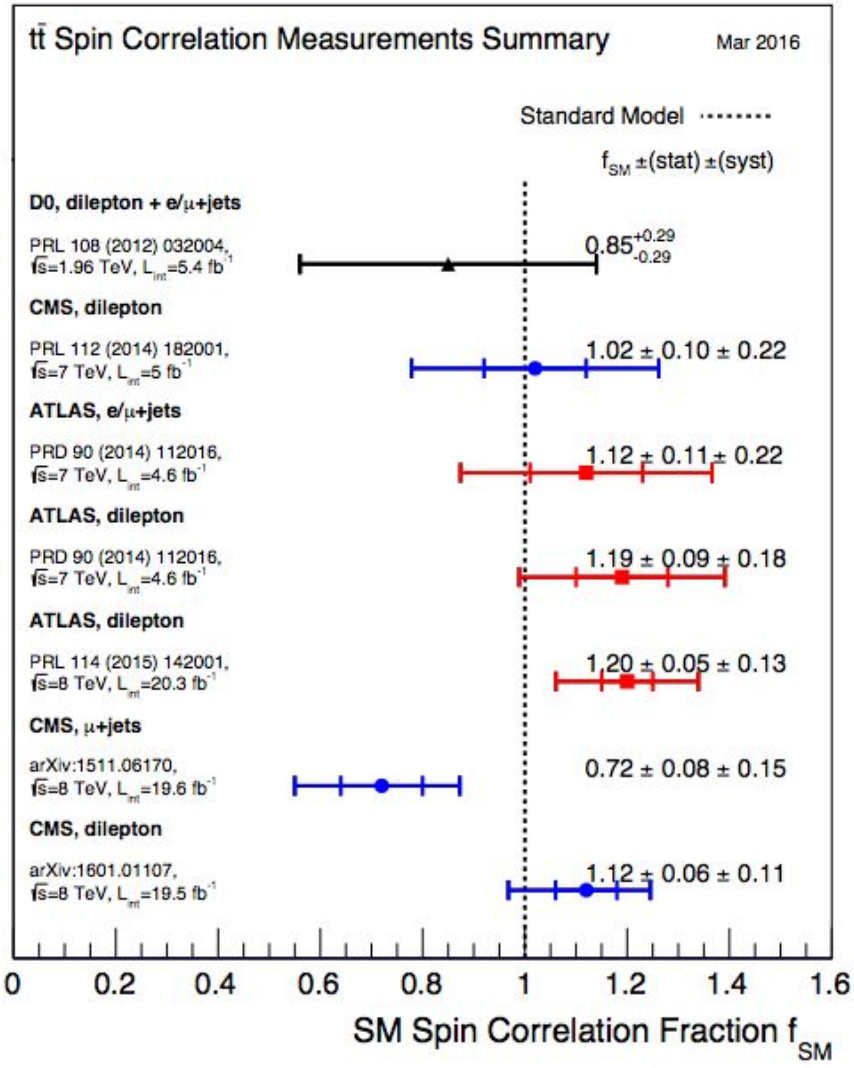


→ Poyraz (CMS)

Spin correlations

- CMS l+jets at 8 TeV, with Matrix Element method

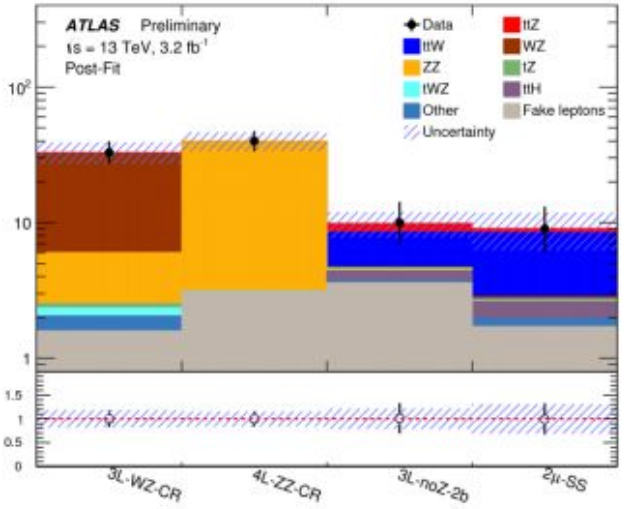




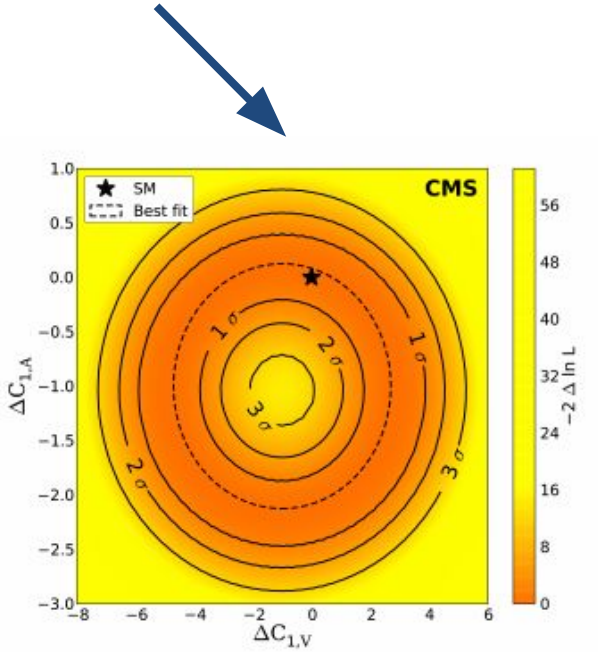
- SUSY hiding in ttbar would look like “uncorrelated” ttbar...
- But: not seen in other spin correlation measurements

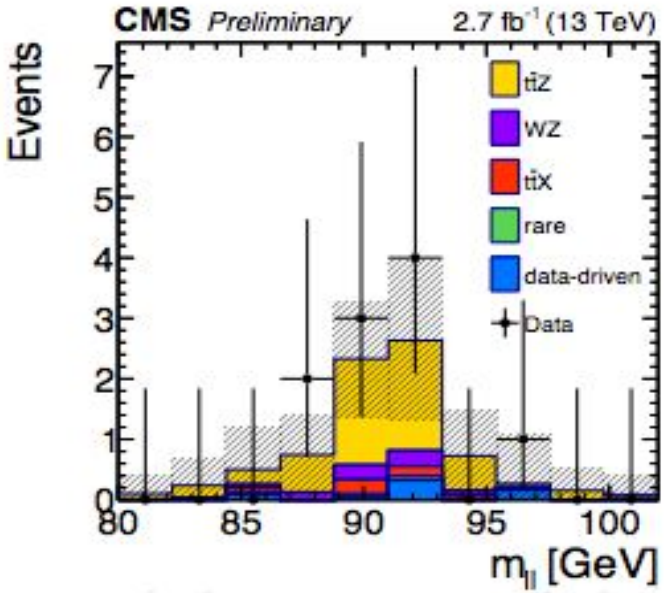
→ Poyraz (CMS) , Khanov (ATLAS) tt+Z/W

- tt+W/Z established at 13 TeV
- expect large sample in Run2
- ttZ allows to probe directly ttZ coupling and place EFT constraints (here 8 TeV)

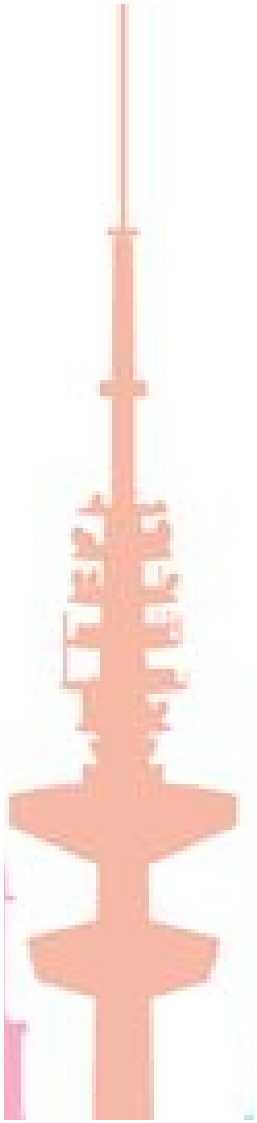


ATLAS-CONF-2016-003





TOP-16-009



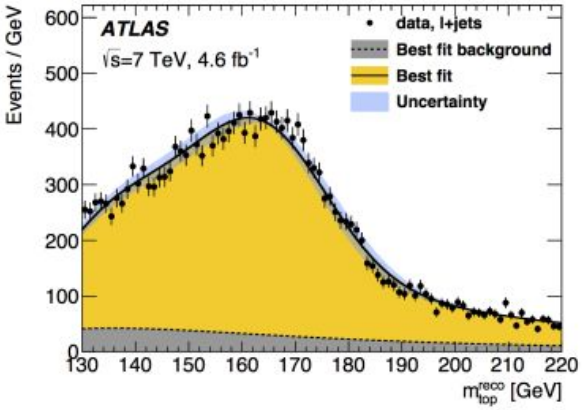
Top Mass

→ Bender

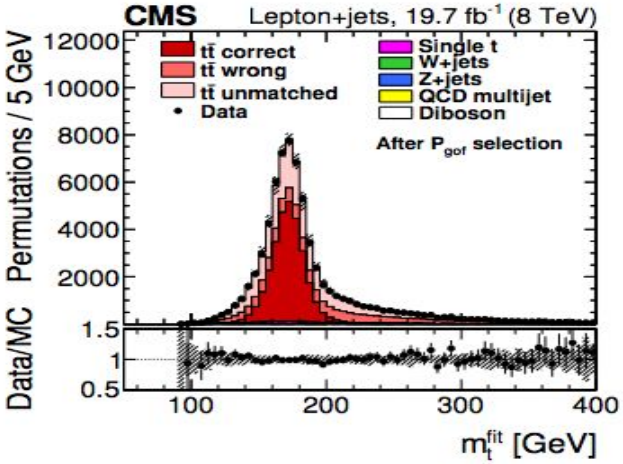
→ Spannagel

Top Mass from full reconstruction

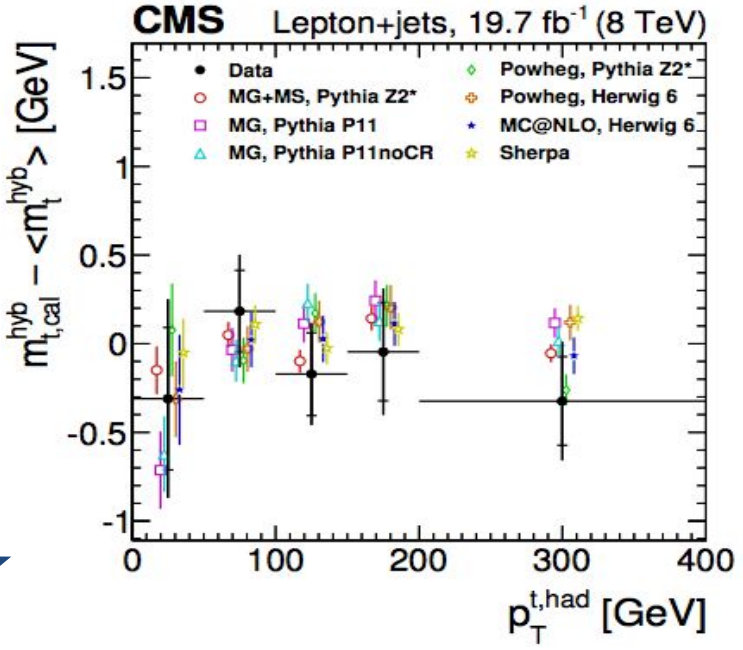
Most precise results in lepton+jets channel:



m_{top} = 172.33 ± 1.27 GeV (@ 7 TeV)



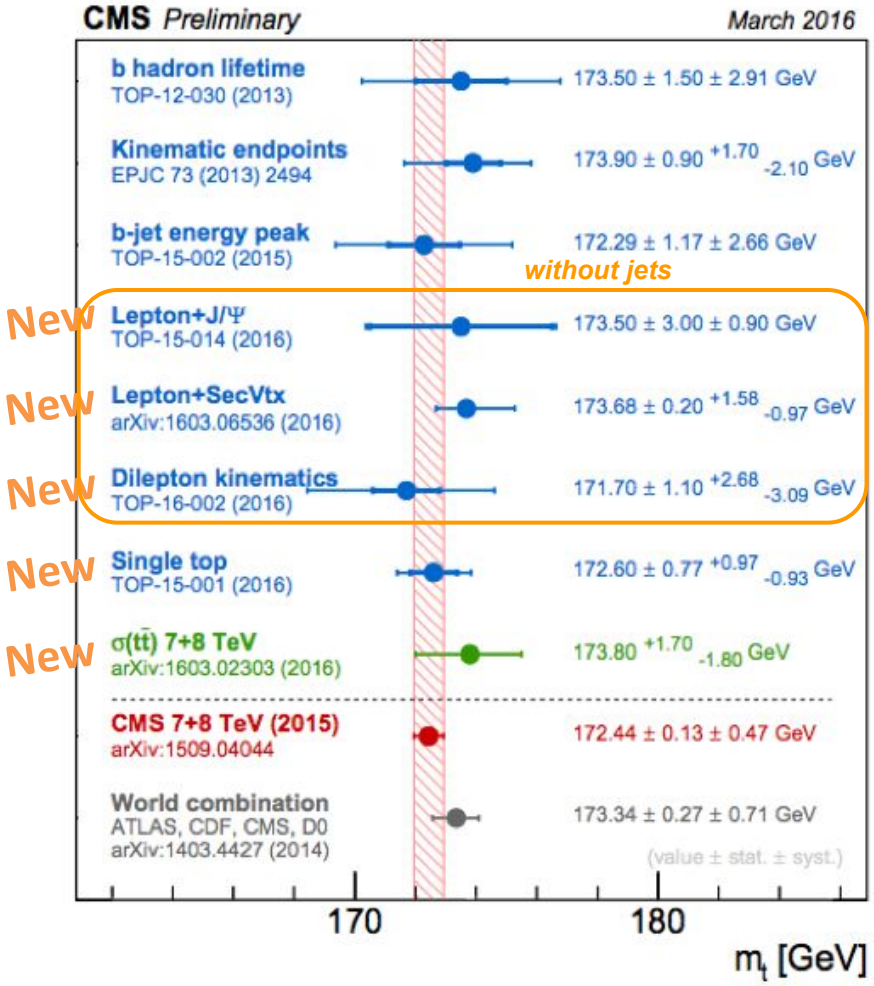
m_{top} = 172.35 ± 0.51 GeV (@ 8 TeV)

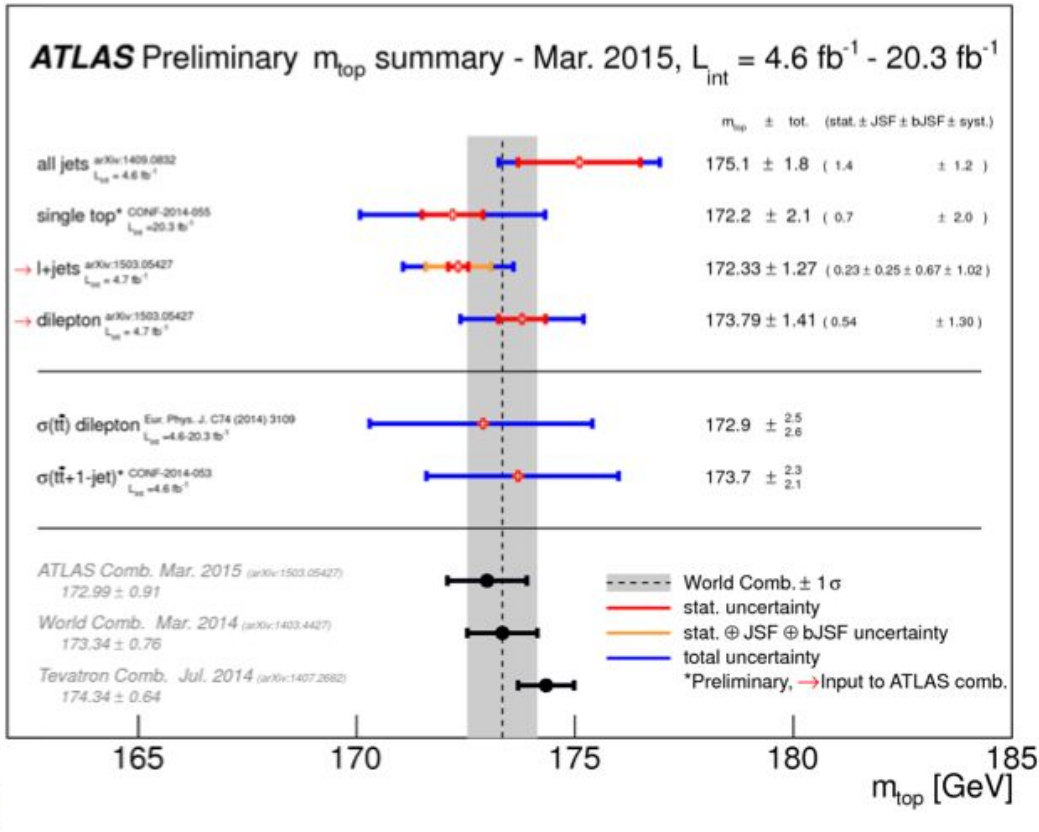


- check stability vs kinematic variables
- vs pT : stable within ~ 300 MeV whole range
- No evidence of mis-modeling of QCD effects
- Will get more powerful with more statistics

Summary of LHC top mass measurements

Also exploring alternative methods and observables :



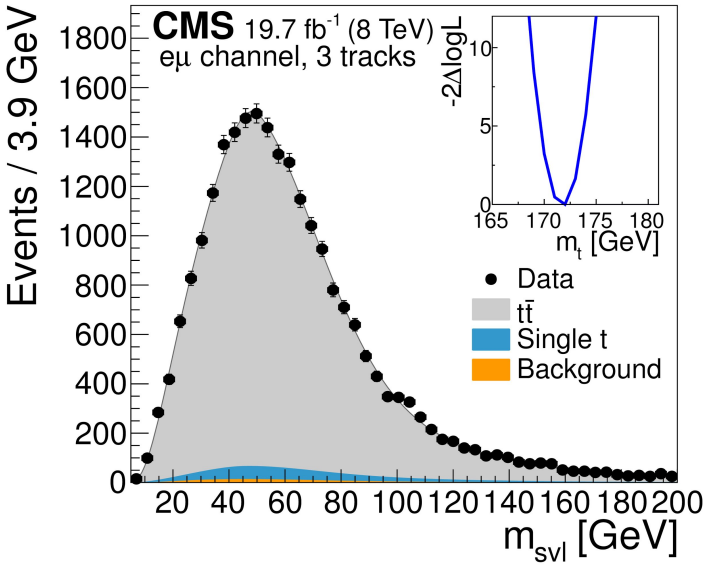


→ Spannagel

Look ma, no ~~hands~~ jets !!

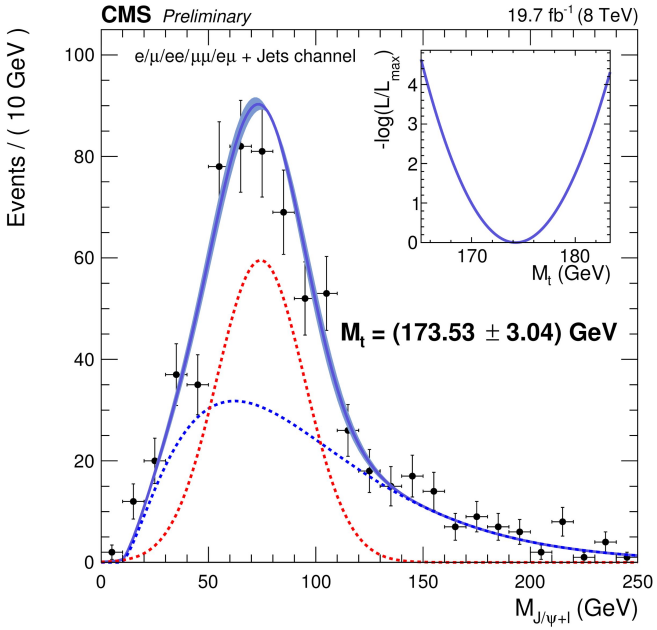
⇒ to minimize impact of jet energy scale uncertainties

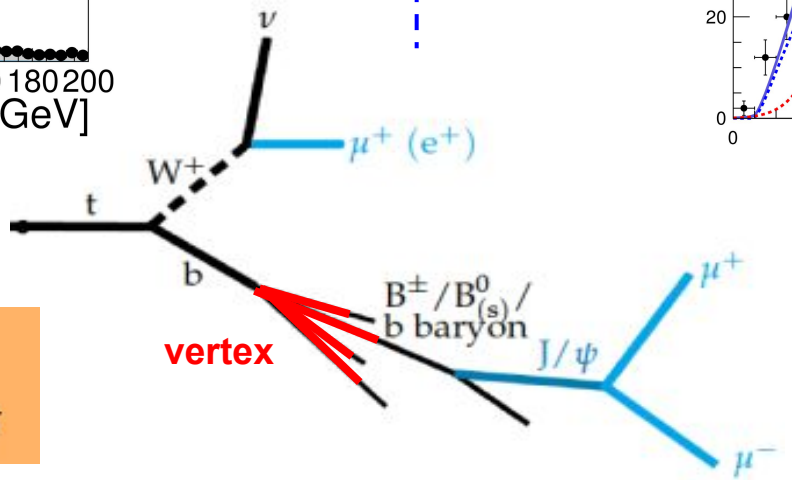
Only using tracks, from lepton + b vertex



$m_t = 173.68 \pm 0.20\,(\text{stat})\ ^{+1.58}_{-0.97}\,(\text{syst})\ \text{GeV}$

Or: lepton + J/Ψ

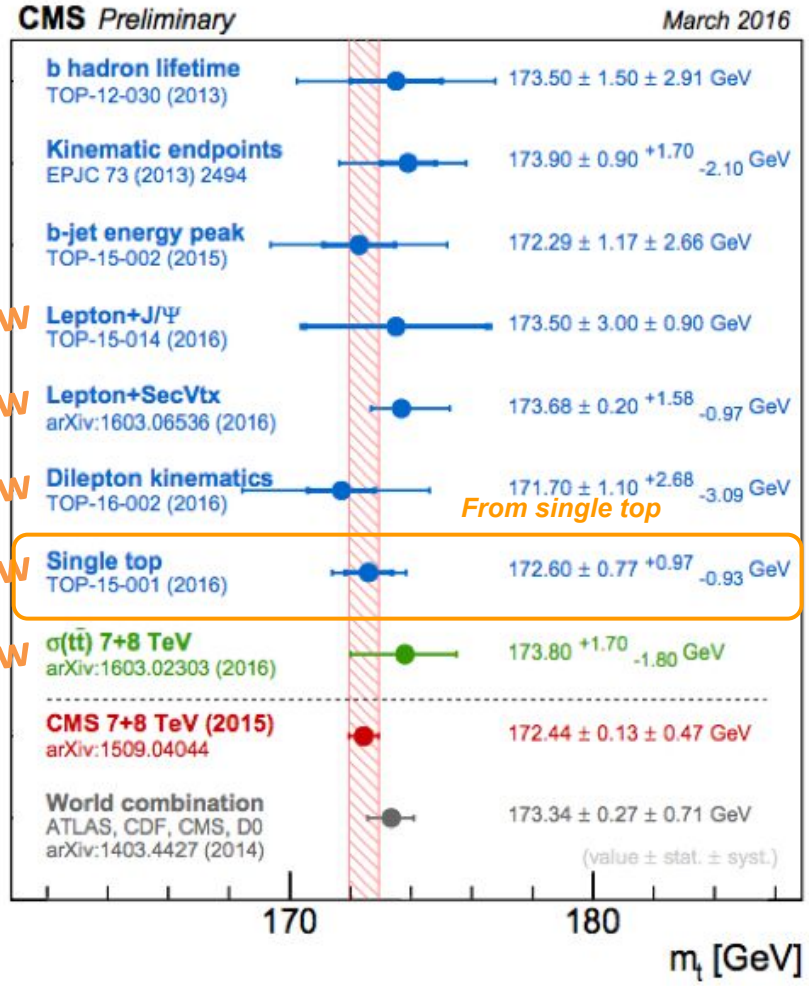


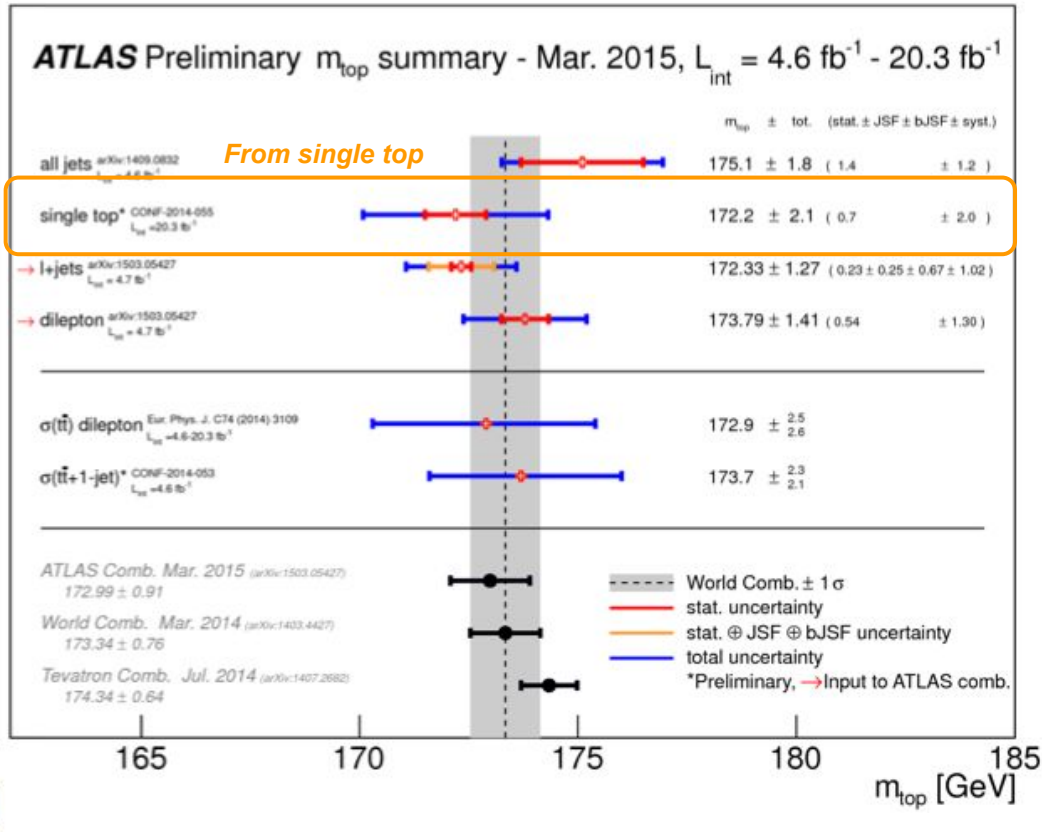


m_{top} = 173.53 ± 3.00 (stat) ± 0.90 (syst) GeV

Summary of LHC top mass measurements

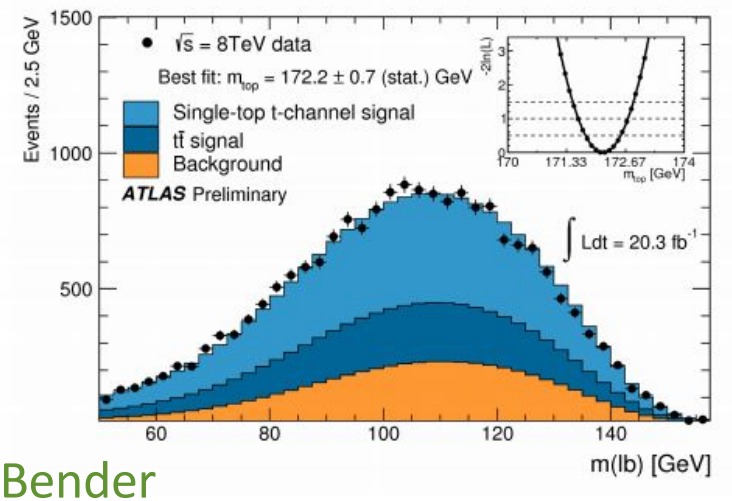
(alternative observables)



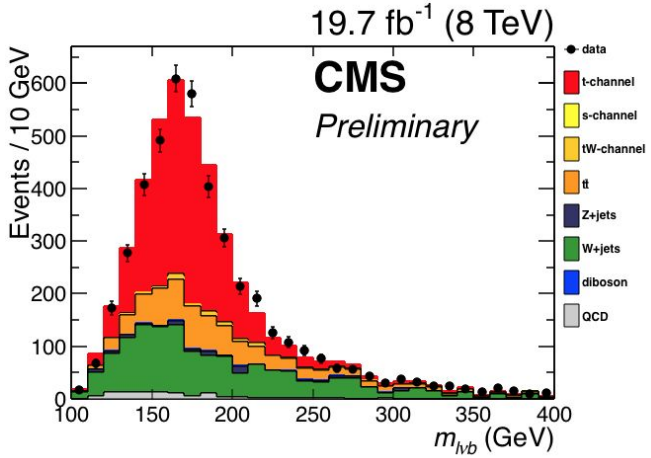


Mass measurements from single top

From invariant mass



→ Bender

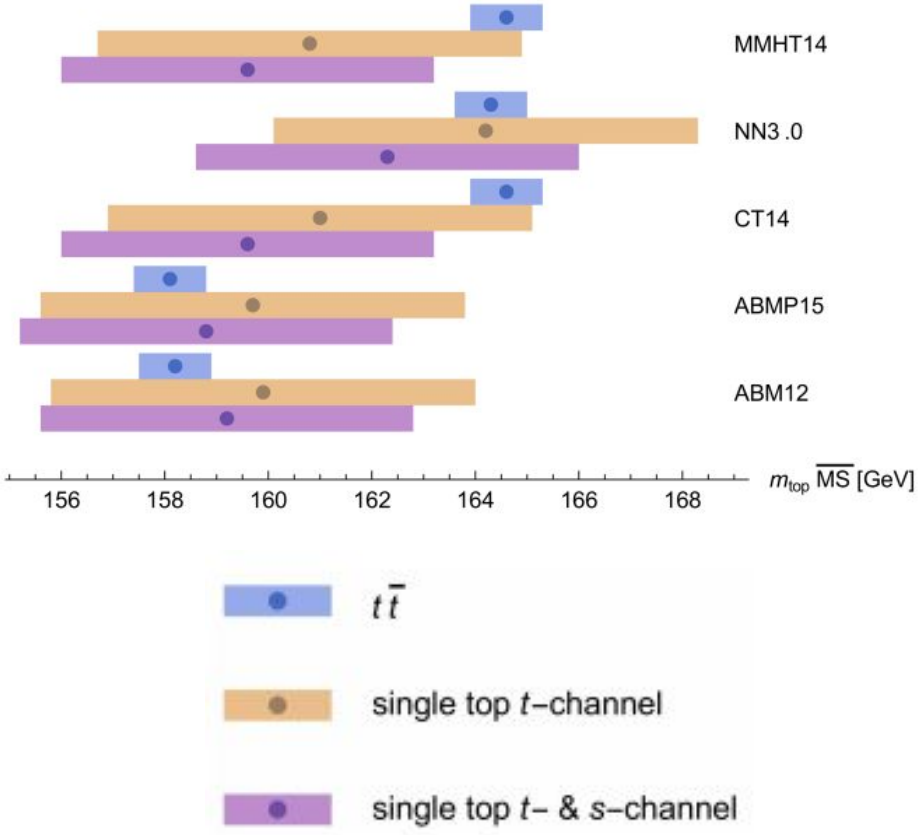


→ Spannagel

Or: inclusive cross-section

MSbar mass fit incl. NNLO$_{approx}$ terms:

→ Thier



pole-MSbar mass relation to 4 loops

Steinhauser

$$m_t^{\rm OS} = m_t^{\overline{\rm MS}} \left[1 + 0.4244\,\alpha_s + 0.8345\,\alpha_s^2 + 2.375\,\alpha_s^3 + (8.49 \pm 0.25)\,\alpha_s^4\right]$$
$$= 163.643 + 7.557 + 1.617 + 0.501 + (0.195 \pm 0.005)\ \text{GeV}$$

$$m_b^{\rm OS} = m_b^{\overline{\rm MS}} \left[1 + 0.4244\,\alpha_s + 0.9401\,\alpha_s^2 + 3.045\,\alpha_s^3 + (12.57 \pm 0.38)\,\alpha_s^4\right]$$
$$= 4.163 + 0.401 + 0.201 + 0.148 + (0.138 \pm 0.004)\ \text{GeV}$$

$$m_c^{\rm OS} = m_c^{\overline{\rm MS}}(3\ \text{GeV}) \times \left(1 + 1.133\,\alpha_s + 3.119\,\alpha_s^2 + 10.98\,\alpha_s^3 + (51.29 \pm 0.52)\,\alpha_s^4\right)$$
$$= 0.986 + 0.286 + 0.202 + 0.182 + (0.217 \pm 0.002)\ \text{GeV}$$

- top: good/reasonable convergence
- bottom, charm: no convergence

Preliminary estimate for residual renormalon uncertainty of top mass:

$$m_t^{\rm OS} = m_t^{\overline{\rm MS}} \left(1 + \sum_{k=1}^{4} r_{k-1}\alpha_s^k\right) + \delta^{(5+)} m_t^{\rm OS}$$

$$\delta^{(5+)} m_t^{\rm OS} = 0.2xx^{+0.04}_{-0.02}(N) \pm 0.07(\text{last term})\ \text{GeV}$$

➪ final uncertainty about (below?) 100 MeV!

[MSbar – thr. mass (1S,PS,RS) relation well under control $\sim 10(5)\text{MeV}$ for top(bottom)!]

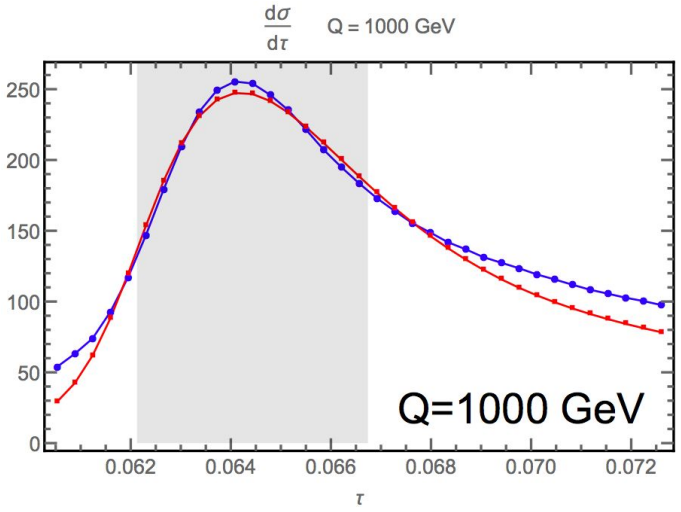
Top mass calibration for MC

Hoang What is the relation of MC mass to SM mass in a well defined scheme?

Method:

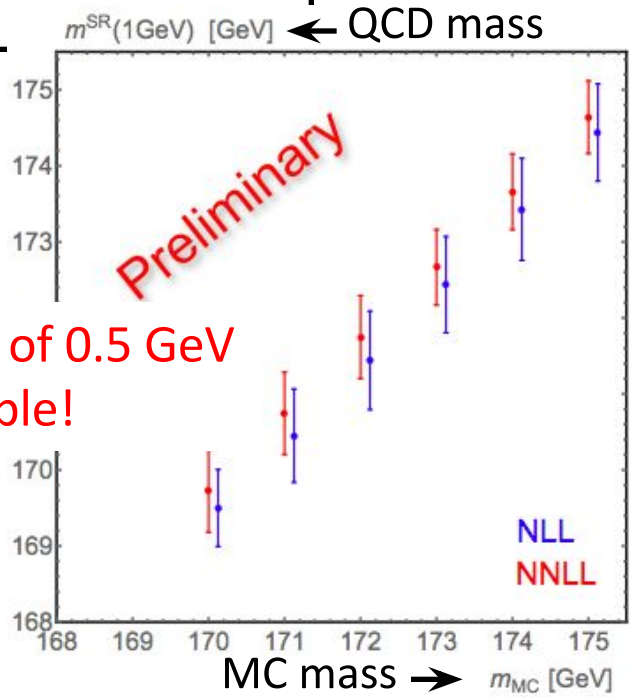
- ✓ 1) Strongly mass-sensitive observable (closely related to reconstructed invariant mass distribution !)
- ✓ 2) Accurate analytic hadron level QCD predictions at ≧ NLL/NLO with full control over the quark mass scheme dependence.
- ✓ 3) QCD masses as function of m_t^{MC} from fits of observable.
- 4) Cross check observable independence

First results for 2-jettiness (thrust) in $e^+ e^-$

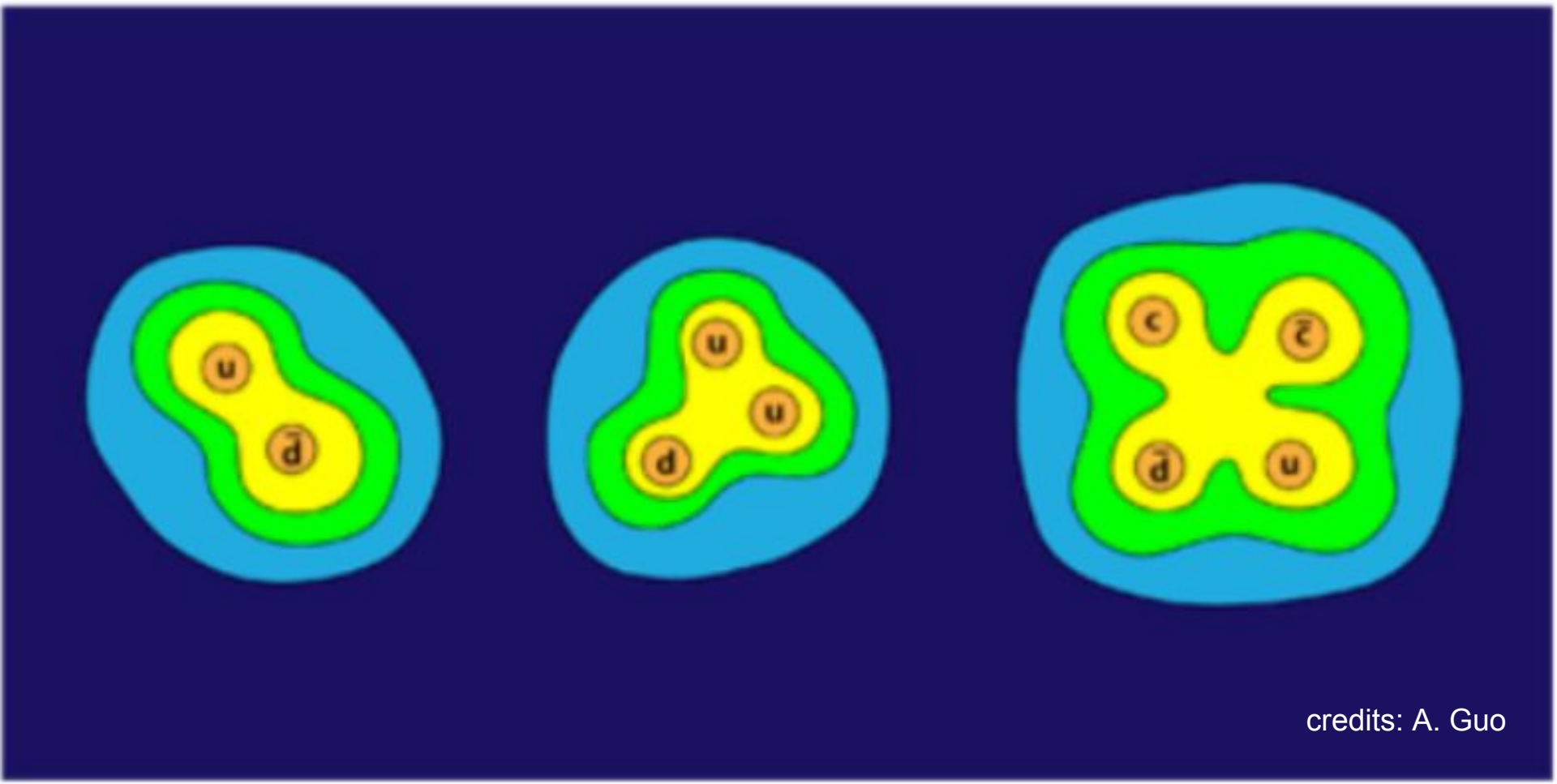


Pythia

QCD



Uncertainty of 0.5 GeV seems feasible!



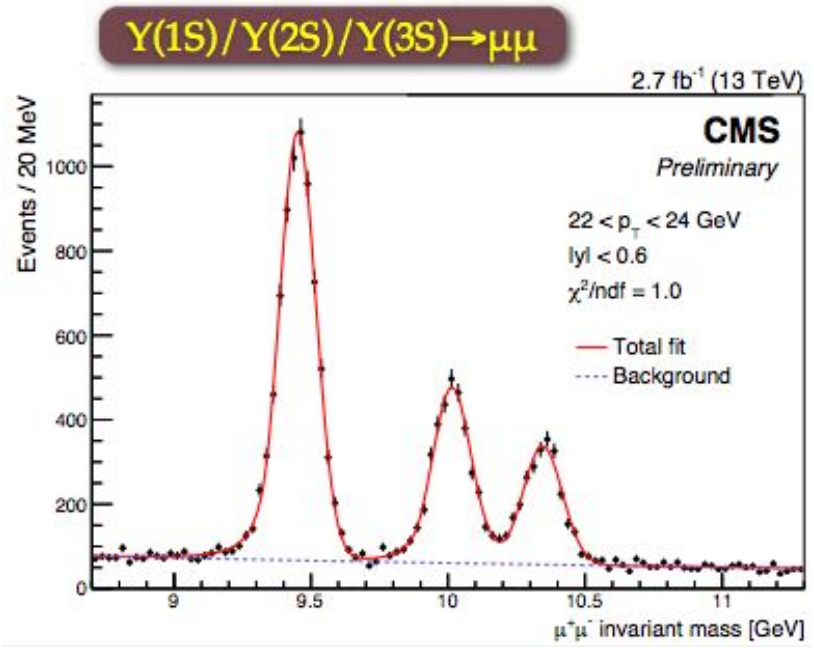
Quarkonia + Exotics

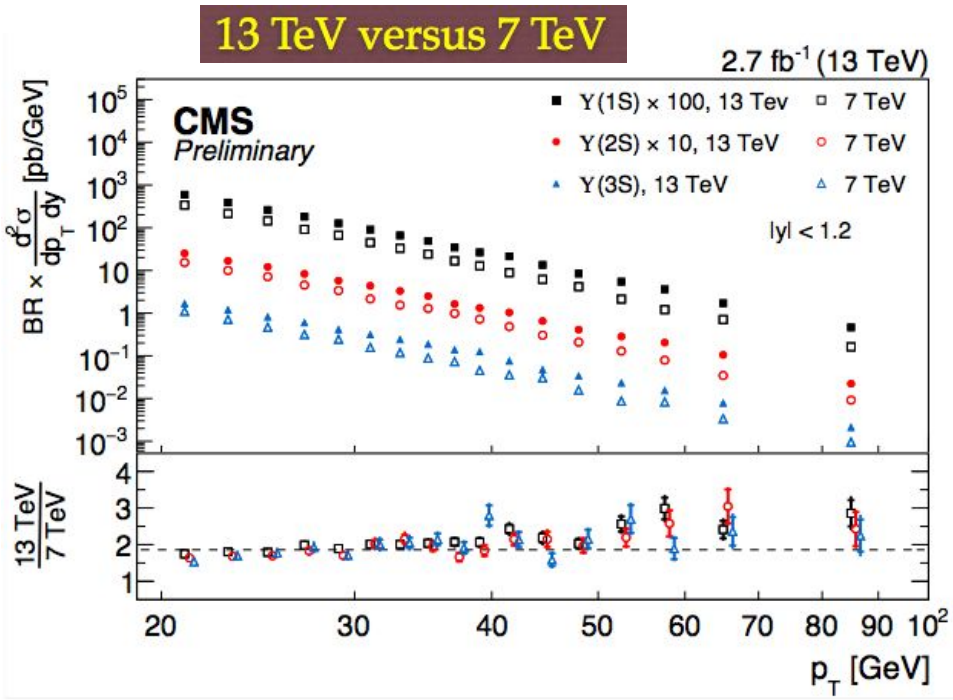
Quarkonia production at 13 TeV

→ Chen

- Differential cross-sections of ψ(nS) vs pT in 4 rapidity bins
- Extending up to 100 GeV
- Look at ratio 13 TeV / 7 TeV

Ref. CMS BPH-15-005

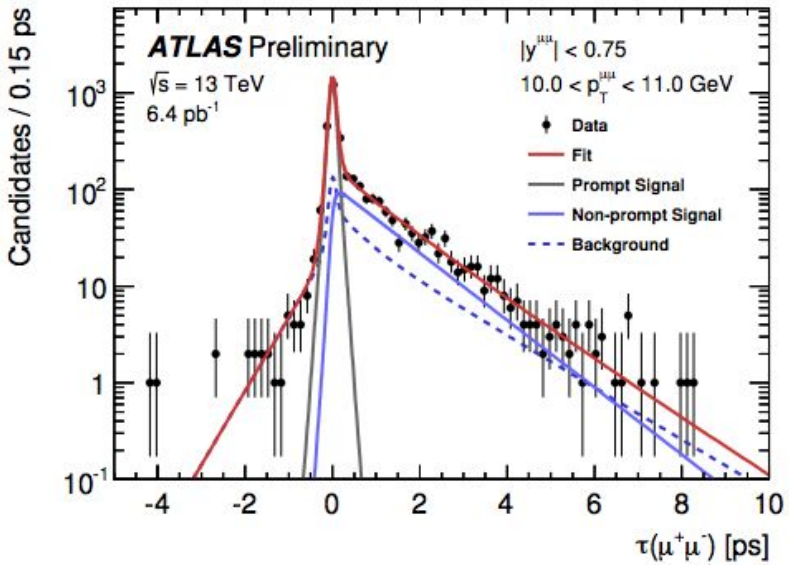


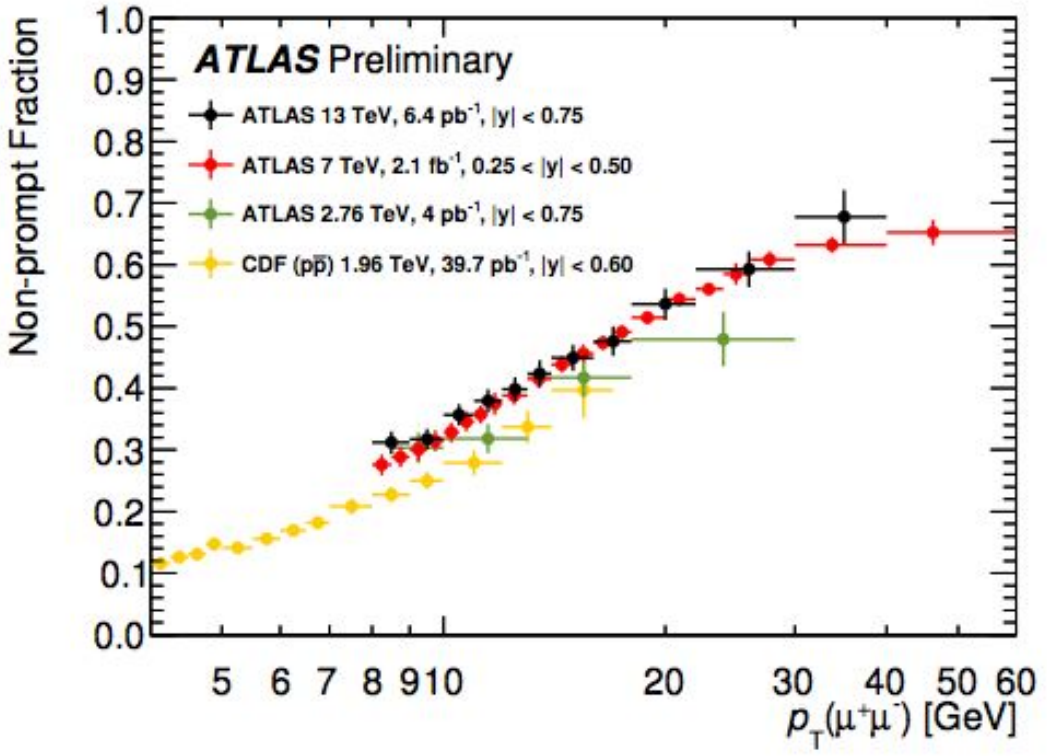


Quarkonia production: prompt vs non-prompt

- Measurement of the differential non-prompt J/ψ fraction
- Fraction increases with p_T
- Checked in 3 bins of rapidity: no significant change
- Some dependence on $\sqrt{s}$ and initial state is observed

→ Maevskiy
→ Cheatham





Quarkonium Production

Color Singlet model vs. NRQCD vs. k_T factorization

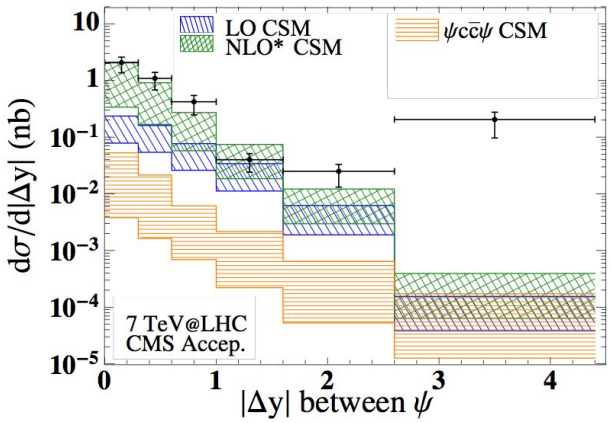
(include color octet states)

None of them successfully describes all available J/ψ data!
("J/ψ polarization puzzle", ...)

Butenschön

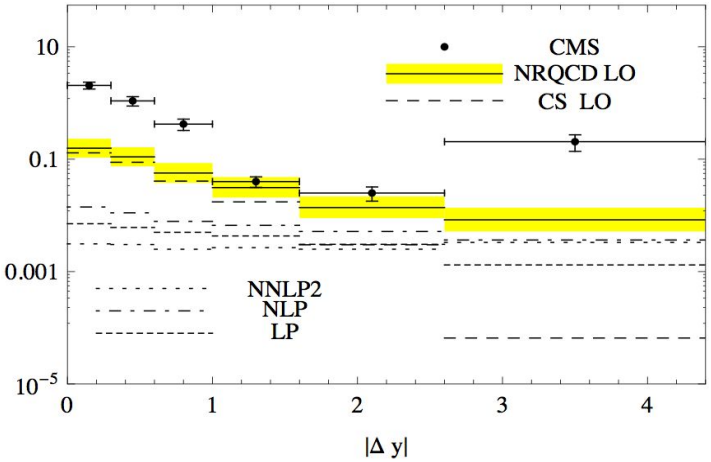
Look at new observables: e.g. J/ψ pair production ⟶ "CMS puzzle"

Lansberg



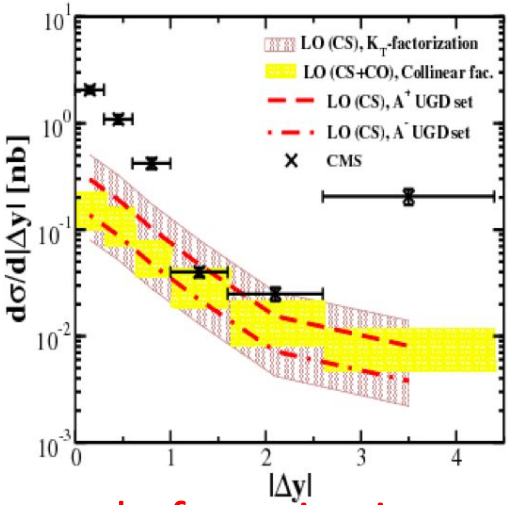
Color Singlet model

He



NRQCD

Baranov



k_T factorization

Quarkonium Production

Color Singlet model vs. NRQCD vs. k_T factorization

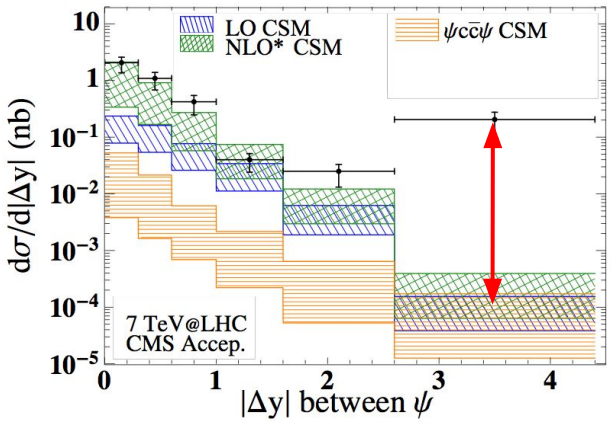
"CMS puzzle": What fills the gap?

- Color Singlet NLO + DPS? Lansberg
- Color Octet NLO? He

None of them s … ("J/ψ polarizat … Butenschön

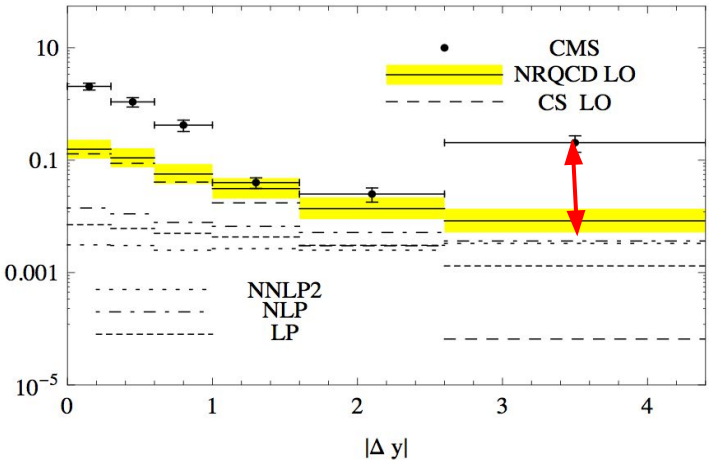
Look at new ob … puzzle"

Lansberg



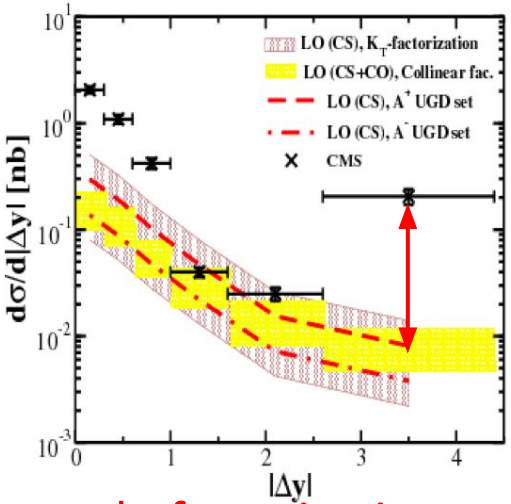
Color Singlet model

He



NRQCD

Baranov

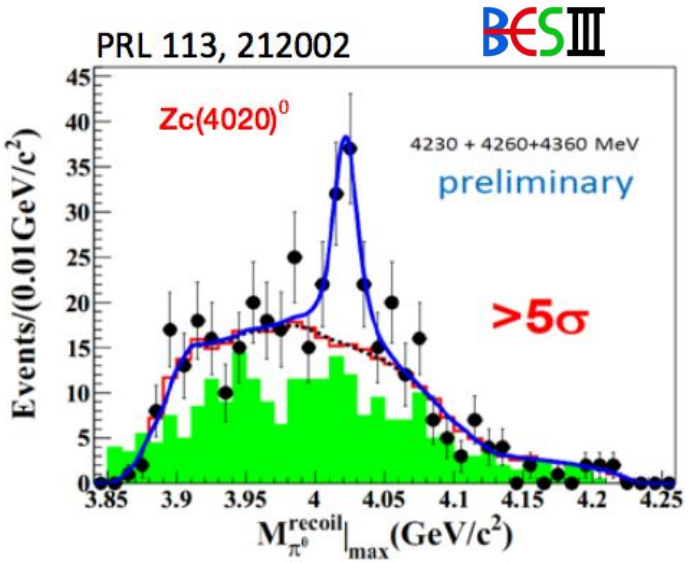


k_T factorization

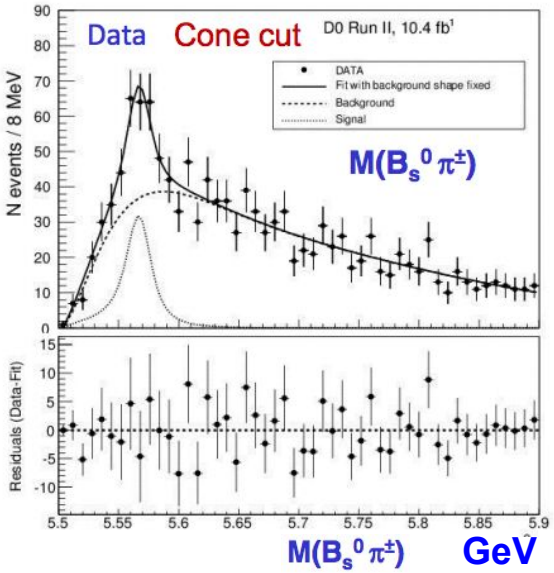
Exotic Quarkonium States X, Y, Z

- Many results on X, Y, Z states from BESIII since 2013
- Observation (5.1 σ) of new $B_s\pi^{\pm}$ state by DZERO
- ATLAS: study of X(3872) in progress; search for / no evidence of Xb

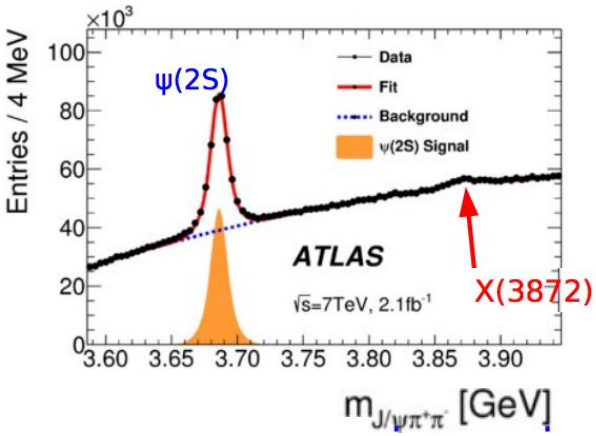
→ Guo



→ Bertram



→ Kordas

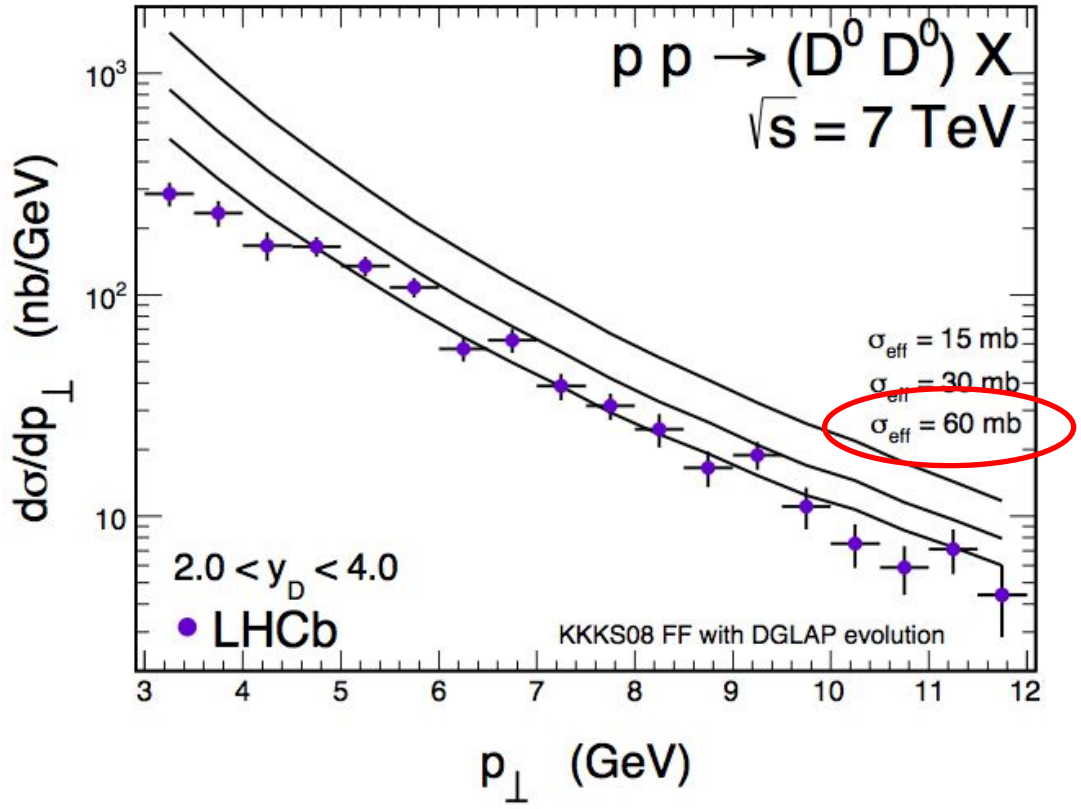


Charm & Beauty Physics

Charmed Meson Production

Karpishkov — D, $D\bar{D}$ production — Parton Reggeization Approach

Szczurek — DD production — different (new) mechanisms, SPS+DPS



What is σ_{eff} ?
(Parameter in DPS model)

Charm hadrons

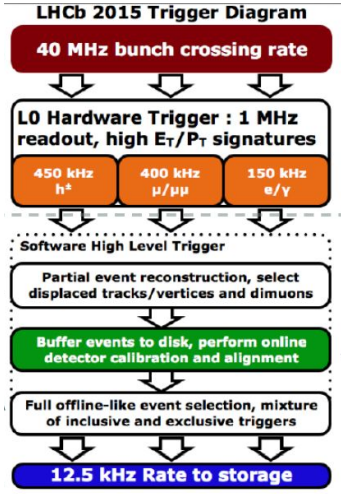
T. Szumiak

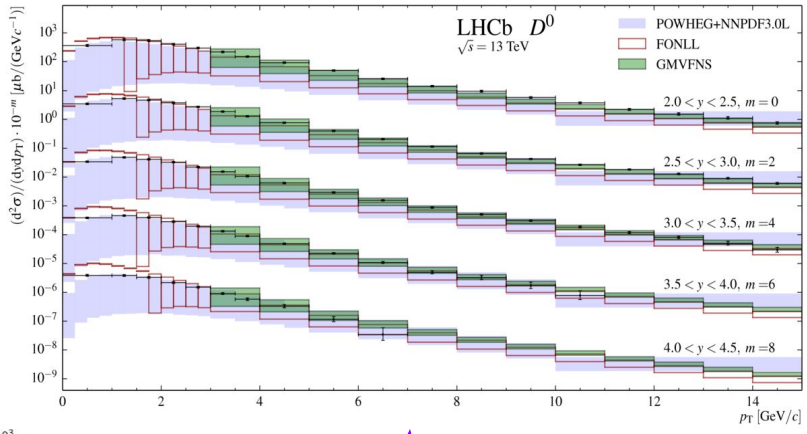
O. Zenaiev

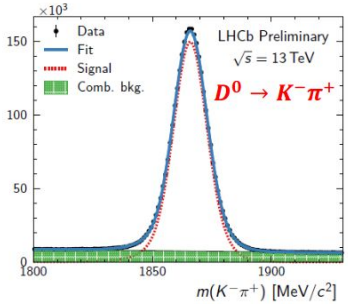
Novel trigger in LHCb for RunII:

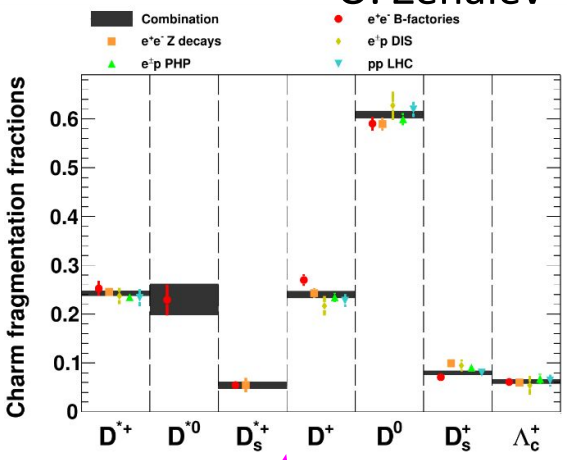
- offline-quality tracking and PID;
- fill-by-fill calibration and alignment;
- 5 kHz TURBO output stream

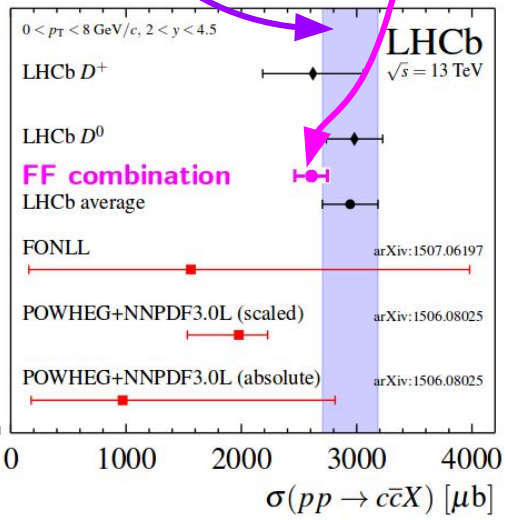
First use in combination of fragmentation fractions







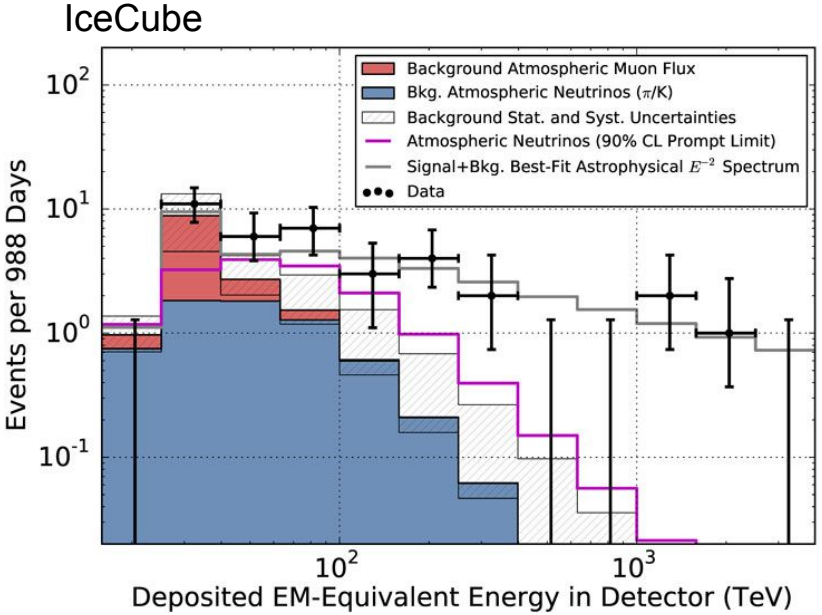


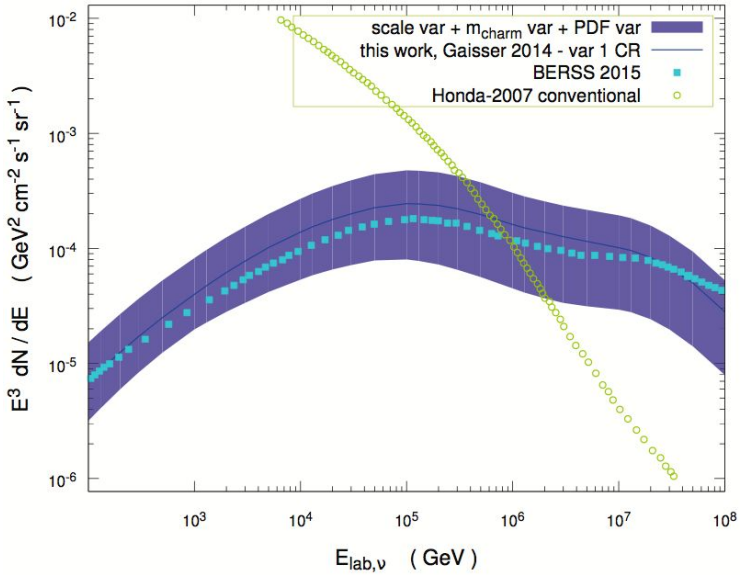


Charm hadroproduction in the atmosphere

Moch

- Cosmic rays + atmospheric nuclei → hadrons → neutrinos + X
- background in neutrino astronomy (astrophysical/DM sources)
  - conventional neutrino flux (from decay of $\pi^{\pm}$, $K^{\pm}$)
  - prompt neutrino flux from charmed and heavier hadrons
- 1st step: pp-collisions at high energy:



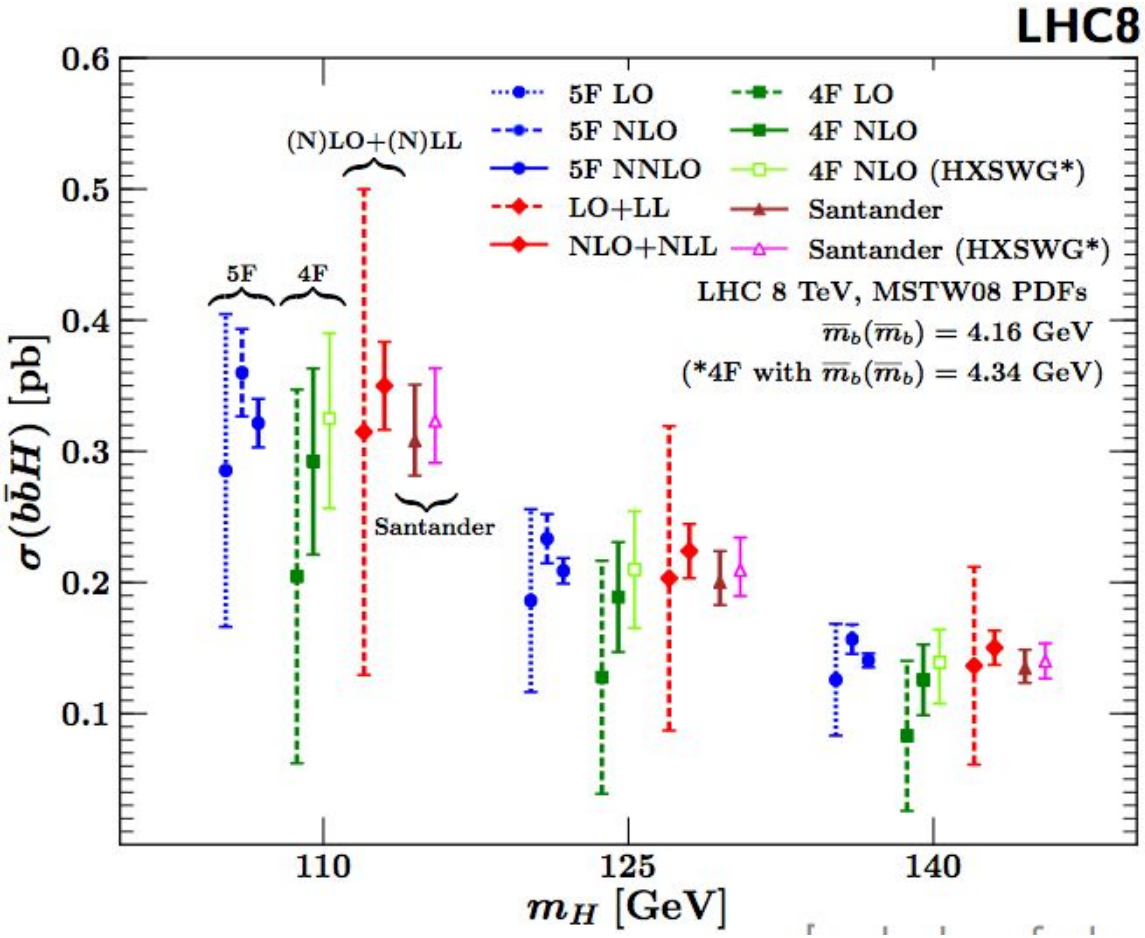


- Not all PDF sets seem to be appropriate for extrapolation to high energies...

bbH production

Papanastasiou

$b\bar{b}H$ production

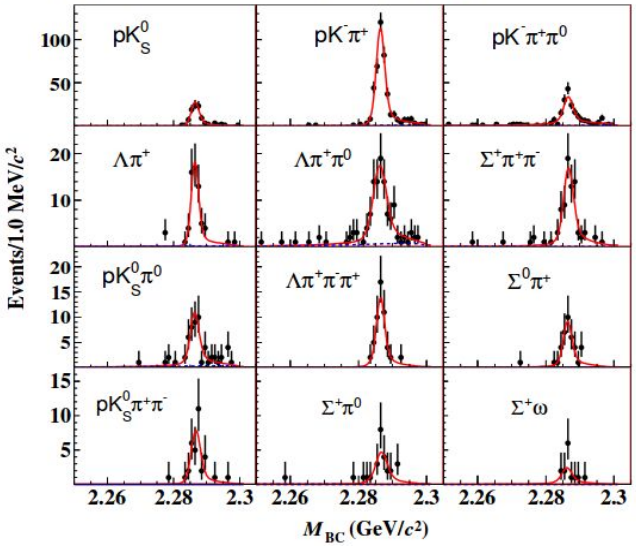


- systematic combination of 4- and 5-Flavour schemes in EFT picture!
- incl. resummation of $\ln \frac{m_b}{m_H}$
- reliable uncertainties from scale variations
  (similar to Santander matching)
- Differs from 4F, 5F, Santander result

Λ_c branching fractions

Z. Yu

Background free double tags



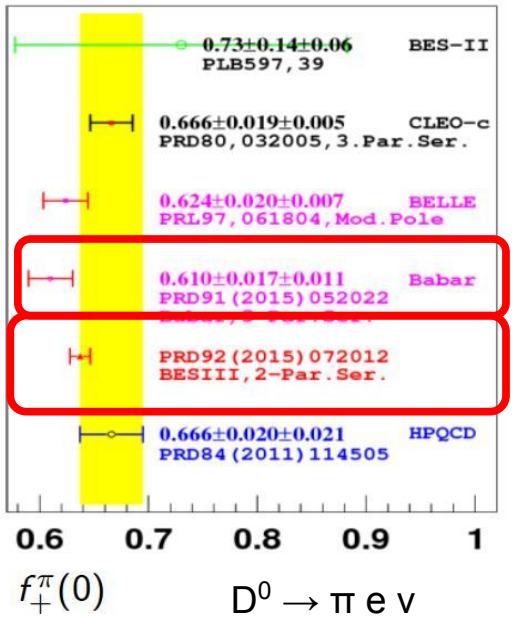
Mode	This work (%)	PDG (%)	BELLE (%)
pK^0_S	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK^0_S\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	(PhysRevLett.113.042002)
$pK^0_S\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	

Full sample of $\Lambda_c\Lambda_c$ events from BESII.

Precision of $B(\Lambda_c \rightarrow pK\pi)$ is comparable with BELLE and superior to PDG2015.

Charm CPV

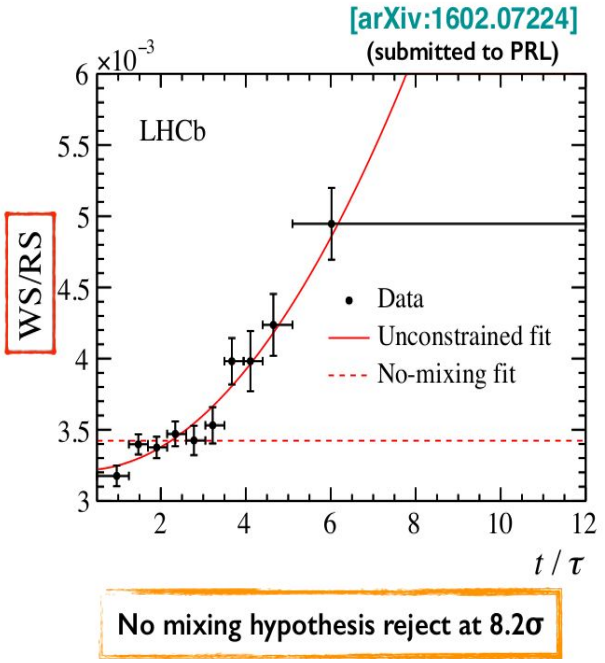
Z. Yu, A. Bevan



$D^0 \to \pi\, e\, \nu$

- Also for decays via K.
- Usage of GPU's for extraction of mixing parameters in BABAR.

P. Marino

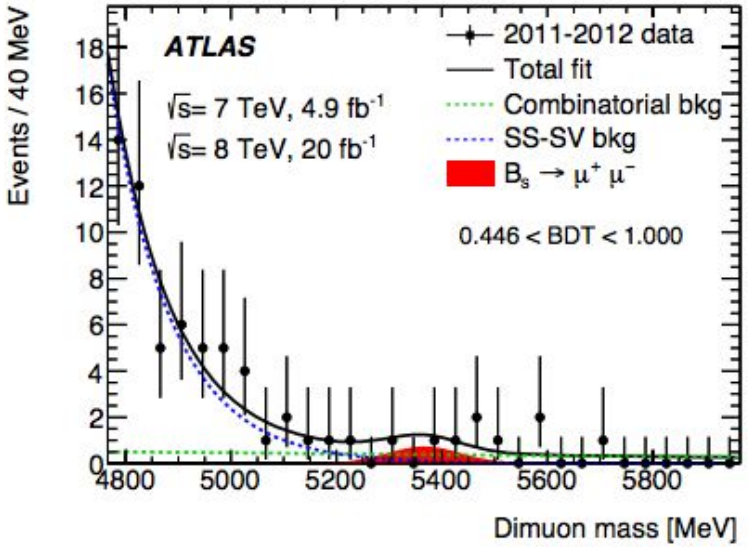


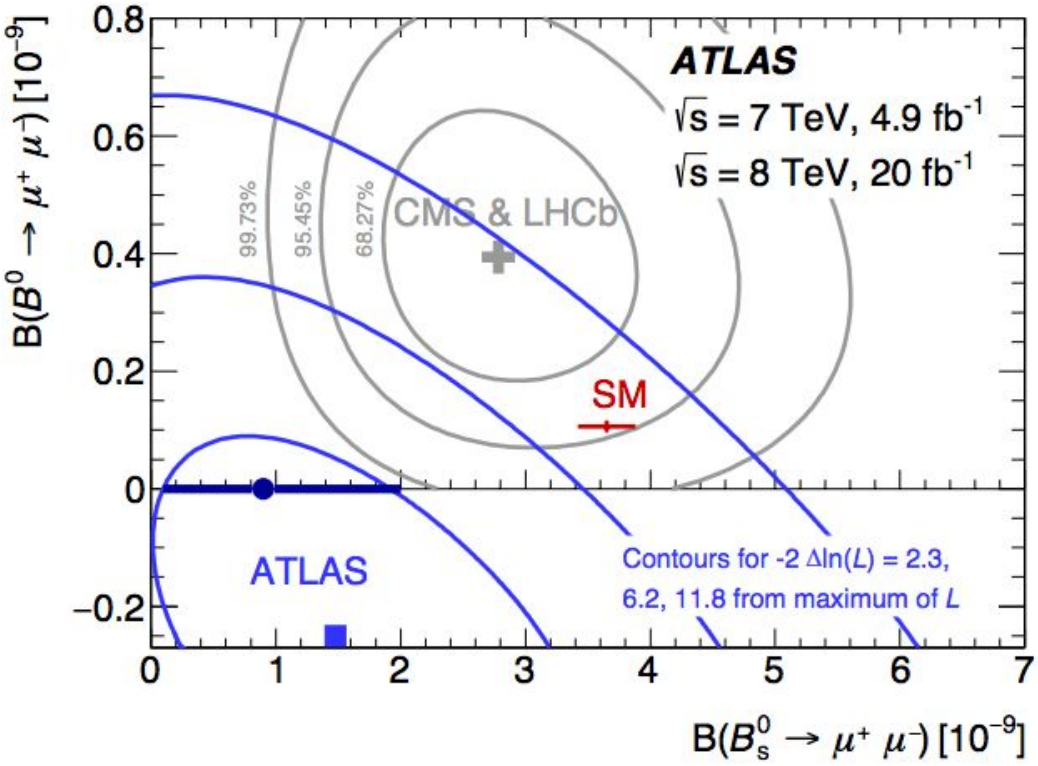
No mixing hypothesis reject at 8.2σ

- First mixing observation in $D^0 \to K^+ \pi^+\pi^-\pi^-$
- $r_D^{K3\pi}$, $R_{WS}^{K3\pi}$ and $y'_{K3\pi}$ were extracted.

ATLAS rare B decays

- ATLAS is consistent with the SM, LHCb and CMS.
- Room for NP destructively interfering with the SM.

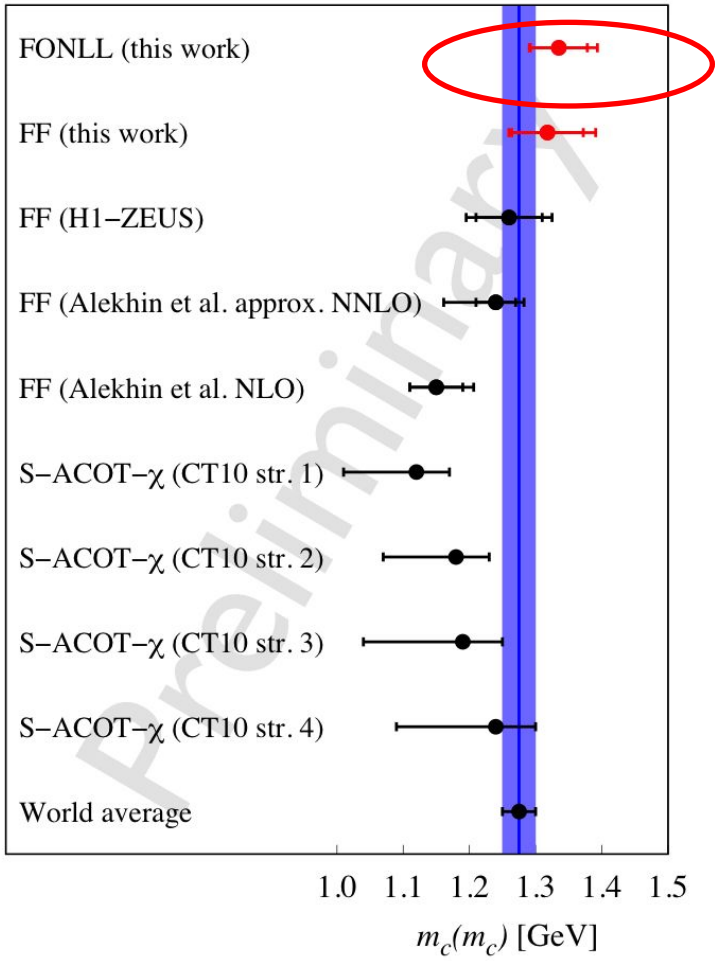




Charm mass from Hera

Bertone

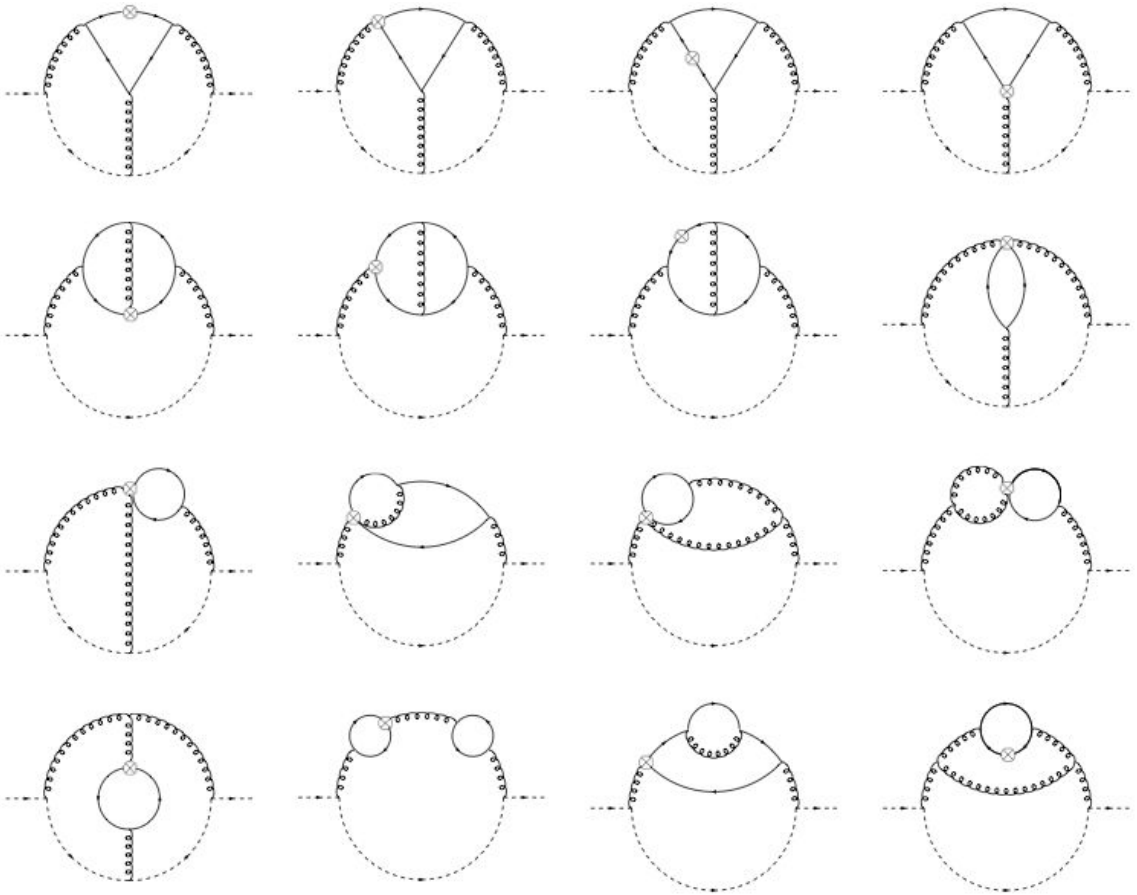
- Charm production in DIS directly sensitive to m_c
- precise Hera data
- new VFNS (FONLL) for Msbar masses implemented in APFEL



$$m_c(m_c) = 1.335 \pm 0.043(\text{exp})^{+0.019}_{-0.000}(\text{param})^{+0.011}_{-0.008}(\text{mod})^{+0.033}_{-0.008}(\text{th})\ \text{GeV}$$

3-Loop Heavy Flavor Corrections to DIS

De Freitas 3-loop matching calculation at large Q

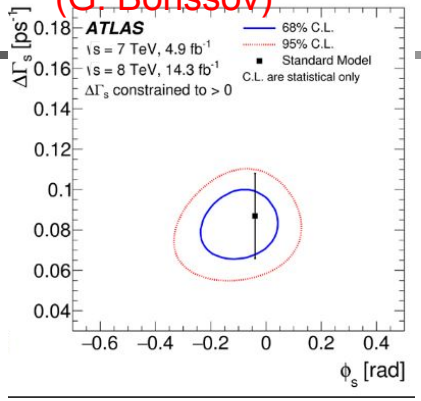


- "heavy" calculation
- uses new technologies (e.g. differential eqs. for MIs)
- Wilson coefficients expressed in terms of heavy quark OMEs
- 6 out of 7 OMEs computed!
- Last OME $A_{Qg}^{(3)}$ partially known, WIP...

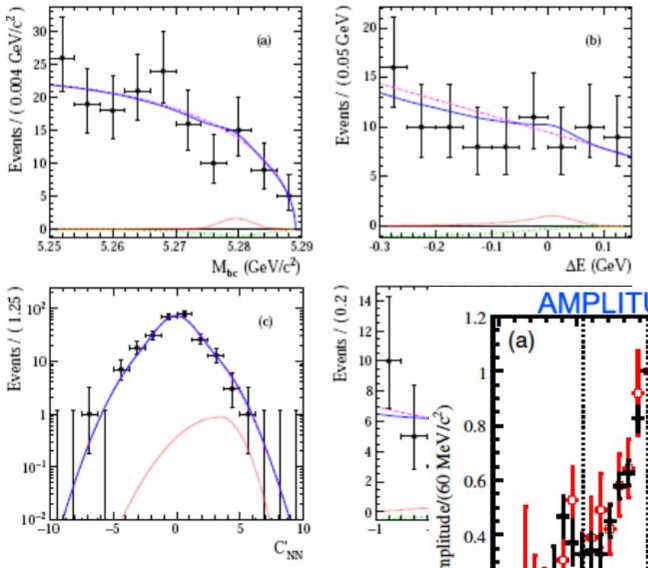
No summary in summary...

Theory and experiment

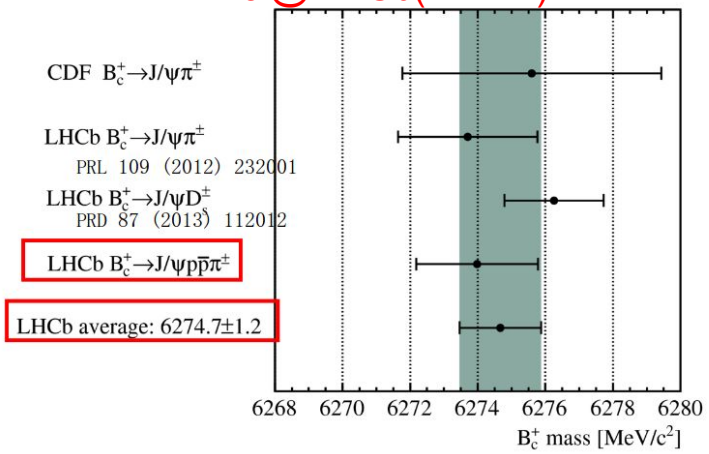
B CPV @ ATLAS
(G. Borissov)



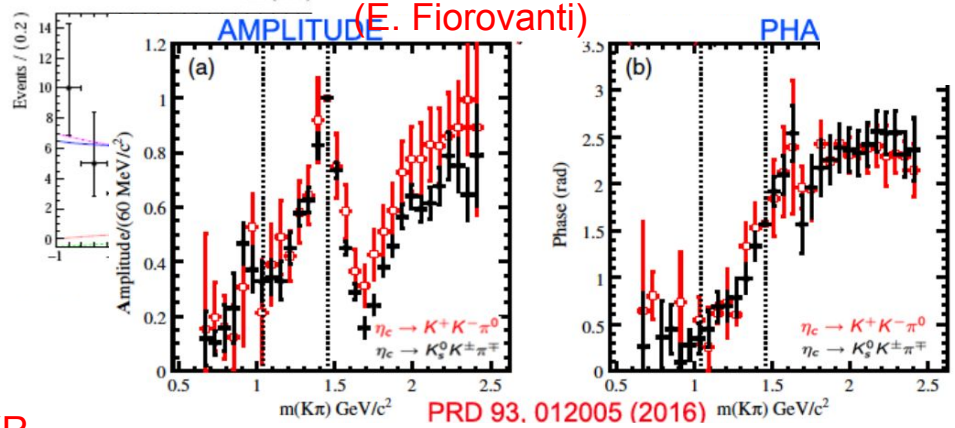
B(B → φγ) < 10^{-7} @ 95% CL @
Belle (D. Dutta)



Bc @ LHCb(H. Yini)

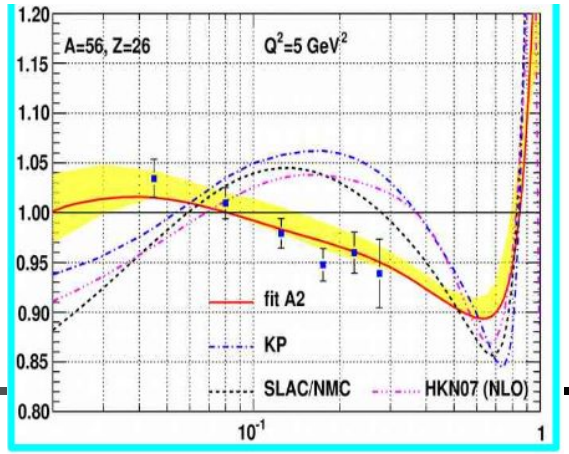


S-wave in K-π @ BaBar
(E. Fiorovanti)

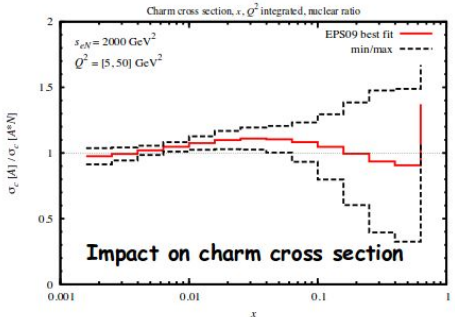


PRD 93. 012005 (2016)

Nuclear PDFs (F. Olness)



Nuclear g @ EIC (R.
Yoshida / C. Weiss)



Diffractive D* in DIS
(K. Cerny)