Summary of EPS Conference 2013

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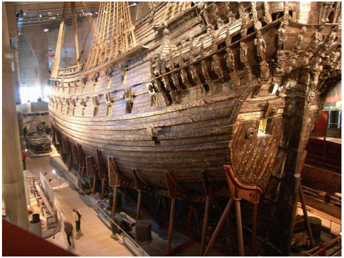
The 2013 European Physical Society Conference on High Energy Physics
Stockholm, Sweden, 18-24 July, 2013

Introduction

- Summary of EPS-HEP 2013
- **MANY** results presented over 6 days
- This is a biased summary
- The conference:
  - Stockholm, Sweden, 18-24 July, 2013
  - Highlights:
    - Reception at City Hall
    - Invited talk from Peter Higgs
    - Conference dinner at Vasa Museum



- 700 physicists present:

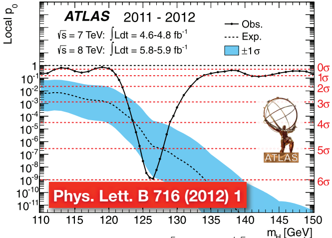
EPS HEPP Prize 2013

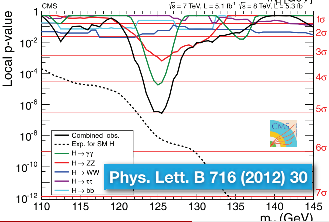
The 2013 High Energy and Particle Physics Prize, for an outstanding contribution to High Energy Physics, is awarded to the ATLAS and CMS collaborations, "for the discovery of a Higgs boson, as predicted by the Brout-Englert-Higgs mechanism", and to Michel Della Negra, Peter Jenni, and Tejinder Virdee, "for their pioneering and outstanding leadership roles in the making of the ATLAS and CMS experiments".

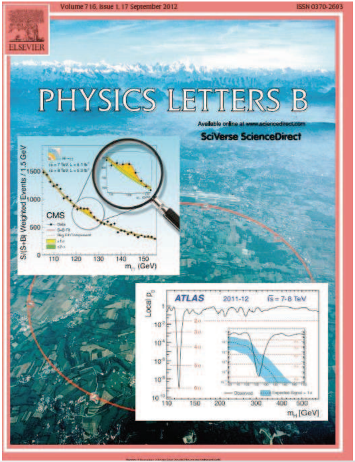
Contents

Higgs Physics

- New Boson discovered July 2012.
- Is it the Higgs Boson?
    - Enough statistics now to start measuring.





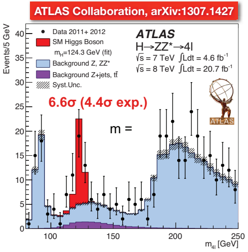


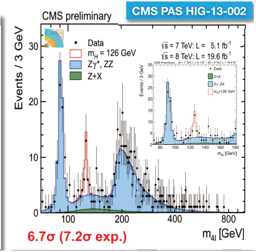
High statistics decay channels

$H \rightarrow ZZ$

- Both experiments now have $> 6\sigma$ in this channel alone.
- High resolution channel.

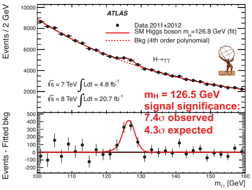
$$m_{\rm H} = 124.3^{+0.6+0.5}_{-0.5-0.3}\ \text{GeV}$$

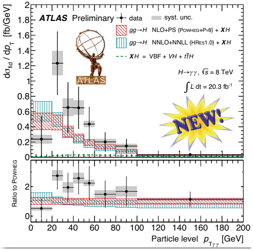




$H \rightarrow \gamma\gamma$

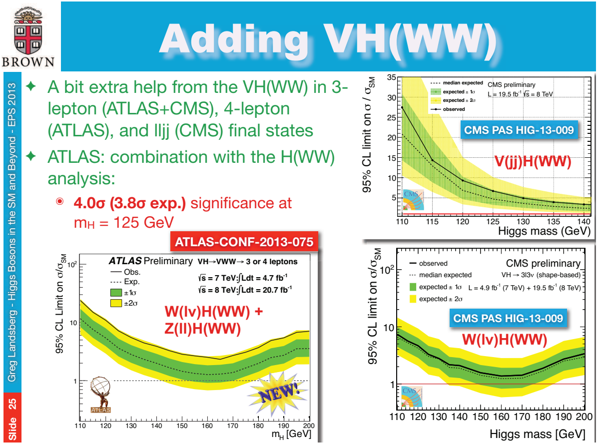
- High backgrounds.
- Sensitive to spin.
- CMS show similar results.
- Some tension in differential production spectra.





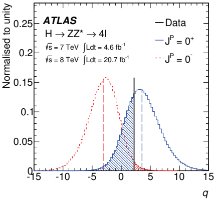
Associated production

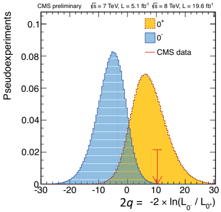
- Starting to add different production mechanisms into the mix.
  - Associated production with a vector boson (VH).
    - Observed in WH channel.
  - Other mechanisms (i.e. VBF): searched still ongoing.



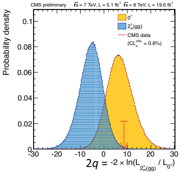
Spin-Parity measurements

- Spin-Parity of the SM model Higgs boson should be $J^P = 0^+$.
- Test against various hypotheses: 0^-, 1^+, 1^-, 2^+.



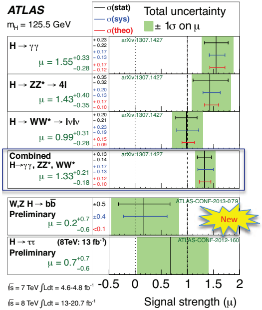


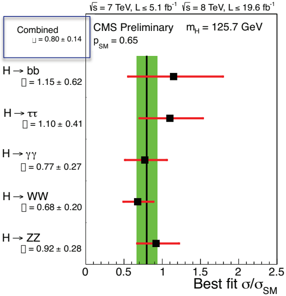
- $J = 1$ states disfavoured by Landau/Yang.
  - Observation of $H \to \gamma\gamma$.
- $H \to ZZ$ used to rule out $J^P = 0^-$
  - ATLAS at 97.8% C.L.
  - CMS at 99.8% C.L.
- Graviton-like $J^P = 2^+$ ruled out.
  - ATLAS >99.9% ($\gamma\gamma + ZZ + WW$)
  - CMS 99.4% ($ZZ + WW$)

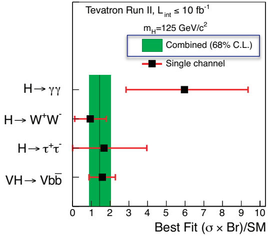


Both experiments favour SM quantum numbers.

Signal Strength $\mu = \sigma/\sigma_{SM}$







- Combined μ → Best accuracy but no strong physics motivation:
  - **ATLAS (γγ, WW* and ZZ*)** μ = **(1.33 ± 0.20)** (1.23±0.18 including bb and ττ)
  - **CMS (γγ, ττ, bb, WW* and ZZ*)** μ = **(0.80 ± 0.14)**
  - **TEVATRON (bb, γγ, ττ, WW*)** μ = **(1.44 ± 0.60)**

Compatible with SM Higgs boson expectation: Accuracy ~ 15%

5/22/13 F. Cerutti LBNL - EPS-HEP Stockolm 2013 15

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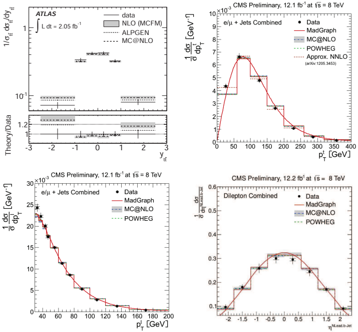
Top Pair Production

- LHC is a top factory:

ATLAS: $\sigma_{t\bar{t}} = 232 \pm 2(\text{stat}) \pm 31(\text{syst}) \pm 9(\text{lumi})$ pb

- Differential cross-sections measured:
  - Consistent with theoretical models.



- Mass measurements
  - ATLAS measured using a 3D fit to $M_{\text{top}}^{\text{reco}}$, $M_{\text{W}}^{\text{reco}}$, and $R_{\text{lb}}^{\text{reco}}$.
  - CMS using a lifetime-based technique.

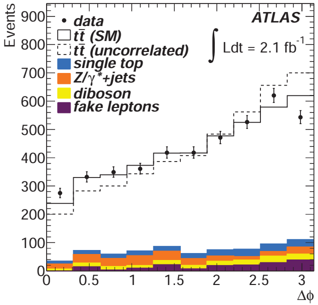
ATLAS:

$$M_{\text{top}} = 172.31 \pm 0.23(\text{stat}) \pm 0.27(\text{JSF}) \pm 0.67(\text{bJSF}) \pm 1.35(\text{syst}) \text{ GeV}$$

CMS: $M_{\text{top}} = 173.5 \pm 1.5(\text{stat}) \pm 1.3(\text{syst}) \pm 2.6(\text{p}_\text{T}) \text{ GeV}$

Spin Correlations

- Spins of top and anti-top are correlated in SM.
- Short top quark lifetime ($\sim 5 \times 10^{-25}$ s) means spin information is carried on to decay products.



- Measure fraction of SM-like events, f^{SM}, using template fit to $\Delta\phi(\ell\ell)$ distribution.
  - $f^{SM} = 0 \rightarrow$ no correlations.
  - $f^{SM} = 1 \rightarrow$ correlations (SM).

ATLAS: $f^{SM} = 1.30 \pm 0.14^{+0.27}_{-0.22} \rightarrow 5.1\sigma$

Phys. Rev. Lett. 108, 212001 (2012)

CMS: $f^{SM} = 0.74 \pm 0.08(\text{stat}) \pm 0.24(\text{syst})$

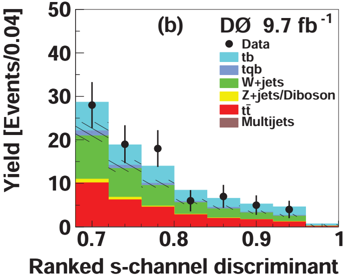
CMS-TOP-12-004

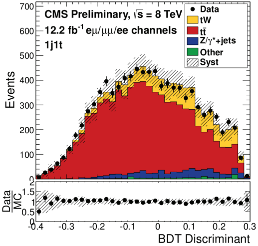
D0: $f^{SM} = 0.85 \pm 0.29 \rightarrow 3.1\sigma$

Phys. Rev. Lett. 108, 032004 (2012)

Single Top Production

- Single-top production occurs in several channels.
  - t-channel production already observed at Tevatron and LHC.
  - New: Evidence for s-channel production at D0.
  - New: Observation of Wt-channel process at CMS.

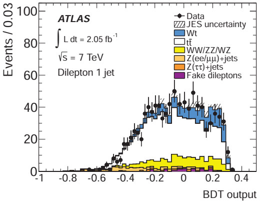




$\sigma = 23.4^{+5.5}_{-5.4}$ pb

6.0σ significance

CMS-PAS-TOP-12-040



$\sigma = 16.8 \pm 2.9(\text{stat}) \pm 4.9(\text{syst})$ pb

3.3σ significance

Phys. Lett. B 716, 142 (2012)

- Also lots of activity looking for new physics with top quarks:
  - CP Violations, FCNC, Baryon Number Violation etc.

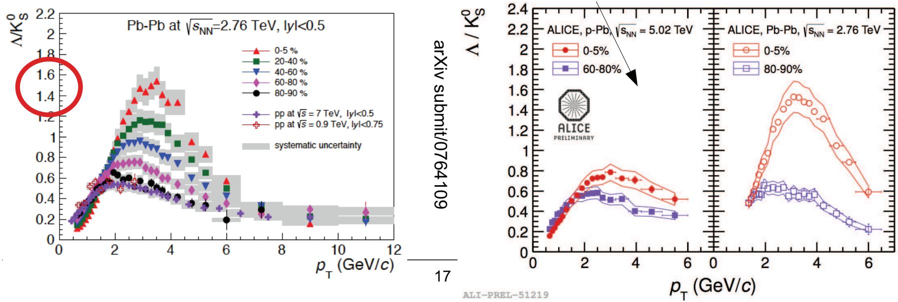
Contents

Heavy Ion Collisions

- Recently results from LHC compare Pb-Pb and p-p collisions.
  - Looking for signatures of new states of matter e.g Quark Gluon Plasma (QGP)
  - Uses p-p collisions as a control channel.
  - Problem is big differences between Pb-Pb and p-p collisions.
- Recent run at LHC in 2013 dedicated to investigating p-Pb collisions.
  - Disentangle initial state effects.
  - Highlights any effects to to cold nuclear matter.
  - Lets LHCb into the Heavy Ion game!
- Collide p-Pb and Pb-p to get forward and backward measurements.

Baryon Anomaly

- Enhanced ratio of Λ/K^0_S at medium p_T.
- Observed in Pb-Pb collisions.
- Also observed at RHIC.
- More enhanced for more central collisions.

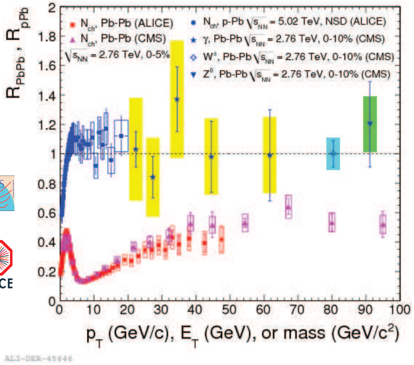


Crucially: not observed in p-Pb collisions

Nuclear Modification Factor

$$R_{\mathrm{AA}} = \frac{\text{Yield in AA}}{\text{Yield in pp}} \times \frac{1}{N_{\mathrm{coll}}}$$

No medium effect → $R_{AA} \approx 1$
Medium effect → medium "slows" down particles → $R_{AA} < 1$



- No modification for vector bosons: γ $W^{\pm}$ Z^0
- Strong suppression for charged hadrons, still significant at 100 GeV/c !
- Look at charm and beauty

ALICE: (Pb-Pb) PLB720 (2013) 52, (p-Pb) PRL 110, 082302 (2013)

CMS: (W) PLB 715 (2012) 66; (Z) PRL 106, 212301 (2011); (γ) PLB 710 (2012) 256; (charged) EPJC (2012) 72:1945

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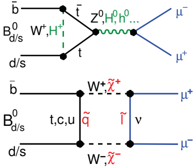
Contents

$B^0_{(s)} \to \mu^+\mu^-$

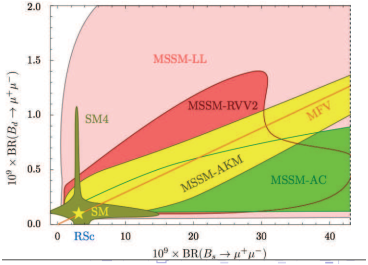
- LHCb and CMS both presented results in the search for these rare decays.
- Will concentrate on details of LHCb analysis
- Interesting decays:
  - FCNC process: forbidden at tree level.
  - New physics/particles enter via the loops.
  - Theoretically very clean.
  - $|V_{ts}| > |V_{td}| \implies B^0$ decay supressed



Branching fractions predicted in SM using Lattice QCD:

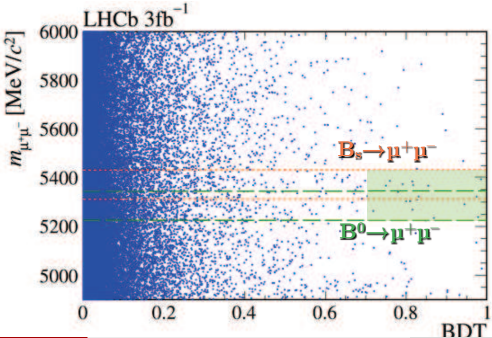
$$\mathcal{B}(B^0_s \to \mu^+\mu^-)_{SM} = (3.57 \pm 0.9) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-)_{SM} = (1.07 \pm 0.1) \times 10^{-10}$$



LHCb Analysis

- LHCb presented first evidence (3.5σ) for $B^0_s \to \mu^+\mu^-$ based on 2011 data.
- Now analysing full $3\,\mathrm{fb}^{-1}$ 2011 + 2012 dataset.
- Analysis performed blind.
- Using a Boosted Decision Tree (BDT).
  - Uses kinematic and geometric variables.
  - Trained using Monte Carlo calibrated to data.
- Unbinned maximum likelihood fit performed in bins of BDT response.



Normalisation

- Two normalisation channels used to control systematics.
  - $B^+ \to J/\psi(\mu^+\mu^-)K^+$
  - $B^0 \to K^+\pi^-$
- Use these to measure relative branching fractions.

$$\mathcal{B} = \mathcal{B}_{\rm cal} \times \frac{\epsilon^{\rm RECO}_{\rm cal} \times \epsilon^{\rm SEL}_{\rm cal}}{\epsilon^{\rm RECO}_{\rm sig} \times \epsilon^{\rm SEL}_{\rm sig}} \times \frac{\epsilon^{\rm TRG}_{\rm cal}}{\epsilon^{\rm TRG}_{\rm sig}} \times \frac{f_{\rm cal}}{f_{\rm d(s)}} \times \frac{N_{\rm sig}}{N_{\rm cal}} = \alpha_{\rm (s)} \times N_{\rm sig}$$

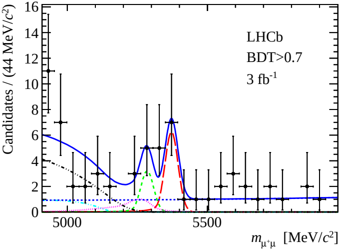
- Reco and sel efficiencies calculated from Monte Carlo, cross checked on data.
- Trigger efficiencies calculated from data sample of $J/\psi \to \mu^+\mu^-$.
- $\frac{f_{\rm d}}{f_{\rm s}}$ dominant systematic for $B^0_{\rm s} \to \mu^+\mu^-$.
- α measured for each control channel and averaged:

$$\alpha_{\rm s} = (9.41 \pm 0.65) \times 10^{-11}$$

$$\alpha = (2.4 \pm 0.09) \times 10^{-11}$$

Results from LHCb

- UML fit to data, integrated over last 3 BDT bins:
- Significance of signal $= 4.0\sigma$



$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (2.9^{+1.1}_{-1.0}(\text{stat})^{+0.3}_{-0.1}(\text{syst})) \times 10^{-9}$$

- Significance of the B^0 signal is only 2.0σ.

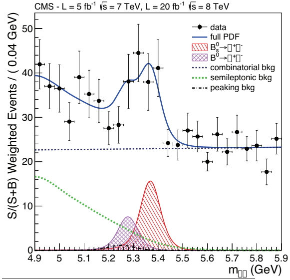
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.7^{+2.4}_{-2.1}(\text{stat})^{+0.6}_{-0.4}(\text{syst})) \times 10^{-10}$$

Use CLs method to place an upper limit on the branching fraction:

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 6.3\ (7.4) \times 10^{-10} \text{ at } 90\%\ (95\%) \text{ CL}$$

Results from CMS

- CMS employs a similar analysis strategy.
- Significance of signal $= 4.3\sigma$



$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.0^{+0.9}_{-0.8}(\mathrm{stat})^{+0.6}_{-0.4}(\mathrm{syst})) \times 10^{-9}$$

- Significance of the B^0 signal is only 2.0σ.

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.5^{+2.1}_{-1.8}) \times 10^{-10}$$

Use CLs method to place an upper limit on the branching fraction:

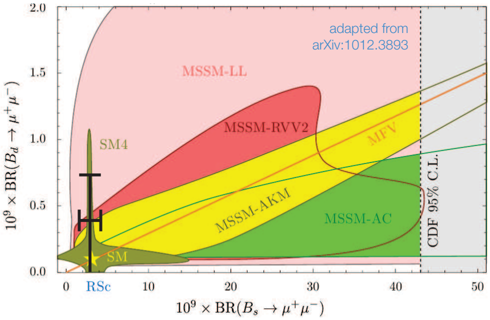
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.1 \times 10^{-9} \text{ at } 95\% \text{ CL}$$

Combined results

- Very quick work from LHCb and CMS to combine results.
- LHCb-CONF-2013-012
- Haven't combined significance of signal properly, but clearly $> 5\sigma$
- No combined limit on $B^0 \to \mu^+\mu^-$.

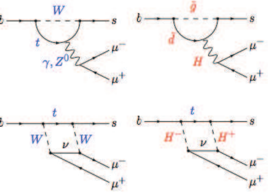
$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

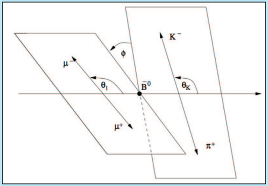
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$$



Contents

$B^0 \to K^* \mu^+ \mu^-$



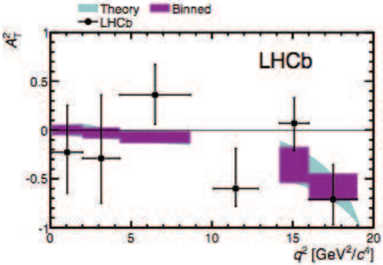


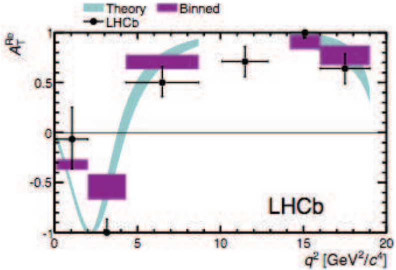
- $b \to s$ transitions are FCNC.
- New physics can alter angular correlations.

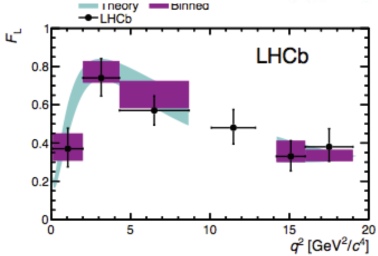
$$
\begin{aligned}
\frac{1}{\Gamma}\frac{d^3(\Gamma+\bar{\Gamma})}{d\cos\theta_\ell \, d\cos\theta_K \, d\phi} = \frac{9}{32\pi}\Big[& \frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell \\
& - F_L\cos^2\theta_K\cos 2\theta_\ell + \\
& S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \\
& S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6^s\sin^2\theta_K\cos\theta_\ell + \\
& S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + \\
& S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi \Big]
\end{aligned}
$$

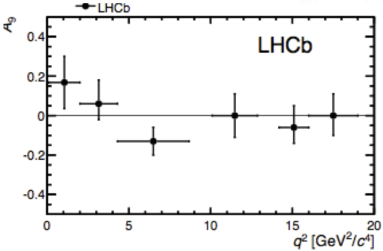
Altmannshofer et al. (2008)

Results I


Theory
Binned
LHCb
A_T^2
LHCb
q^2 [GeV^2/c^4]


Theory
Binned
LHCb
A_T^{Re}
LHCb
q^2 [GeV^2/c^4]


Theory
Binned
LHCb
F_L
LHCb
q^2 [GeV^2/c^4]

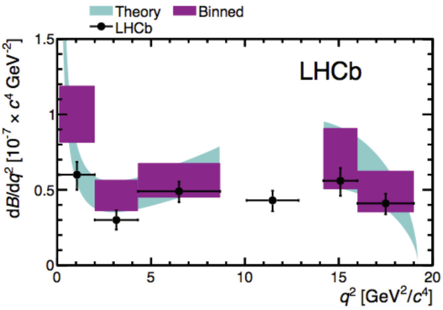

LHCb
A_9
LHCb
q^2 [GeV^2/c^4]

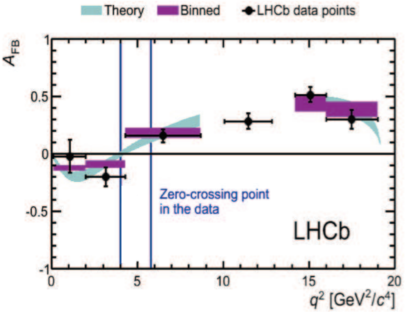
Results II

- Forward-backward asymmetry of particular interest.
  - Crossing point sensitive to new physics.
  - LHCb present first measurement.

$$q_0^2 = 4.9 \pm 0.9\ \mathrm{GeV}^2/\mathrm{c}^2$$

$$q_0^{2\ \mathrm{SM}} = 3.95 \pm 0.38\ \mathrm{GeV}^2/\mathrm{c}^2$$





New Angular Variables

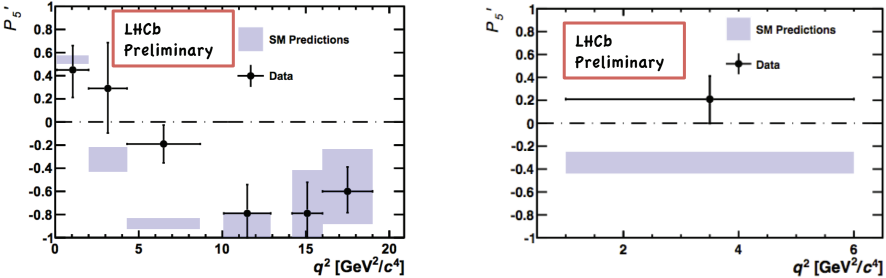
- Theorists propose new angular variables
  - Slightly less dependant on form factor models.

$$
\begin{aligned}
\frac{1}{\Gamma}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[& \frac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K + F_{\mathrm{L}}\cos^2\theta_K + \frac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K\cos 2\theta_\ell \\
& - F_{\mathrm{L}}\cos^2\theta_K\cos 2\theta_\ell + \frac{1}{2}(1-F_{\mathrm{L}})A_{\mathrm{T}}^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \\
& \sqrt{F_{\mathrm{L}}(1-F_{\mathrm{L}})}P_4'\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \sqrt{F_{\mathrm{L}}(1-F_{\mathrm{L}})}P_5'\sin 2\theta_K\sin\theta_\ell\cos\phi + \\
& (1-F_{\mathrm{L}})A_{Re}^{\mathrm{T}}\sin^2\theta_K\cos\theta_\ell + \sqrt{F_{\mathrm{L}}(1-F_{\mathrm{L}})}P_6'\sin 2\theta_K\sin\theta_\ell\sin\phi + \\
& \sqrt{F_{\mathrm{L}}(1-F_{\mathrm{L}})}P_8'\sin 2\theta_K\sin 2\theta_\ell\sin\phi + (S/A)_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\ \Big]
\end{aligned}
$$

Results III

NEW

LHCb collaboration (1fb^{-1}), LHCb-PAPER-2013-037

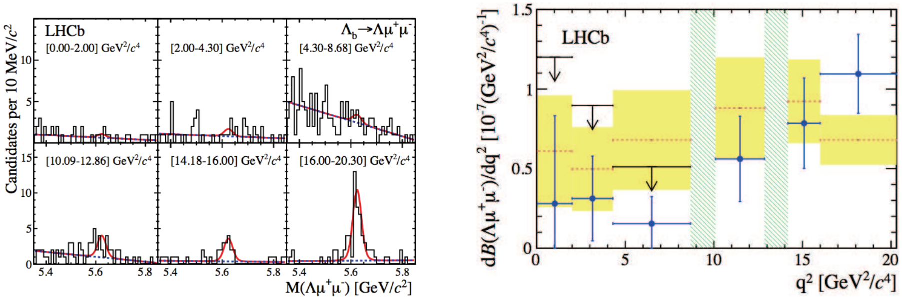


- Some tension between measurement and theory for P_5'
  - $\approx 2.8\sigma$ when consider 24 independant measurements.

$\Lambda_b^0 \to \Lambda\mu^+\mu^-$

- Other $b \to s$ decays available.
  - $B^0 \to K^0\mu^+\mu^-$, $B_s^0 \to \phi\mu^+\mu^-$, $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ ...
- First results from LHCb for $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ shown:
  - $\Lambda_b^0 \to \Lambda J/\psi$ as control channel.
  - Differential branching fraction measured in q^2 bins.
  - Total of 80 events in all bins.

$$\mathcal{B}(\Lambda_b^0 \to \Lambda\mu^+\mu^-) = (0.96 \pm 0.16(\text{stat}) \pm 0.13(\text{syst}) \pm 0.21(\text{norm})) \times 10^{-6}$$



Predictions from Detmold et al. (2012)

Contents

Introduction

- Search for $\Lambda_b^0 \to \Lambda\eta'$ and $\Lambda_b^0 \to \Lambda\eta$.
- Investigate the phenomena of η–η' mixing.
  - $\eta^{(\prime)}$ mass eigenstates described by mixing of flavour eigenstates.

$$\begin{pmatrix} |\eta\rangle \\ |\eta'\rangle \end{pmatrix} = \begin{pmatrix} \cos\phi_{\mathrm{p}} & -\sin\phi_{\mathrm{p}} \\ \sin\phi_{\mathrm{p}} & \cos\phi_{\mathrm{p}} \end{pmatrix} \begin{pmatrix} |\eta_q\rangle \\ |\eta_s\rangle \end{pmatrix}.$$

$$|\eta_q\rangle = \frac{1}{\sqrt{2}}|u\overline{u} + d\overline{d}\rangle$$

$$|\eta_s\rangle = |s\overline{s}\rangle$$

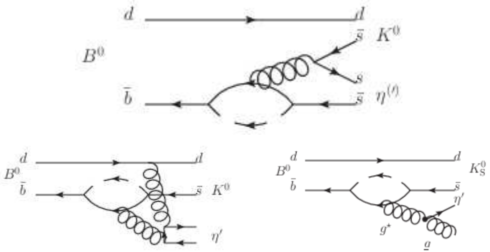
  - Introduce gluonic component to η' wavefunction.

$$|\eta\rangle \approx \cos\phi_{\mathrm{p}}|\eta_q\rangle - \sin\phi_{\mathrm{p}}|\eta_s\rangle$$

$$|\eta'\rangle \approx \cos\phi_{\mathrm{G}}\sin\phi_{\mathrm{p}}|\eta_q\rangle + \cos\phi_{\mathrm{G}}\cos\phi_{\mathrm{p}}|\eta_s\rangle + \sin\phi_{\mathrm{G}}|\mathrm{gg}\rangle.$$

  - Has interesting consequences for branching fractions.

Branching Fractions



- Extra Feynman Diagrams available for η' decays $\Longrightarrow$ interference!

$$\mathcal{B}(B^0 \to K^0\eta') = (66 \pm 4) \times 10^{-6}$$

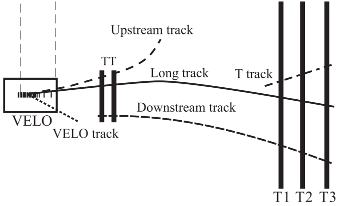
$$\mathcal{B}(B^0 \to K^0\eta) = (1.23^{+0.27}_{-0.24}) \times 10^{-6}$$

- Measure relative branching ratio of $B \to X\eta'$ to $B \to X\eta$ decays.
- Many different decays needed to measure ϕ_{p} and ϕ_{G}
- No baryonic decay yet observed.

Expected: $\mathcal{B}(\Lambda_b^0 \to \Lambda\eta^{(\prime)}) \approx (2 - 40) \times 10^{-6}$ arxiv:hep-ph/0305031

Analysis

- Based on LHCb-CONF-2013-010
  - Preliminary results presented.
  - Using 2012 dataset ($2\,\mathrm{fb}^{-1}$).
  - Search for $\Lambda_b^0 \to \Lambda\eta'$.
  - Using $B^0 \to K_S^0\eta'$ as control channel.



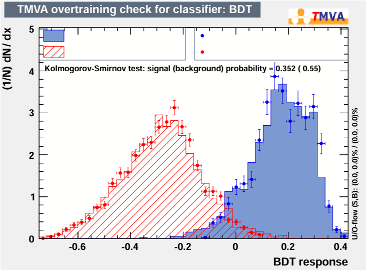
- Reconstruct $\eta' \to \pi^+\pi^-\gamma$, $K_S^0 \to \pi^+\pi^-$ $\Lambda \to p\pi^-$
- Selection is cut-based preselection + BDT.
- PID selection to separate π K and p.
  - Data reweighted by PID efficiency.
- Selection different depending where the K_S^0/Λ decays.
  - Upstream of VeLo: Long-Long selection (LL).
  - Downstream of VeLo: Down-Down selection (DD).
- Selection optimised separately for two categories.

Boosted Decision Tree (BDT)

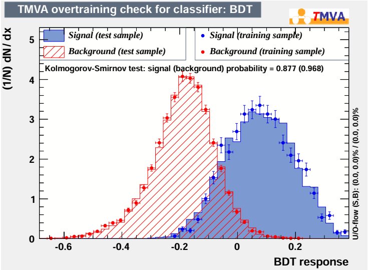
- Takes many variables which discriminate between signal and background
- Combines them into one powerful discriminant (BDT response)
- Trained using signal MC and data sidebands to model the background

Particle	Variables
B^0 (Λ_b^0)	p_T, log(FD χ^2), log($\tau\chi^2$), log(1 - DIRA Angle), Decay Vertex χ^2
K_S^0 (Λ^0)	p, log(IP χ^2), log(FD χ^2)
η'	p_T, log(IP χ^2)
γ	log(E_T)

BDT Response (LL)



BDT Response (DD)



Normalisation

- Measuring ratio of branching fractions:

$$R = \frac{\mathcal{B}(\Lambda_b^0 \to \Lambda^0\eta')}{\mathcal{B}(B^0 \to K^0\eta')} = \frac{N_S(\Lambda_b^0)}{N_S(B^0)} \times \frac{\epsilon_{acc}(B^0)}{\epsilon_{acc}(\Lambda_b^0)} \times \frac{\epsilon_{tot}(B^0)}{\epsilon_{tot}(\Lambda_b^0)} \times \frac{f_d}{f_{\Lambda_b}} \times \frac{0.5 \times \mathcal{B}(K_S^0 \to \pi^+\pi^-)}{\mathcal{B}(\Lambda^0 \to p\pi^-)}$$

- Production fractions measured by LHCb
  - Function of p_{T}
  - Largest systematic uncertainty (27%)

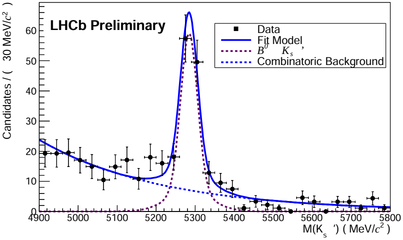
$$\frac{f_{\Lambda_b}}{(f_u + f_d)} = (0.404 \pm 0.109) \times [1 - (0.031 \pm 0.005) \times p_T(\mathrm{GeV})]$$

$$\frac{f_{\Lambda_b}}{(f_u + f_d)} = 0.319 \pm 0.086 \implies \frac{f_d}{f_{\Lambda_b}} = 1.57 \pm 0.42$$

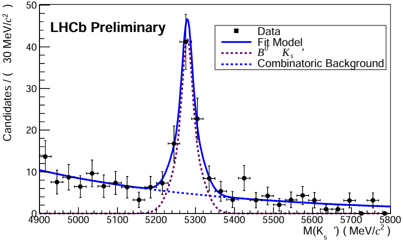
- Ratio of selection efficiencies (ϵ) measure using Monte Carlo
  - Second dominant systematic uncertainty (22%)
  - Easily improved with more Monte Carlo

Mass fits to B^0

- Selection applied to data and fit performed to reweighted B^0 mass.



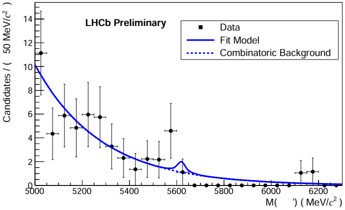
N(LL)$=125 \pm 13(14.8\sigma)$



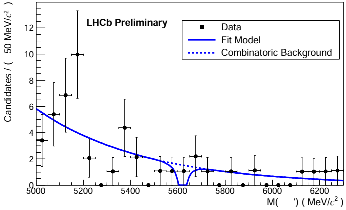
N(DD)$=75 \pm 12(11.7\sigma)$

Mass fits to Λ_b^0

- After unblinding, no significant signal is observed.
- All parameters in signal model fixed to MC values. Yield left to float.
- Number of events extracted from fit used to place a limit on branching fraction.



N(LL)=1



N(DD)=–3

Limits

- Use Feldman-Cousins method and information from the fit to set an upper limit on branching fraction.
- Absolute branching fraction using $\mathcal{B}(B^0 \to K_S^0 \eta') = 66 \times 10^{-6}$.

$$R = \frac{\mathcal{B}(\Lambda_b^0 \to \Lambda^0 \eta')}{\mathcal{B}(B^0 \to K^0 \eta')} < 9.6 \times 10^{-2} \text{ at } 90\% \text{ CL}$$

$$\mathcal{B}(\Lambda_b^0 \to \Lambda^0 \eta') < 6.3 \times 10^{-6} \text{ at } 90\% \text{ CL}$$

- c.f. Theoretical prediction:

Expected: $\mathcal{B}(\Lambda_b^0 \to \Lambda\eta^{(\prime)}) \approx (2 - 40) \times 10^{-6}$ arxiv:hep-ph/0305031

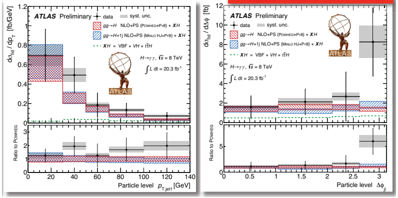
Contents

Conclusions

All measurements are consistent with Standard Model predictions

Back-Up Slides

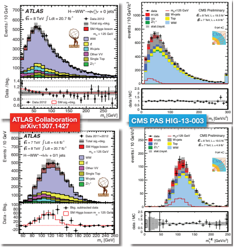
ATLAS-CONF-2013-072



BROWN

H(WW→lνlν)

- High-yield, low-resolution channel
  - Most discriminating variables: M_{ll} and M_T (dilepton transverse mass)
  - Search done in 0-, 1-, and 2-jet categories; in the ee, eμ, and μμ channels
- ATLAS: fit to the M_T distribution
- CMS: 2D analysis in M_{ll} vs. M_T for the eμ channel and cut-based analysis for the same-flavor channels (also as a cross-check in eμ)

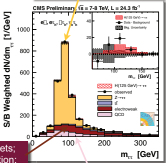


H(ττ) in CMS

- Updated to full statistics; based on eμ, μμ, $e\tau_h$, $\mu\tau_h$, and $\tau_h\tau_h$ channels
- Analysis is done separately in 0-, 1-, and 2-jet (VBF) categories
  - 0- and 1-jet categories are each split in two, depending on the p_T of the τ-decay products
  - $\tau_h\tau_h$ doesn't use 0-jet category and the 1- and 2-jet categories are not split
- Also include VH(ττ) channels
- Optimized ττ mass reconstruction (SVFIT) with ~20% resolution
- Benefits significantly from particle-flow reconstruction

CMS PAS HIG-13-004

Embedding (replace μ with simulated τ in Z(μμ) sample); normalization from Z(μμ) (5% syst.)



Dominated by W+jets; shape from simulation; normalization from control regions (10-20% syst.)

QCD: from SS sample (10% syst.)

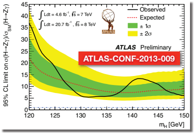
Greg Landsberg - Higgs Bosons in the SM and Beyond - EPS 2013

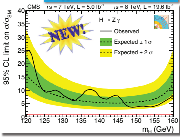
Slide 31

H(Zγ) Results

- Similar branching fraction to H(γγ), but an additional price to pay for the leptonic branching fraction of the Z
- Decay can be enhanced/suppressed independently of H(γγ)
  - Sensitive to new physics via loops
- Not sensitive to the SM Higgs boson (yet), set the following limits:
  - ATLAS: $\mu <$ 18.2 @ 95% CL (13.5 expected)
  - CMS: $\mu <$ 10 @ 95% CL (10 expected)

CMS Collaboration
CERN-PH-EP-2013-113
to appear on the arXiv tomorrow

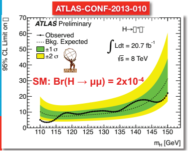


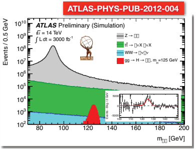


BROWN

H(□□) Results

- Observing H(μμ) decay may be the only way to prove non-flavor-universal couplings of the Higgs boson
  - N.B. Coupling to charm is very hard to probe
- Requires very large statistics for observation: a strong case for HL-LHC
- First search has been done already by ATLAS
  - Sets limit μ < 9.8 (8.2 expected) @ 95% CL





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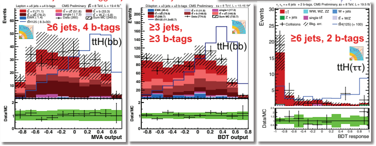
CMS Search in ttH(bb+ττ)

- New analysis; supersedes recent publication arXiv:1303.0763 based on 5+5 fb^{-1}
  - Updated to the full 2012 statistics (7 TeV not reanalyzed) and added the ττ decay channel (8 TeV only)
  - tt decays are reconstructed in the lepton+jets and dilepton channel; 2 or more b-tagged jets required for the ttH(bb) search
  - H(ττ) decays are looked for in $\tau_h\tau_h$ channel, with tt decaying in lepton+jets, with 1 or 2 b-tagged jets
  - Signal extraction via BDTs; separate BDTs for each jet and b-tagged jet multiplicity

CMS PAS HIG-13-019

NEW!



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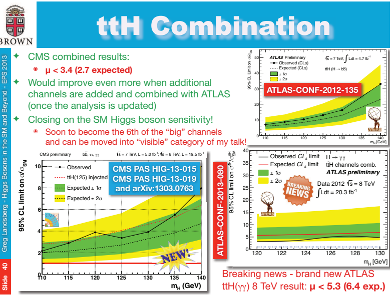
ttH Combination
BROWN
CMS combined results:
μ < 3.4 (2.7 expected)
Would improve even more when additional channels are added and combined with ATLAS (once the analysis is updated)
Closing on the SM Higgs boson sensitivity!
Soon to become the 6th of the "big" channels and can be moved into "visible" category of my talk!
ATLAS-CONF-2012-135
CMS PAS HIG-13-015
CMS PAS HIG-13-019
and arXiv:1303.0763
NEW!
ATLAS-CONF-2013-080
Observed
ttH(125) injected
Expected ± 1σ
Expected ± 2σ
95% CL limit on σ/σSM
mH (GeV)
Observed CLs limit
Expected CLs limit
H → γγ
ttH channels comb.
ATLAS preliminary
Data 2012 √s = 8 TeV
∫Ldt = 20.3 fb⁻¹
BREAKING NEWS
mH [GeV]
Breaking news - brand new ATLAS ttH(γγ) 8 TeV result: μ < 5.3 (6.4 exp.)
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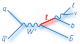
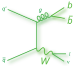
Slide 40

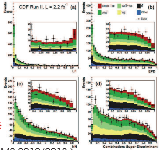
Single Top Production



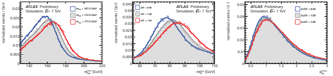


- Direct probe of Wtb coupling and of V_{tb} in CKM matrix.
- Challenging, mainly due to the background from W+jets.
- Need MVA techniques.
- $s+t$-channel production observed at CDF and D0 in 2009.
- t-channel observed both at Tevatron and LHC.
- Evidence for s-channel production at D0.
- Observation of Wt-channel production at CMS.

(Evidence by both ATLAS and CMS 2012/2013.)



New 3D Fit by ATLAS

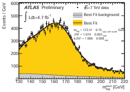


- 3D fit to $m_{\text{top}}^{\text{reco}}$, m_W^{reco} and $R_{\text{lb}}^{\text{reco}}$.

$$R_{\text{lb}}^{\text{reco},1b} = \frac{p_{\text{T}}^{b_{\text{tag}}}}{(p_{\text{T}}^{W_{\text{jet1}}} + p_{\text{T}}^{W_{\text{jet2}}})/2}$$

$$R_{\text{lb}}^{\text{reco},2b} = \frac{p_{\text{T}}^{b_{\text{had}}} + p_{\text{T}}^{b_{\text{lep}}}}{p_{\text{T}}^{W_{\text{jet1}}} + p_{\text{T}}^{W_{\text{jet2}}}}$$

- In-situ calibration of JES and bJES.
- Systematic uncertainties reduced by 40% w.r.t. previous measurement.

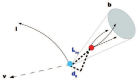


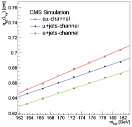
$m_{\text{top}} = 172.31 \pm 0.23(\text{stat}) \pm 0.27(\text{JSF}) \pm 0.67(\text{bJSF}) \pm 1.35(\text{syst})$ GeV

NEW

SARA STRANDBERG, STOCKHOLM UNIVERSITY P. 16 EPSHEP 2013, STOCKHOLM, JULY 22, 2013

New Lifetime-Based Measurement by CMS





- Lifetime-based technique, using $L_{xy} = \gamma_b \beta_B \tau_B \approx 0.4 \cdot \frac{m_t}{m_B} \beta_B \tau_B$.
- First used at CDF.
  Phys. Rev. D75, 071102 (2007)
- Linear mass dependence, ΔL_{xy}/GeV $= 25 - 30\mu$m
- Complementary systematics to traditional measurements, e.g. minimal dependence on jet energy scale.
- In each event, select secondary vertex with largest L_{xy}.
- Median, $\widehat{L_{xy}}$, is used to extract m_{top}.

$$m_{\text{top}} = 173.5 \pm 1.5(\text{stat}) \pm 1.3(\text{syst}) \pm 2.6(p_T(t)) \text{ GeV}$$

NEW

Top Forward-Backward and Charge Asymmetries

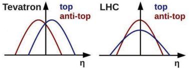
- New physics in top sector can alter angular distributions.
- Study forward-backward and charge asymmetries.

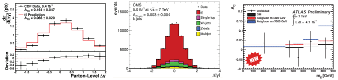
$$A_{FB}^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

with $\Delta y = y_t - y_{\bar{t}}$

$$A_{C}^{t\bar{t}} = \frac{N(\Delta |y| > 0) - N(\Delta |y| < 0)}{N(\Delta |y| > 0) + N(\Delta |y| < 0)}$$

with $\Delta |y| = |y_t| - |y_{\bar{t}}|$



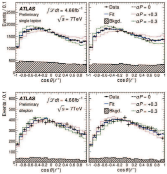


Phys. Rev. D 87 092002 (2013)   Phys. Lett. B 717, 129 (2012)   ATLAS-CONF-2013-078

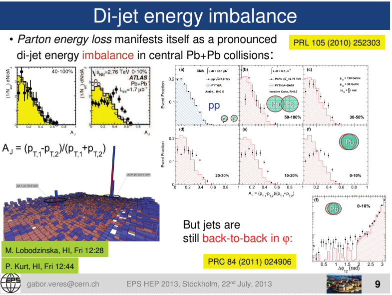
- Tevatron $A_{FB}^{t\bar{t}}$ measurements in tension with SM at $\sim 2.5\sigma$.
- LHC $A_{C}^{t\bar{t}}$ measurements consistent with SM.

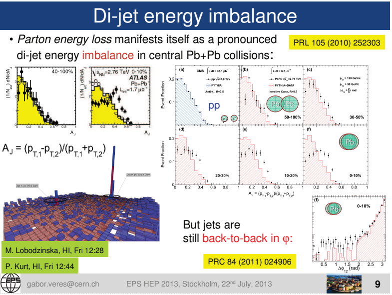
Top Quark Polarization

- Top quarks in $t\bar{t}$ events have negligible polarization in SM.
- Can occur in BSM scenarios (e.g. models with large FB asymmetry).
- Polar angle of decay product i distributed as:
  $W(\cos\theta_i) = \frac{1}{2}(1 + \alpha_i P \cos\theta_i)$
  P = degree of polarization, α_i = spin-analyzing power.
- At tree level, charged leptons and down-type quarks from W-boson decays have $\alpha_i = 1$.
- Fit $\cos\theta_\ell$ distributions for e and μ to extract $\alpha_\ell P$. NEW



$\alpha_l P_{\text{CPC}} = -0.035 \pm 0.014 \pm 0.037$
$\alpha_l P_{\text{CPV}} = 0.020 \pm 0.016^{+0.013}_{-0.017}$


Di-jet energy imbalance
• Parton energy loss manifests itself as a pronounced di-jet energy imbalance in central Pb+Pb collisions:
PRL 105 (2010) 252303
40-100%
ATLAS
Pb+Pb
A_J = (p_T,1-p_T,2)/(p_T,1+p_T,2)
pp
50-100%
30-50%
20-30%
10-20%
0-10%
Event Fraction
But jets are
still back-to-back in φ:
PRC 84 (2011) 024906
M. Lobodzinska, HI, Fri 12:28
P. Kurt, HI, Fri 12:44
gabor.veres@cern.ch
EPS HEP 2013, Stockholm, 22nd July, 2013
9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pp
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50-100%
30-50%
20-30%
10-20%
0-10%
Event Fraction
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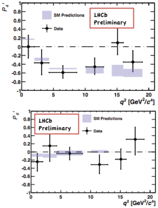
P. Kurt, HI, Fri 12:44
gabor.veres@cern.ch
EPS HEP 2013, Stockholm, 22nd July, 2013
9

Results for new observables

NEW

LHCb collaboration (1fb^{-1}), LHCb-PAPER-2013-037



Good agreement with SM predictions (from J.Matias et al. arXiv:1303.5794)

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