

LHCb: Looking Forward



Daniel Brandenburg  THE OHIO STATE UNIVERSITY
On behalf of the LHCb Collaboration

LHC Forward Physics Meeting
March 15, 2024
CERN

Supported in part by an
Early Career award from the



U.S. DEPARTMENT OF
ENERGY

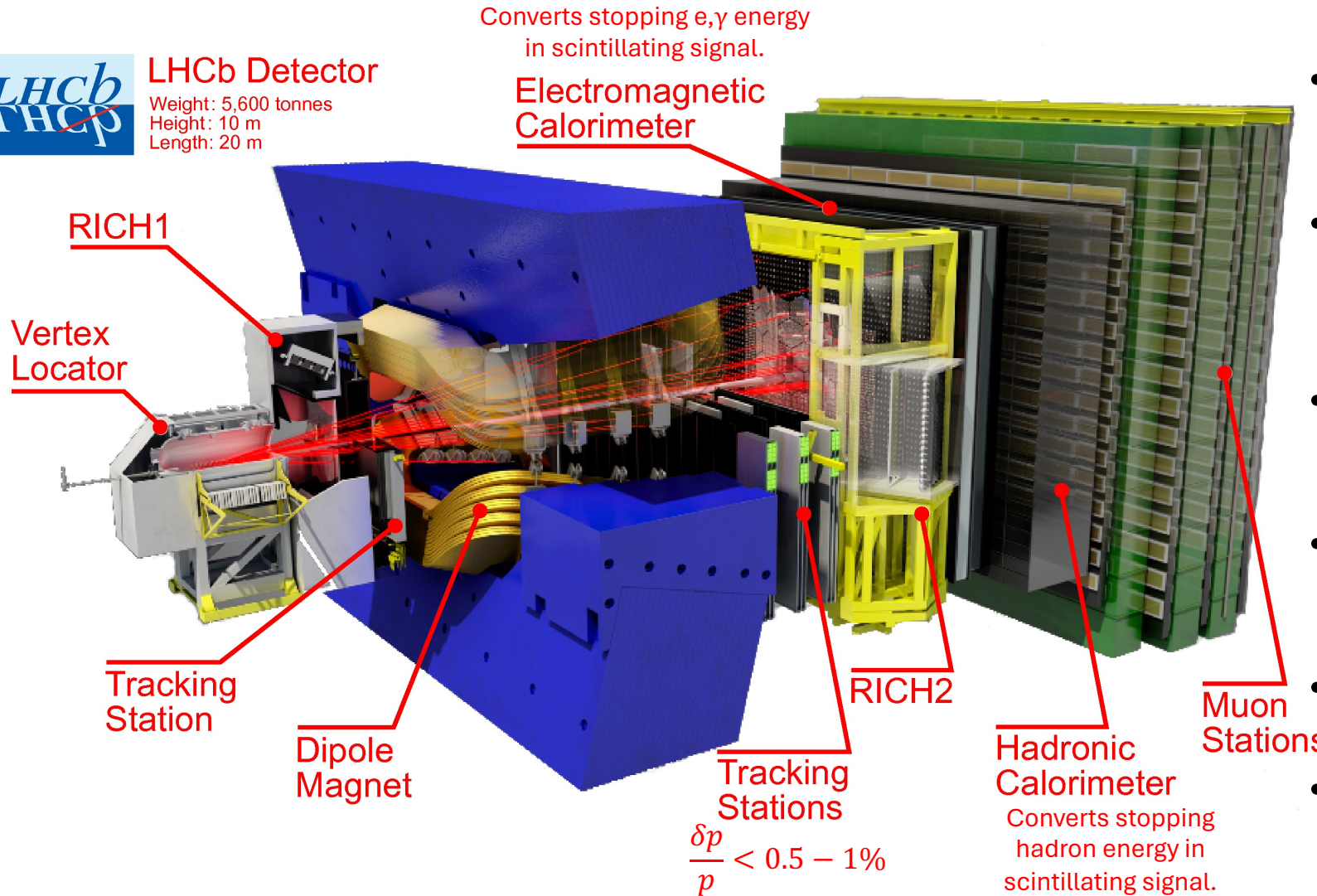
Office of Science

The *beauty* of LHCb



LHCb Detector

Weight: 5,600 tonnes
Height: 10 m
Length: 20 m



- Unique coverage
 - Rapidity
 - Low transverse momentum
- Collider & Fixed Target modes
 - Unique coverage
 - Access lower COM energies at LHC
- SMOG2
 - Enables fixed target mode
 - Plethora of collision species
- Resolution
 - Precise vertex determination
 - Powerful invariant mass resolution
- Particle Identification
 - $e, \mu, \pi, K, p, \gamma$ in $1 < p < 100$ GeV
- Unique forward instrumentation for heavy ion physics

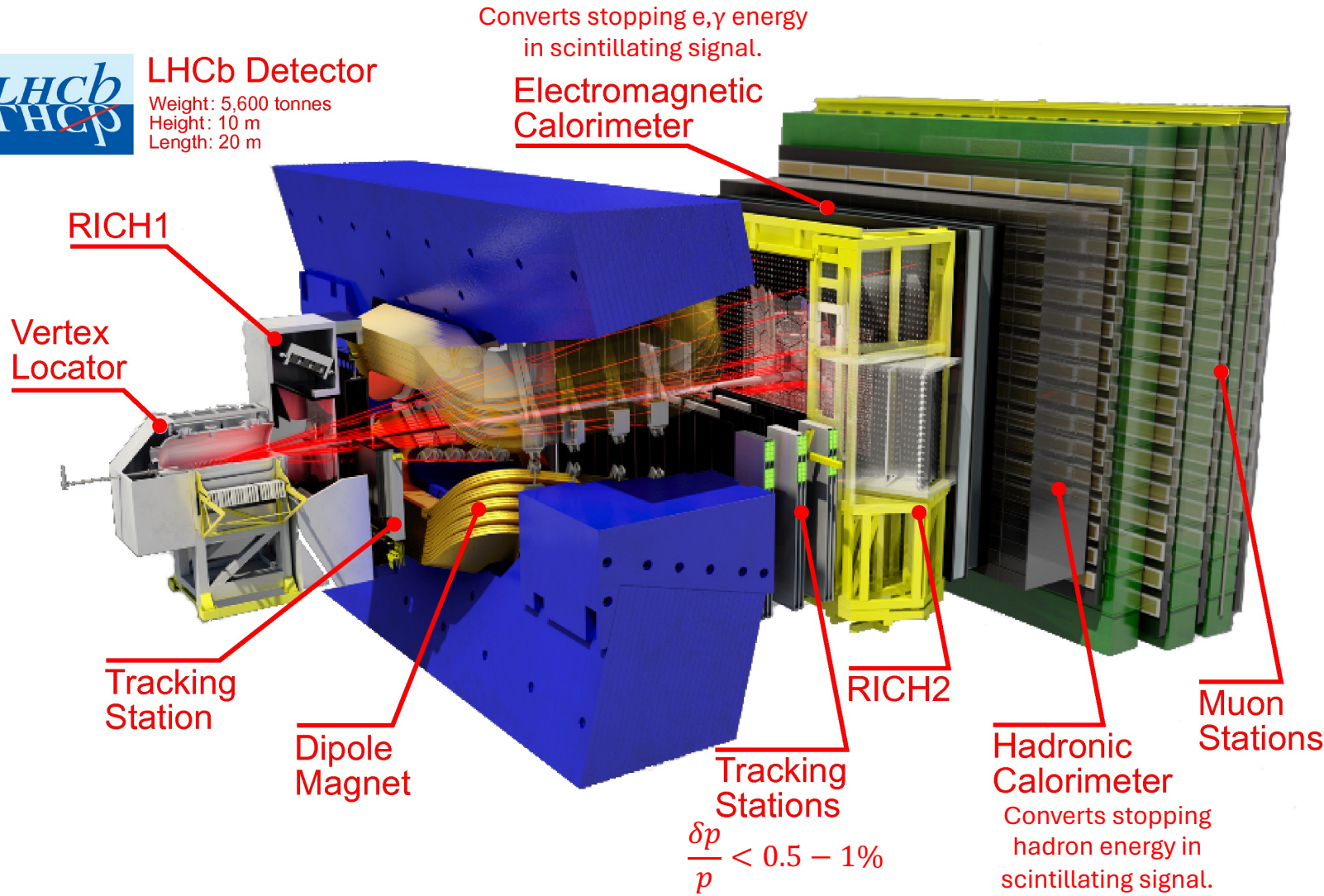
J. of Instr.,3(08):S08005, 2008

The *beauty* of LHCb

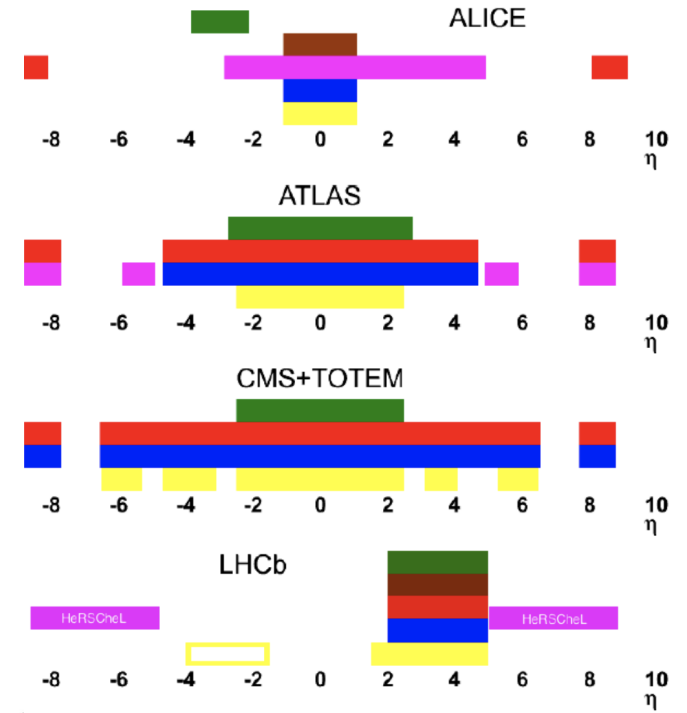


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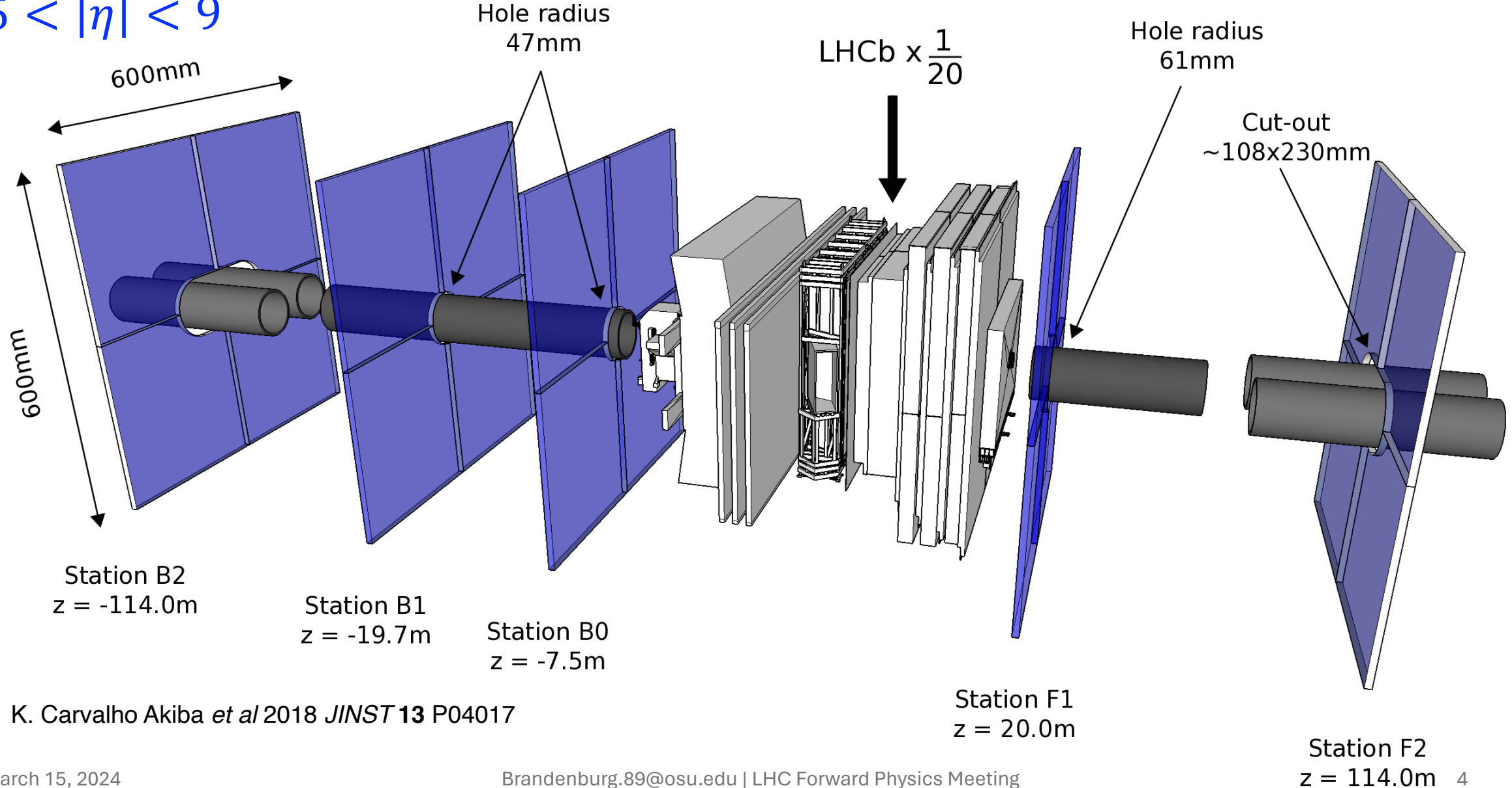
- hadron PID
- muon system
- lumi counters
- HCAL
- ECAL
- tracking



J. of Instr.,3(08):S08005, 2008

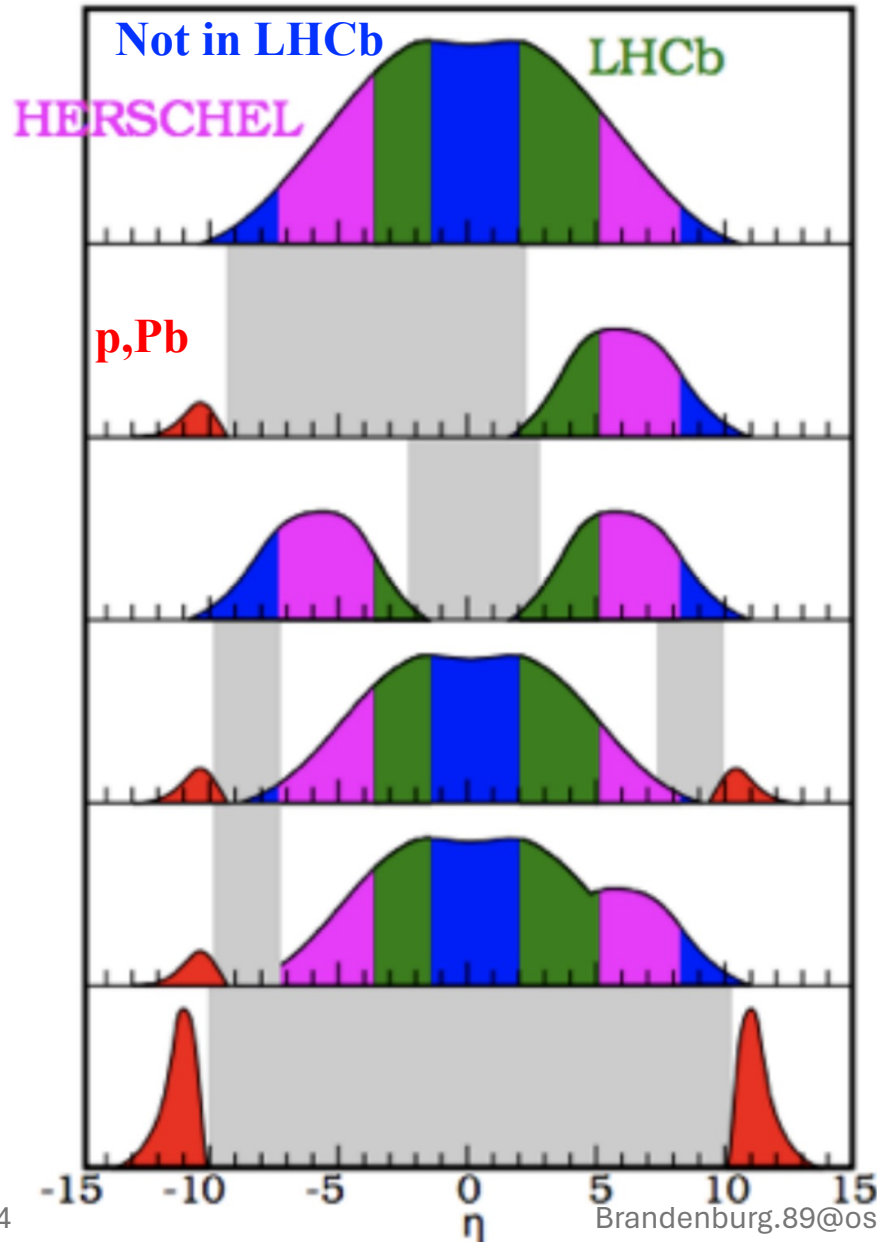
HeRSChel: High-Rapidity Shower Counters for LHCb

$$5 < |\eta| < 9$$

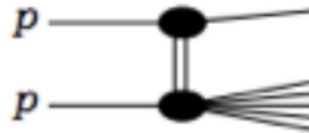


K. Carvalho Akiba *et al* 2018 *JINST* 13 P04017

LHCb rapidity coverage



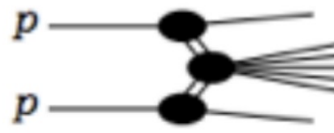
inelastic



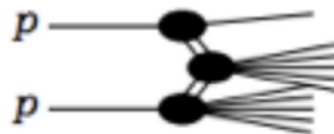
single diffraction



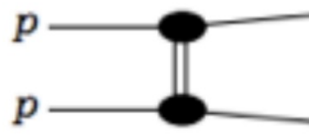
double diffraction



CEP+UPC elastic



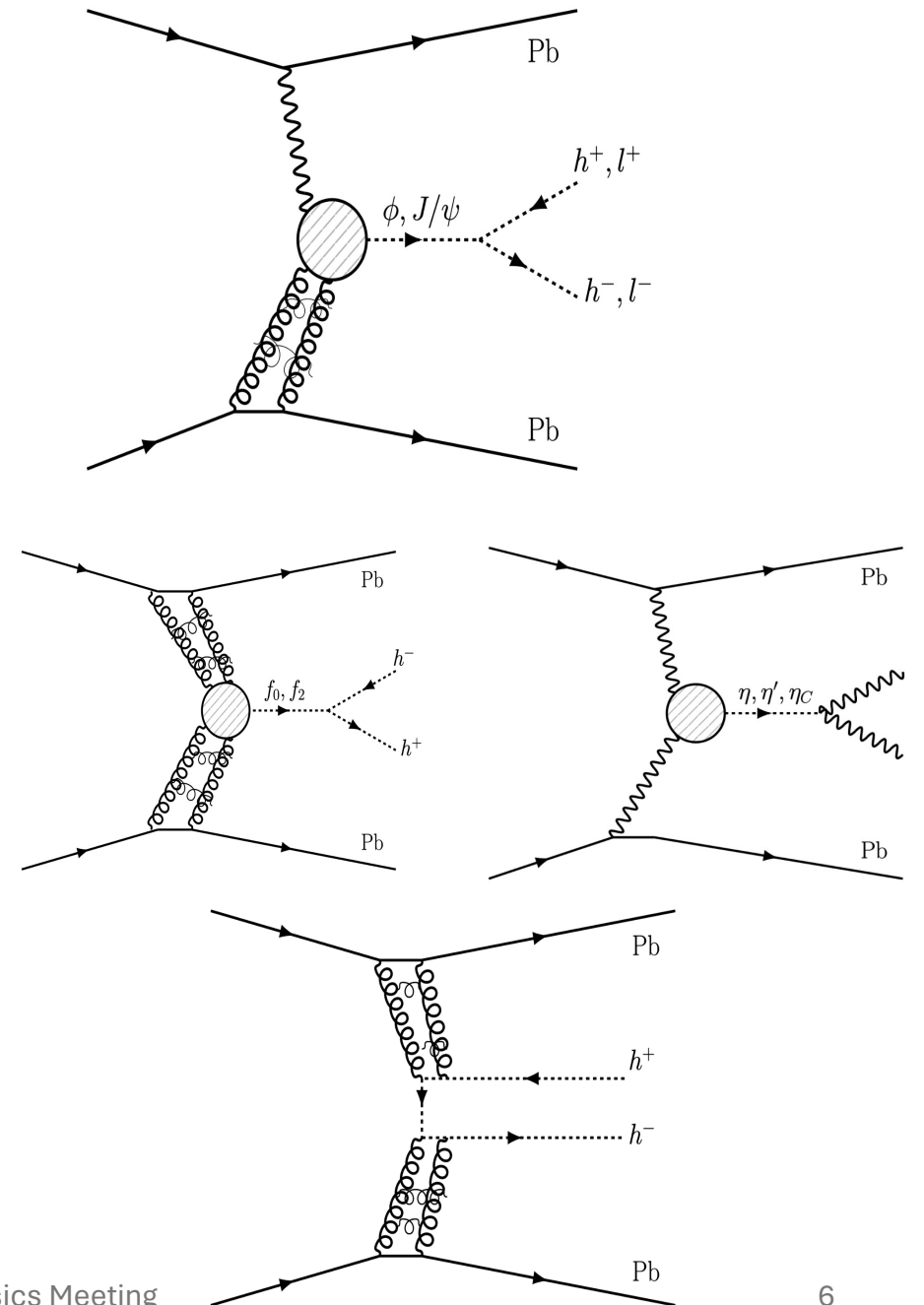
CEP+UPC inelastic



Elastic

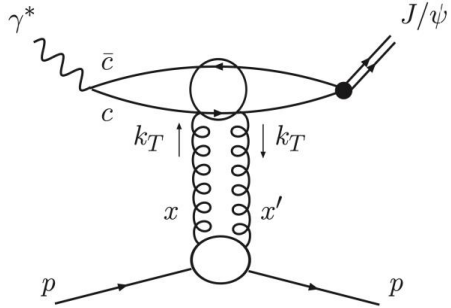
Outline & Physics Topics

- Photoproduction (in pp and AA)
 - Vector meson production
- Exotic states, scalar and tensor mesons from $\mathbb{P} + \mathbb{P}$ and $\gamma + \gamma$ interactions
 - Searches for glueballs + tetraquark states
- In this talk:
 - Previous results
 - Photoproduction of J/ψ & $\psi(2s)$ in Pb+Pb UPC
 - Studies of η & η' in pp and pPb Collisions
 - Looking Forward



Photoproduction measurements from CEP

LHCb measurements cover a unique range in W with high precision



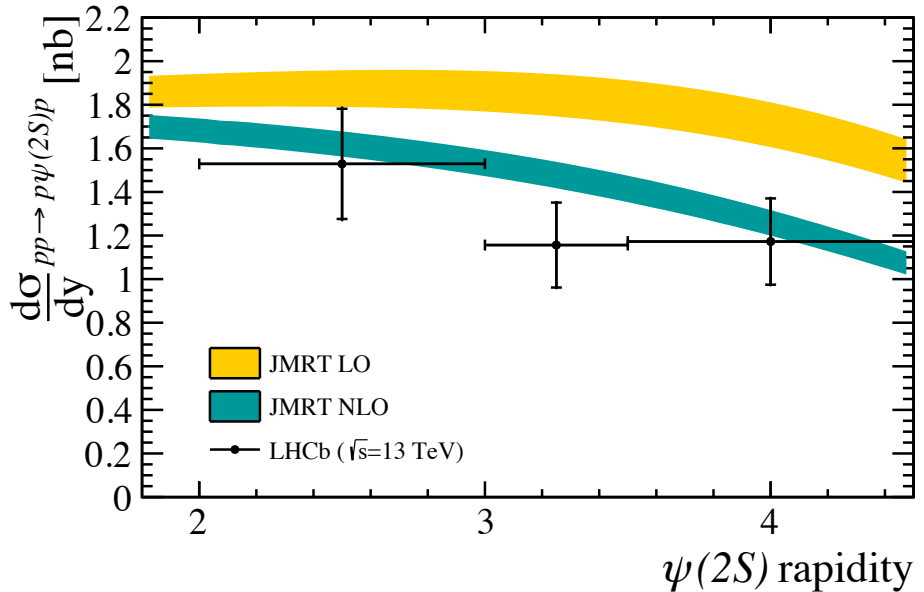
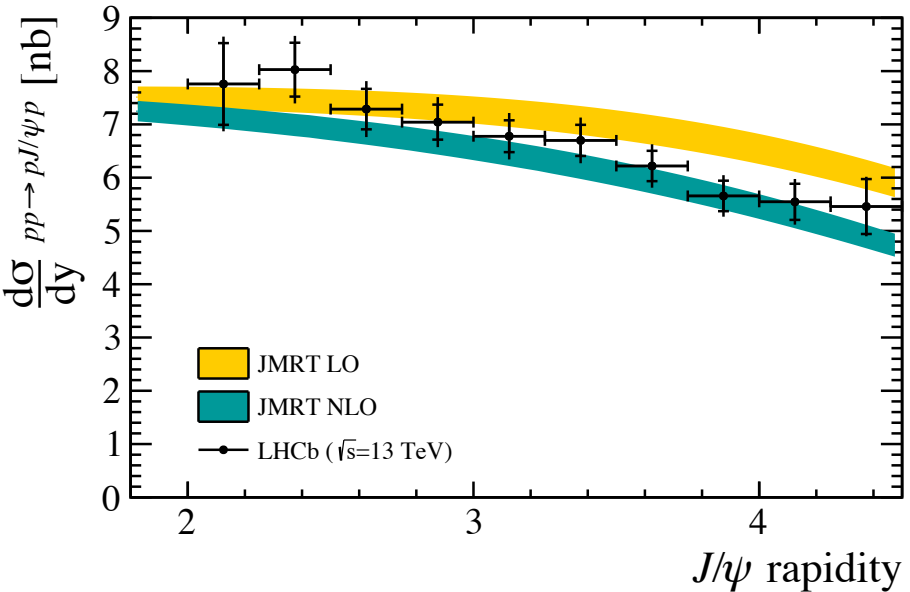
photon energy
 $k_{\pm} \equiv (M_{\psi}/2)e^{\pm y_{\psi}}$

Invariant mass of the photon-proton system
 $W_{\pm}^2 = 2k_{\pm}\sqrt{s}$

External inputs
 gap survivor photon flux

Photoproduction result from H1(HERA)
 parametrization = $a \left(\frac{W}{90 \text{ GeV}}\right)^{\delta}$

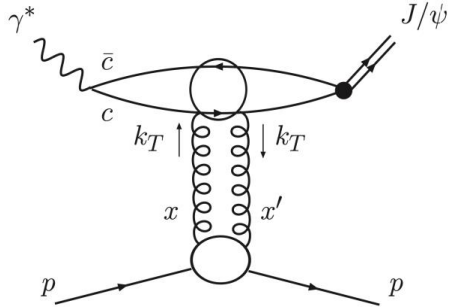
$$\sigma_{pp \rightarrow p\psi p} = r(W_+) \left(\frac{dn}{dk_+}\right) k_+ \sigma_{\gamma p \rightarrow \psi p}(W_+) + r(W_-) \left(\frac{dn}{dk_-}\right) k_- \sigma_{\gamma p \rightarrow \psi p}(W_-)$$



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Photoproduction measurements from CEP

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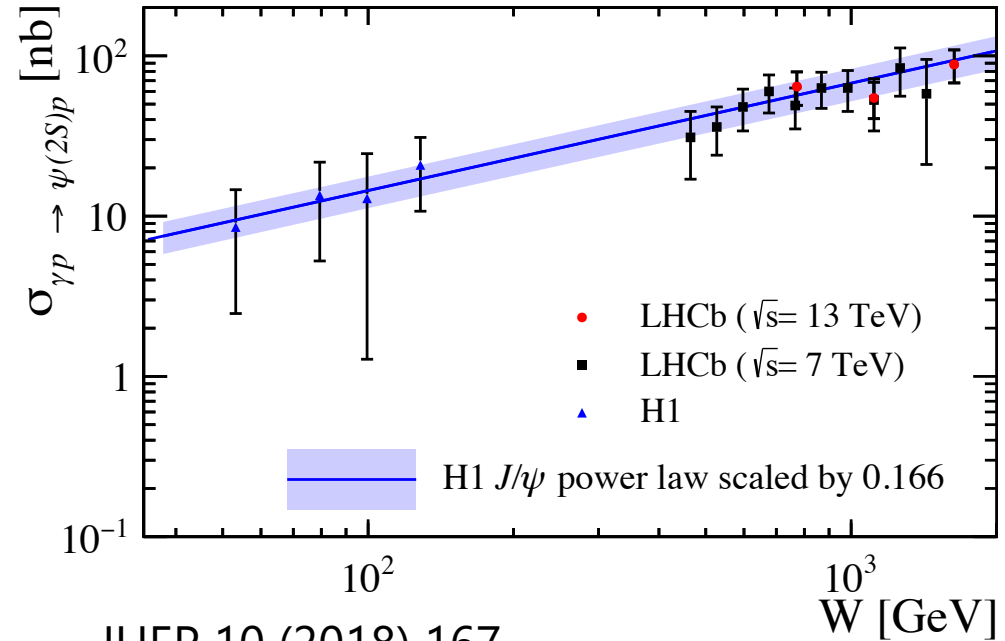
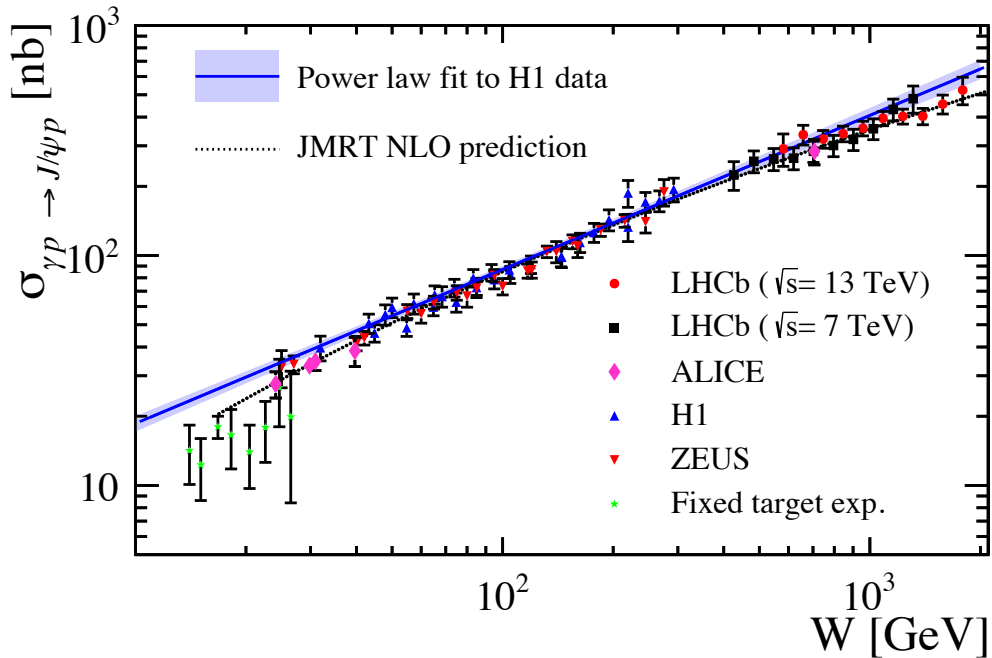
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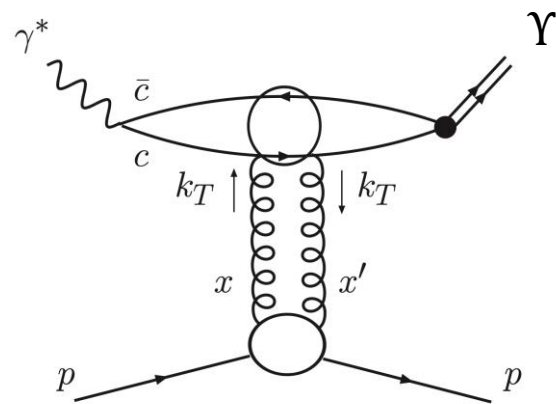
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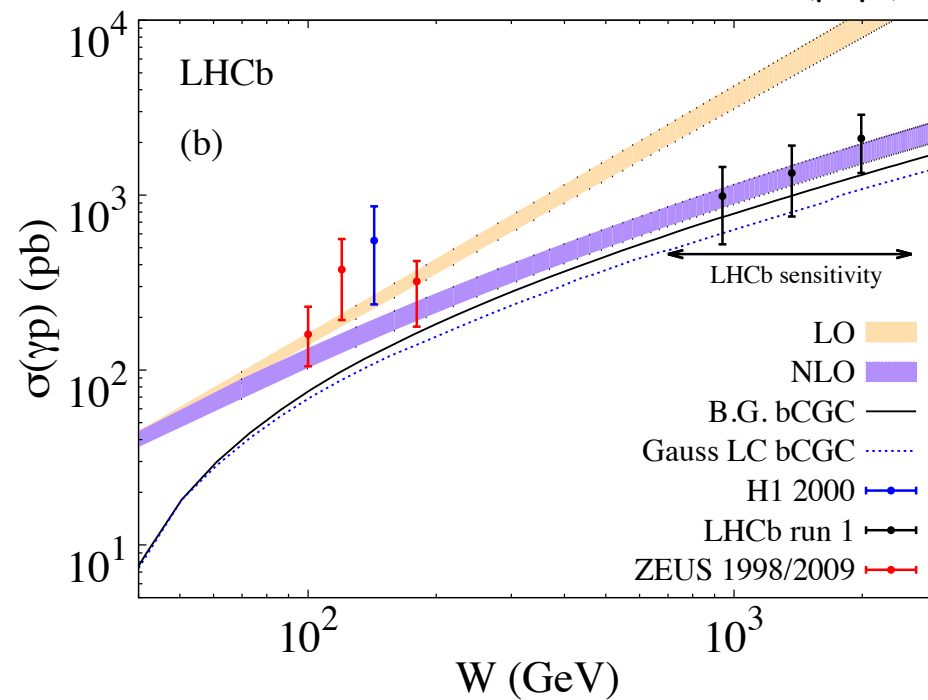
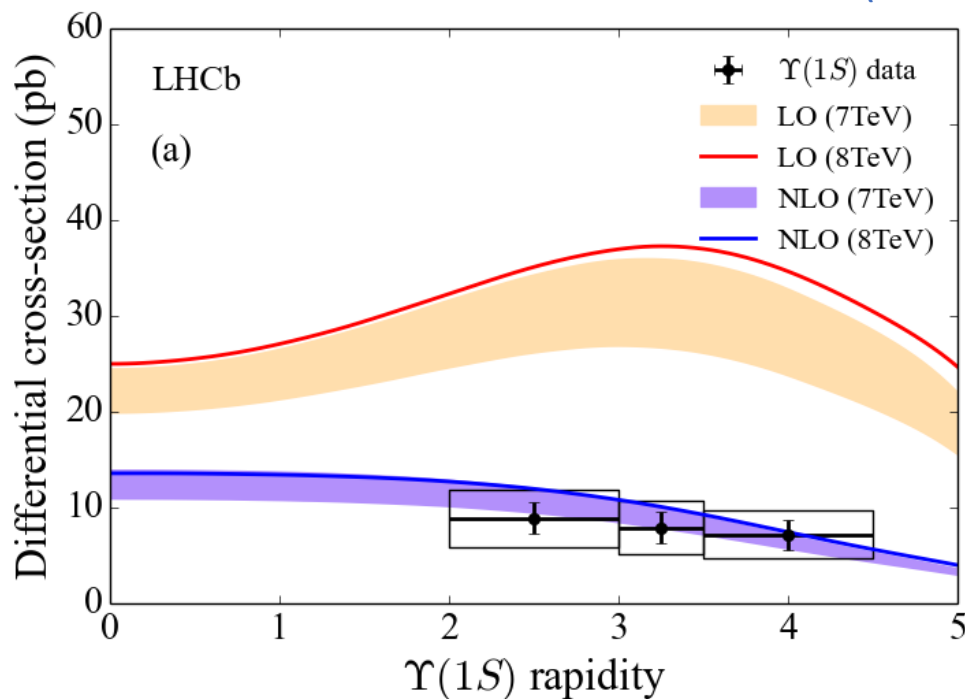
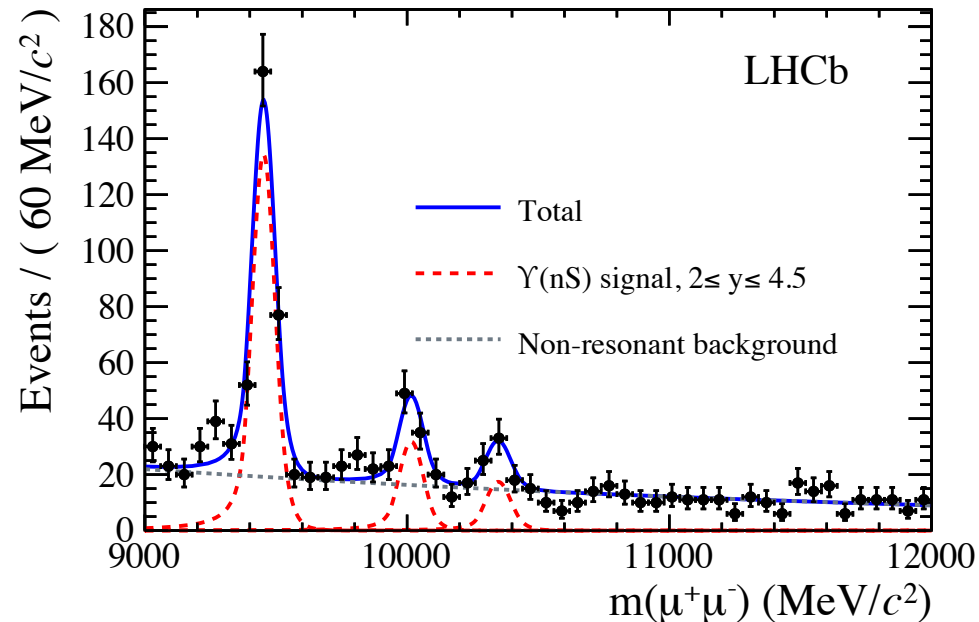
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Bottomonia photoproduction in CEP

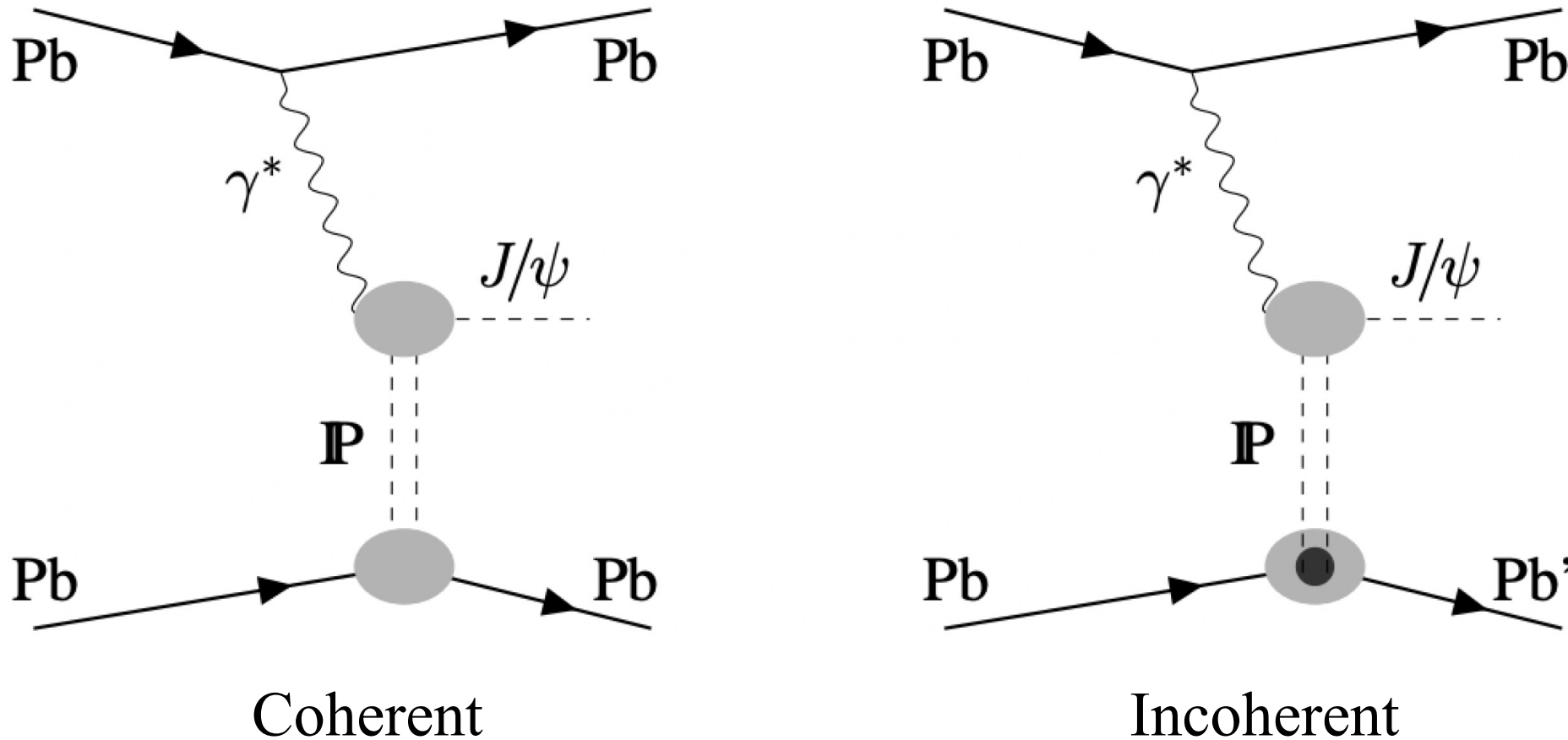
- Access to Bottomonias $\Upsilon(nS)$
- $Q^2 \approx 25 \text{ GeV}^2$



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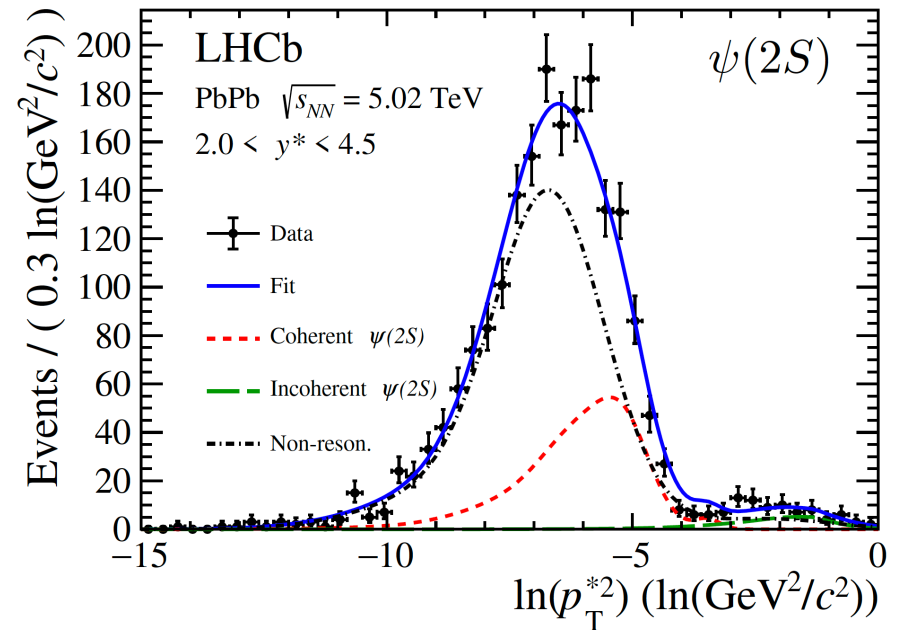
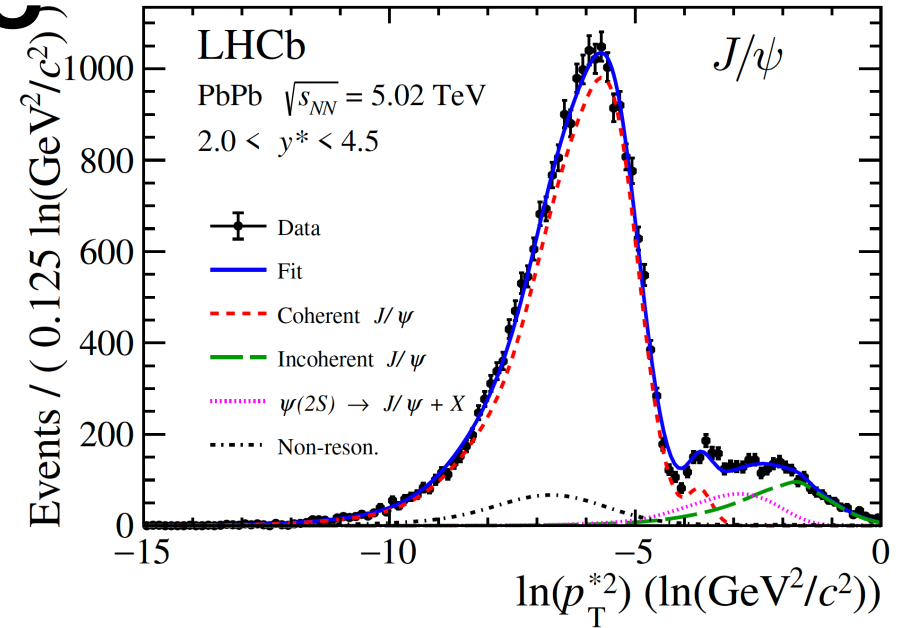
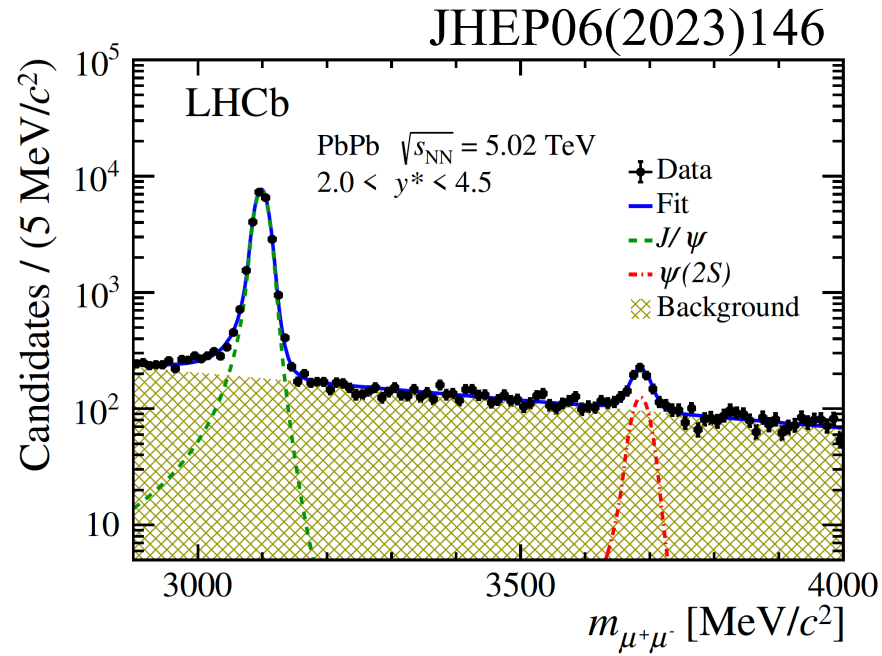
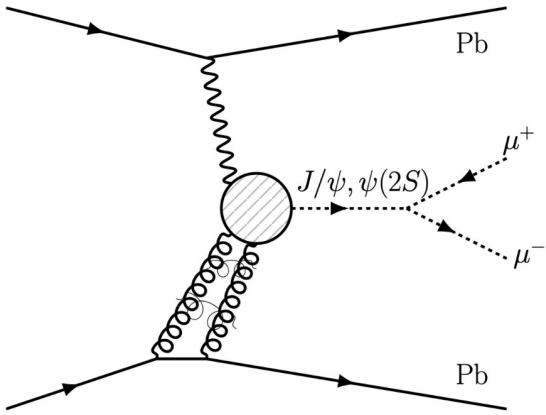


Vector Meson Photoproduction in UPC of PbPb



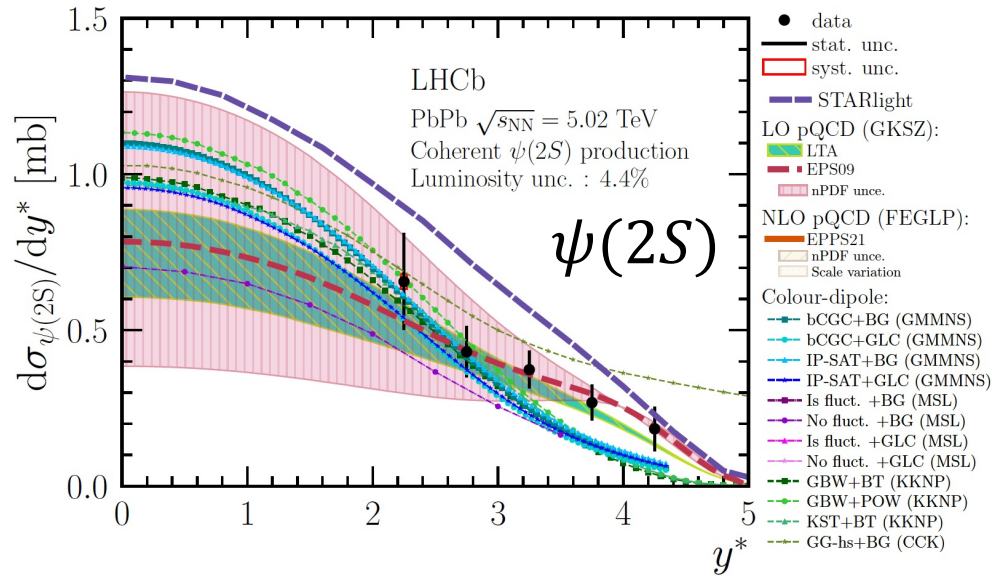
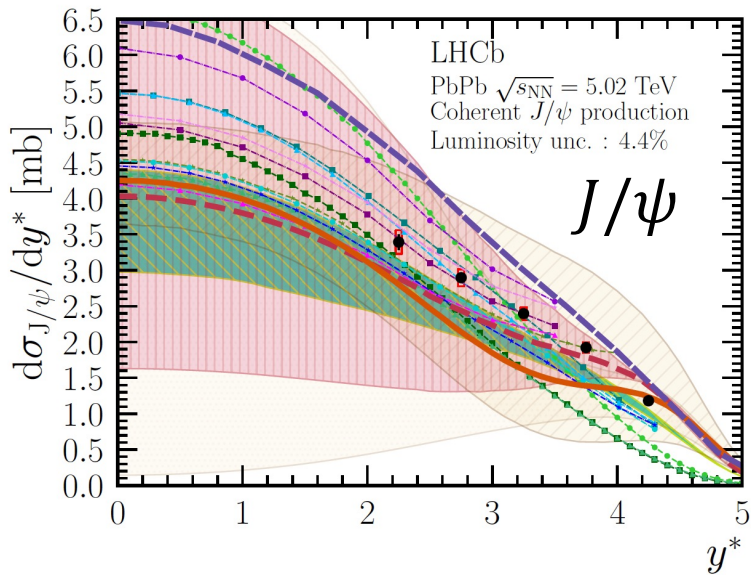
Efficient separation of coherent and incoherent thanks to HeRSChel

J/ψ , $\psi(2S)$ photoproduction in UPC



- Excellent separation between coherent and incoherent components, thanks to
 - HeRSCHeL
 - High p_T resolution – allows measurement of $d\sigma/dp_T$ at LHC

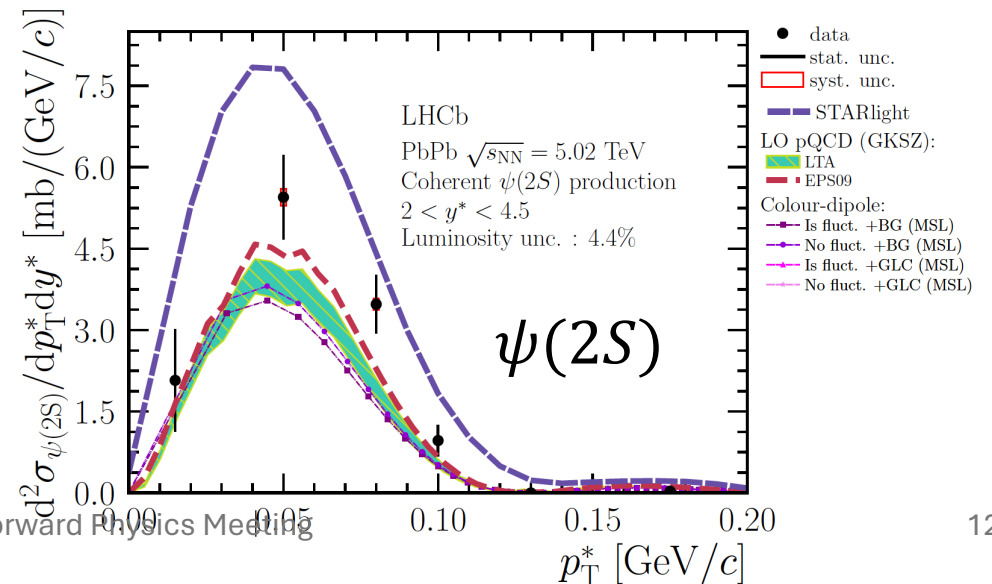
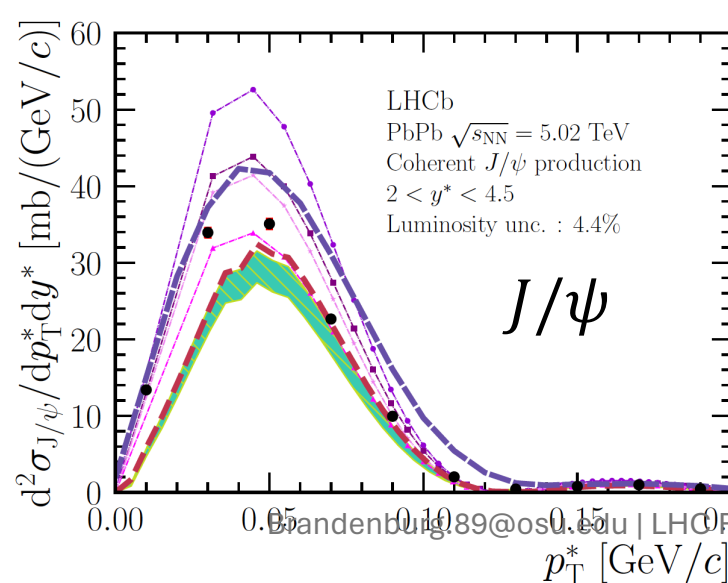
J/ψ and $\psi(2S)$: Comparison With Theory



Comparison with:

- LO pQCD
- NLO pQCD
- Color-dipole models
- Gluon saturation models
- Sub-nucleonic fluctuations

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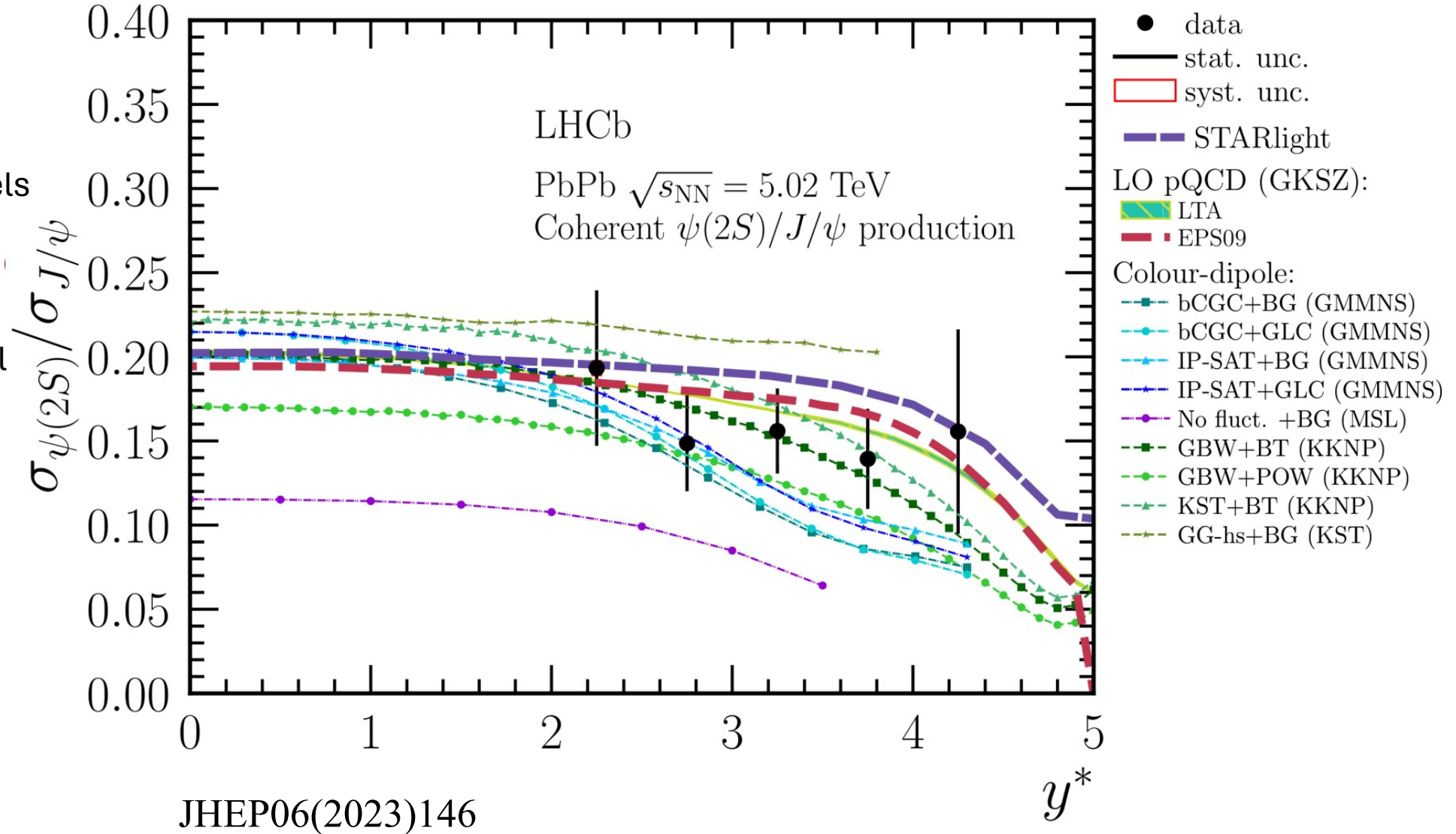


J/ψ and $\psi(2S)$: Comparison With Theory

Comparison with:

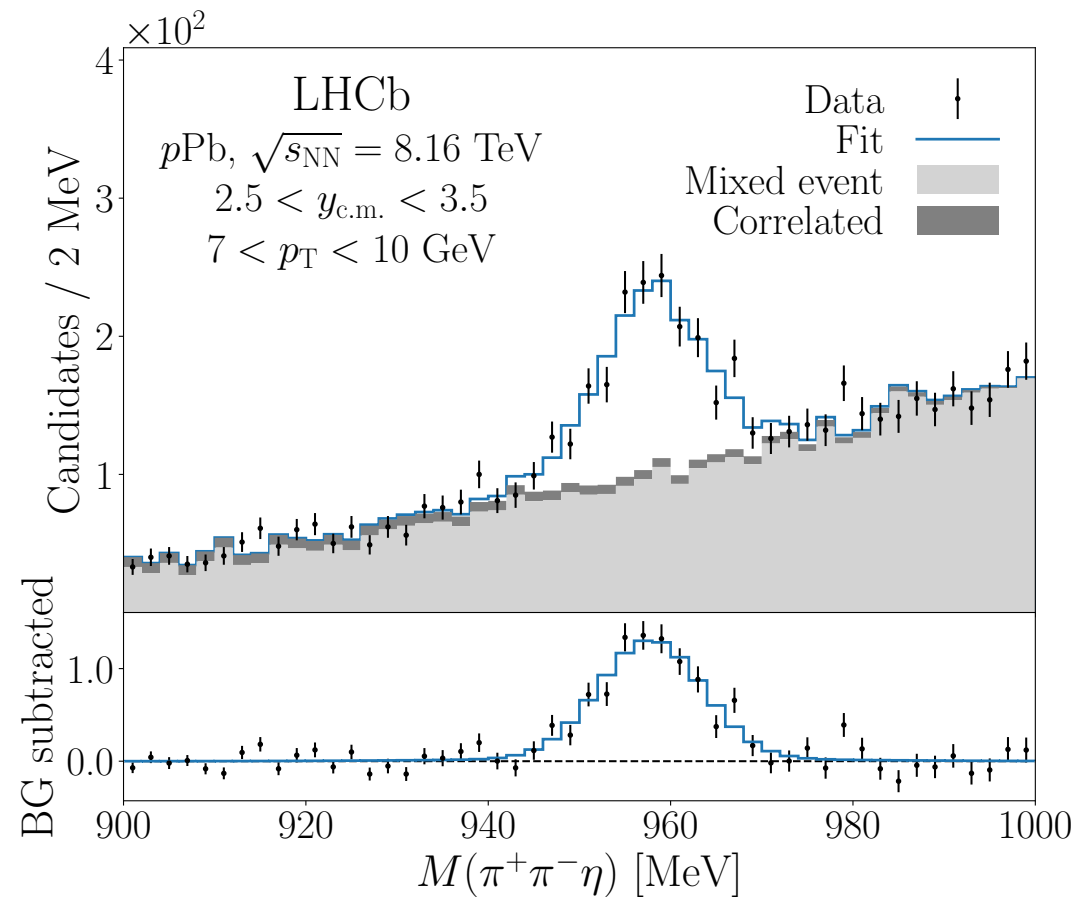
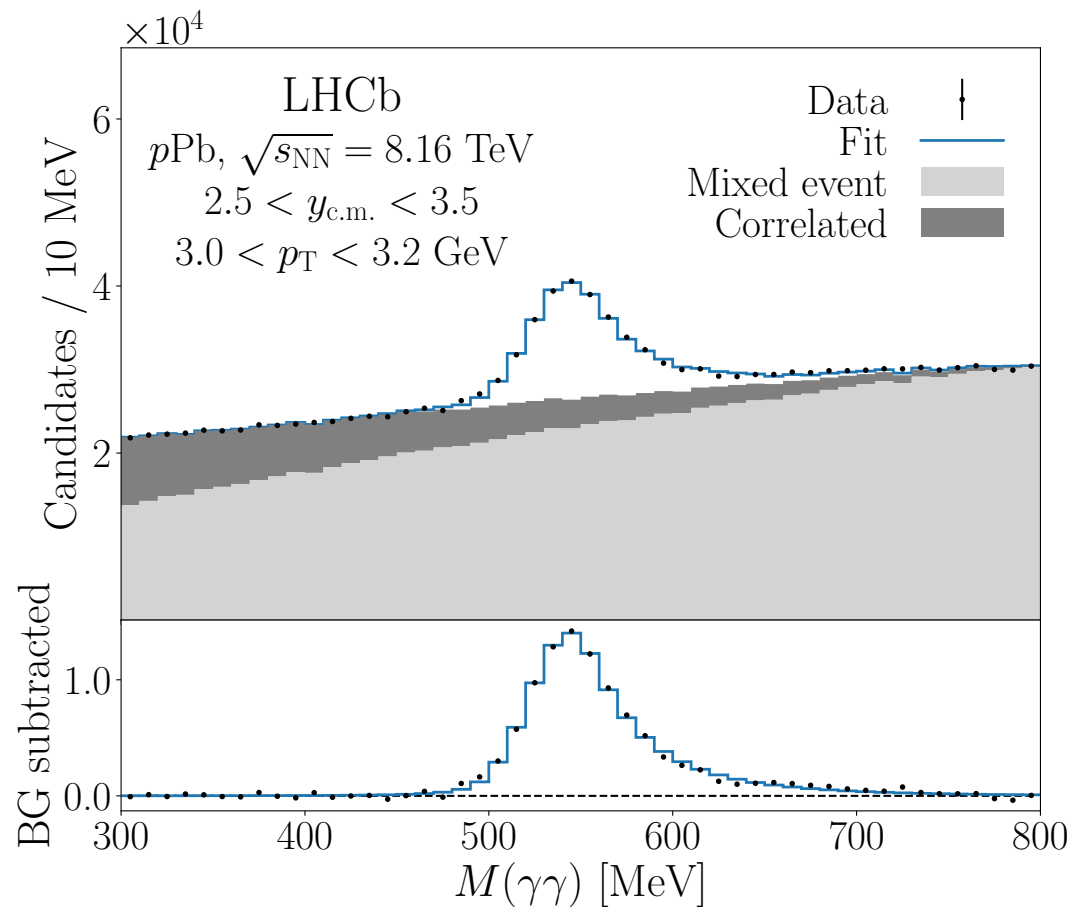
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Future measurements will help distinguish model predictions



η and η' in pp and pPb

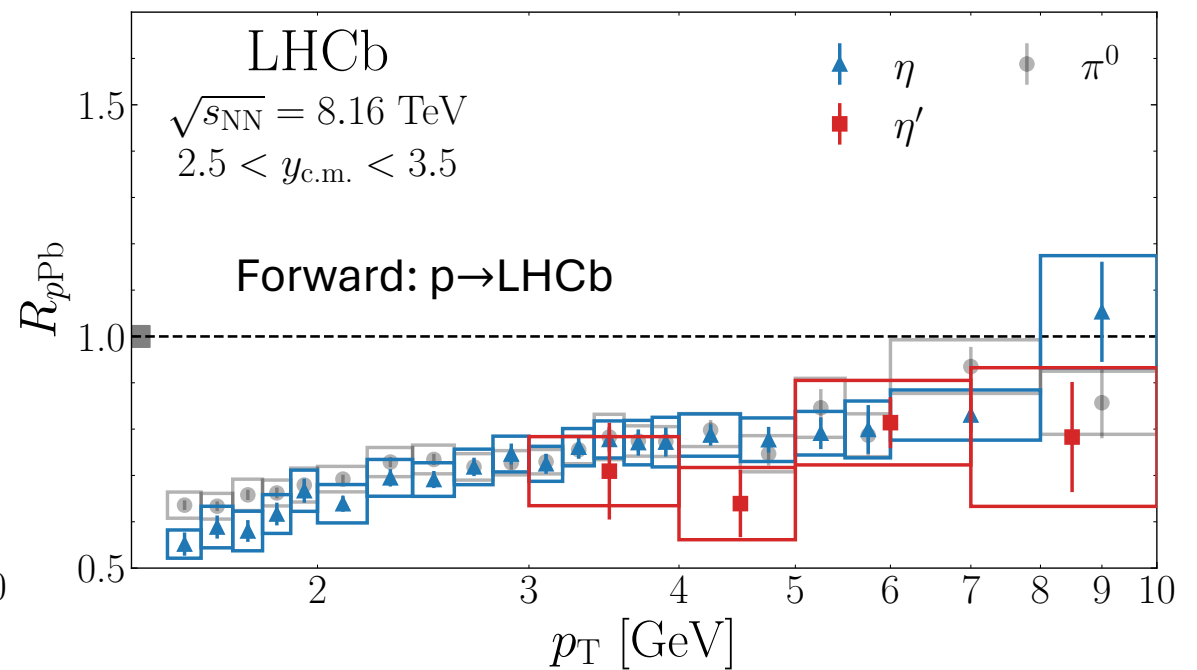
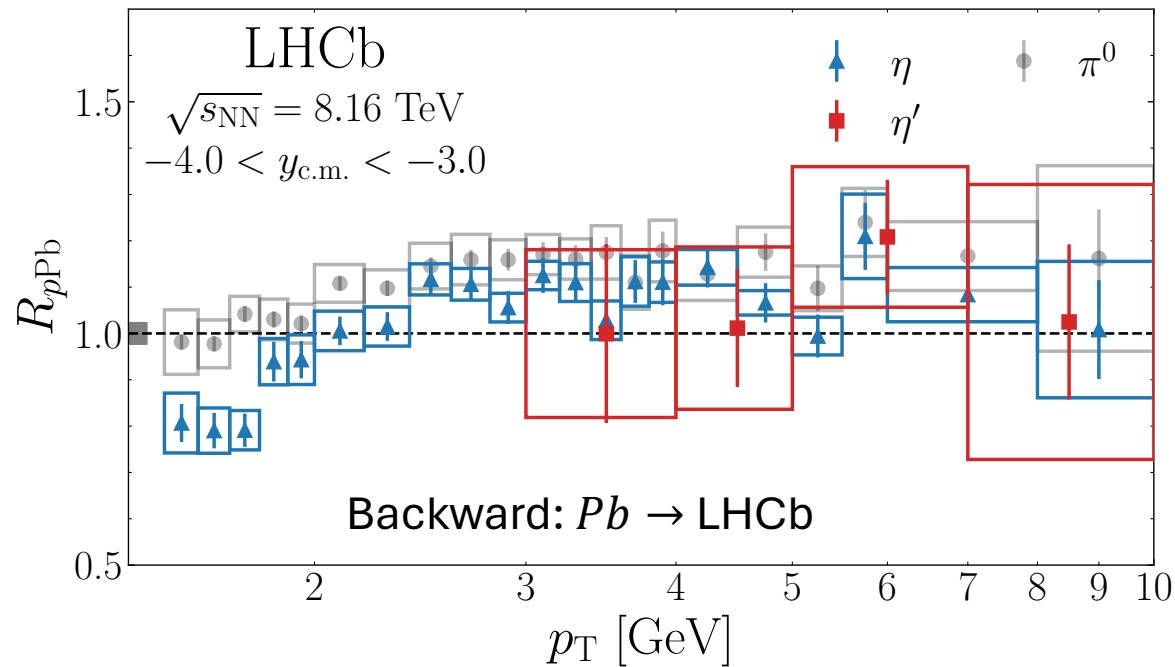
[10.1103/PhysRevC.109.024907](https://arxiv.org/abs/10.1103/PhysRevC.109.024907)



- Clear identification of η and η' via invariant mass reconstruction in pPb
- η reconstructed from γ pairs identified in ECAL (clusters $p_{\text{T}} > 500$ MeV + isolated from charged tracks)
- η' reconstructed from η candidates ($500 < M_{\gamma\gamma} < 600$ MeV) and charged pion pairs

η and η' in pp and pPb

[10.1103/PhysRevC.109.024907](https://arxiv.org/abs/10.1103/PhysRevC.109.024907)



Nuclear modification for η and η' in the backward and forward directions

- Consistent with π^0 at both forward and backward rapidity

η and η' in pp and pPb

[10.1103/PhysRevC.109.024907](https://arxiv.org/abs/10.1103/PhysRevC.109.024907)

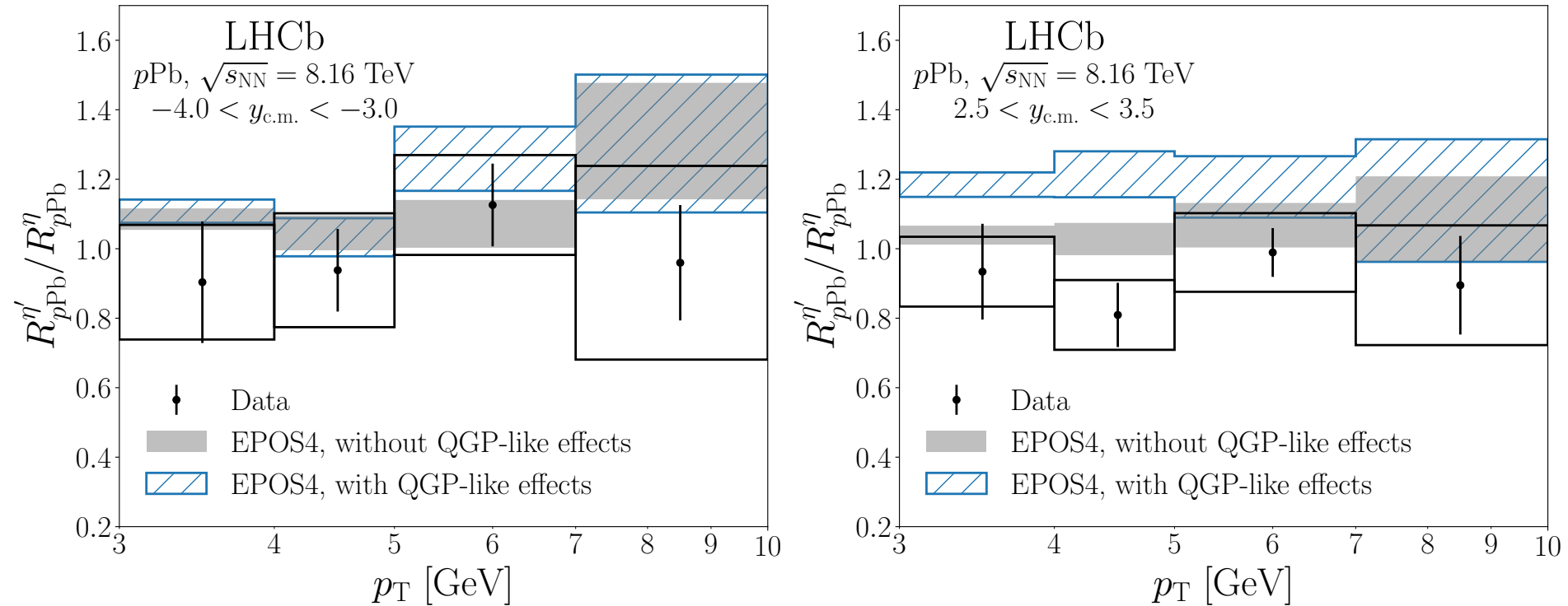


Figure 5: Measured $R_{pPb}^{\eta'}/R_{pPb}^{\eta}$ in the (left) backward and (right) forward regions. Error bars show the statistical uncertainties, while the boxes show the systematic uncertainties. The systematic uncertainties are approximately fully correlated in p_T . The results are compared to predictions from EPOS4 with and without QGP-like effects. The shaded and hatched regions show the statistical 68% confidence-level regions of the predictions.

Exciting NEW Results coming SOON!

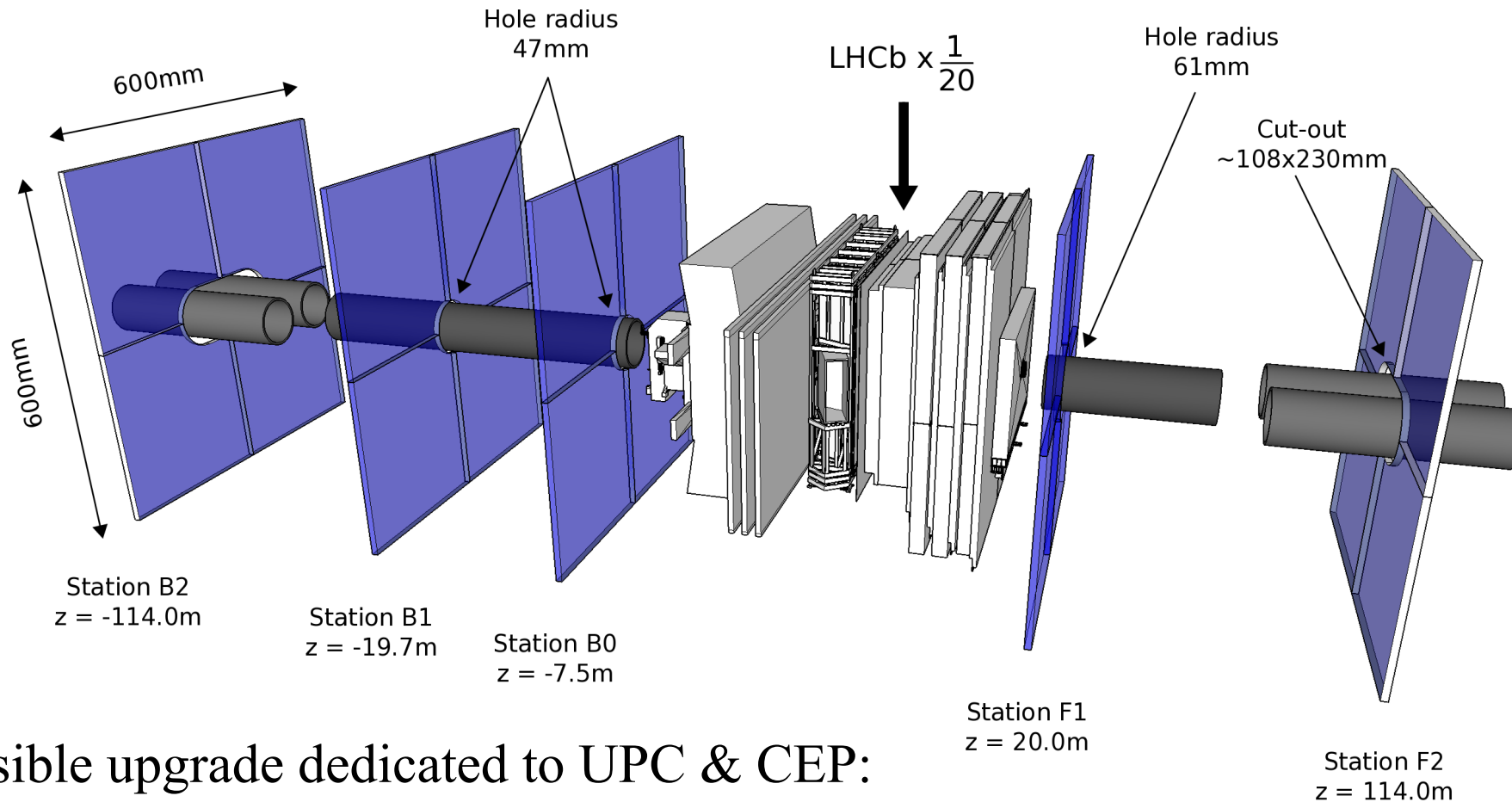
- **Near future**

- Tetraquark production in CEP through $J/\psi + \phi$ in pp events produced through $\gamma + \gamma$, photoproduction, and double pomeron interactions
- Invariant mass spectrum of K^+K^- pairs from A+A UPC
 - Needs theoretical input to identify scalar and tensor meson nonets and glueballs

- **Further future**

- ϕ photoproduction in A+A UPC
 - Covers gluon density at lower Q^2 and x than J/ψ
- ρ^0 photoproduction in A+A UPC
 - Unique coverage and precision

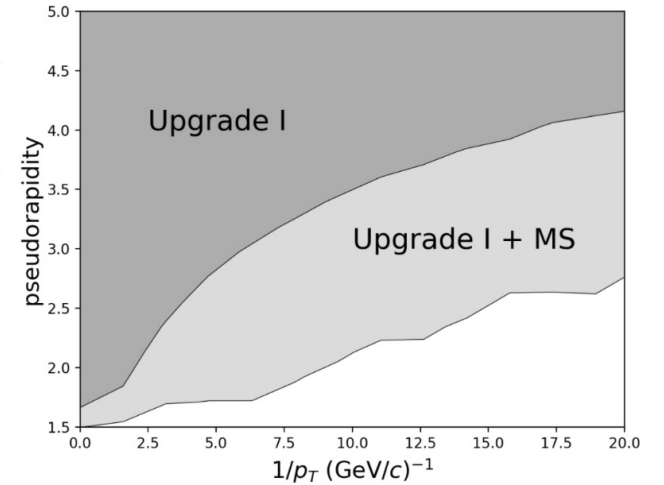
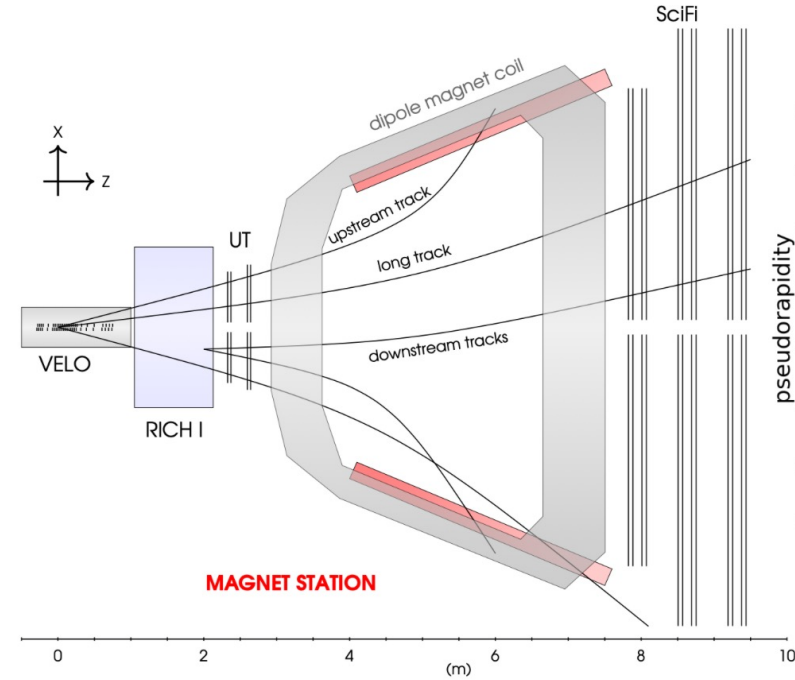
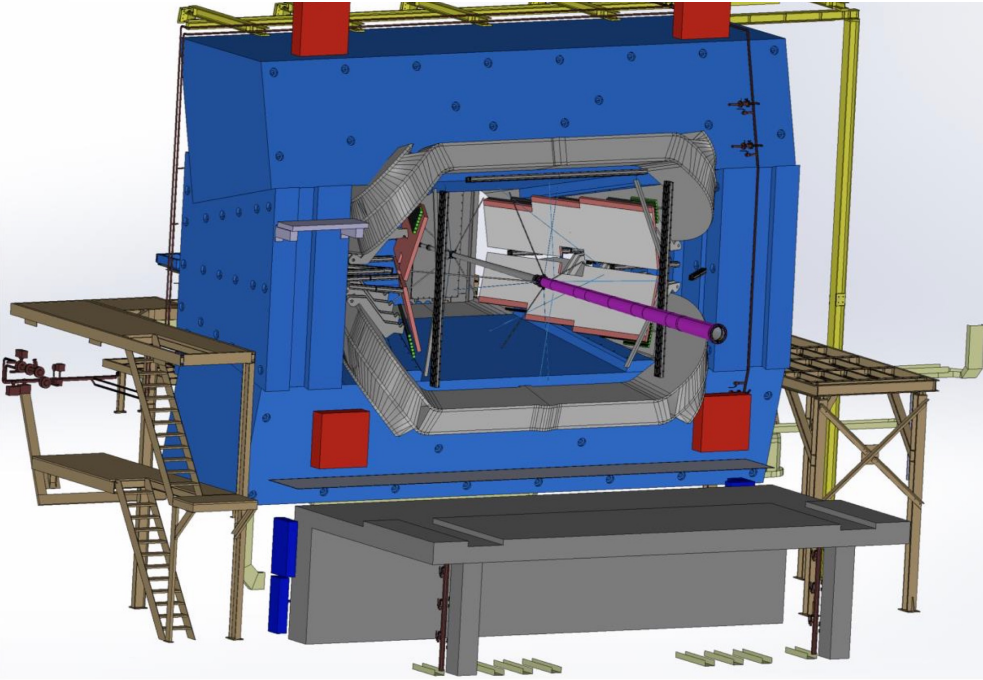
Possible Future Upgrades: Renewed HeRSCHeL



Possible upgrade dedicated to UPC & CEP:

- Replace radiation damaged scintillators.
- Add another station

Future Upgrades : Magnet Stations



- Instrument the internal magnet walls with a scintillator-based soft particle tracker
- Tracking for $p_T > 50$ MeV/c
 - Essential to complete the UPC program
 - high-statistics low-mass vector, scalar and tensor mesons
 - Exotic hadrons with multiple decay products
 - Low-mass dielectrons and photon conversions

Summary

- LHCb is a powerful detector for forward physics

- Software-based trigger
- Excellent particle identification
- Unique coverage (rapidity and low-pT)

- Recent new results

- Photoproduction in PbPb UPC
- Measurements of scalar mesons

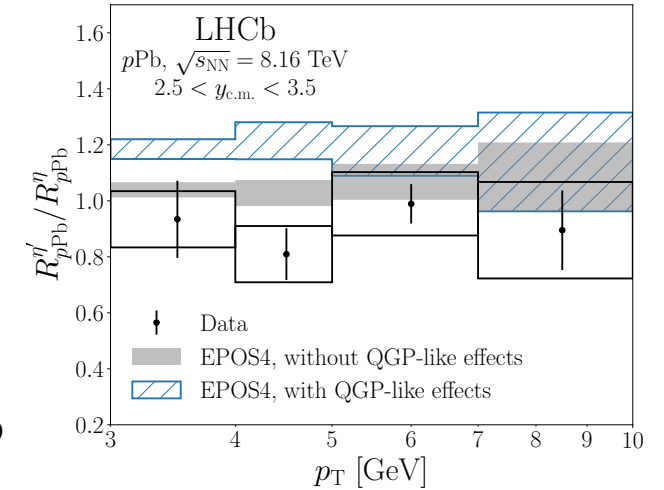
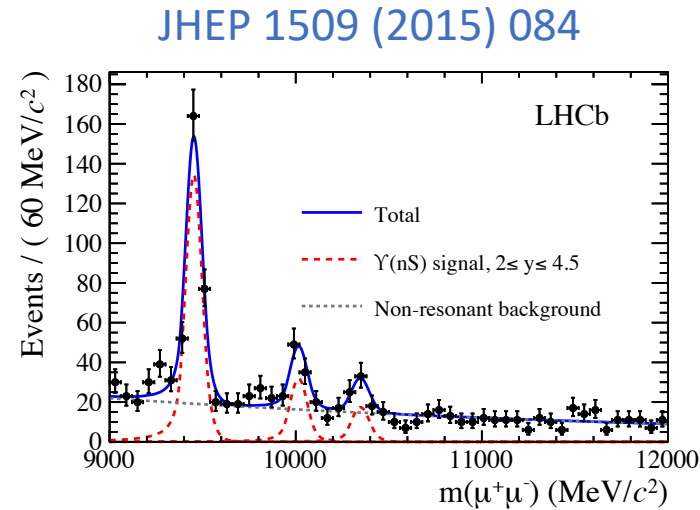
- Results coming soon!

- First measurement of **exclusive** $X \rightarrow J/\psi\phi$ in pp collisions
- UPC $K+K^-$ production
- Unique look at UPC ρ^0 production

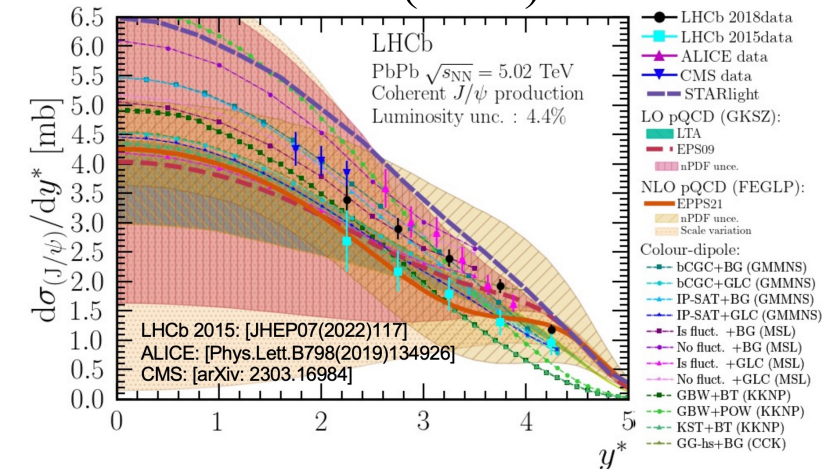
- Upgrades on the horizon

- Potential future upgrades dedicated to forward physics program!
 - Improved HerSChEL for UPC and CEP measurements
- Even lower pT tracking via Magnet Stations

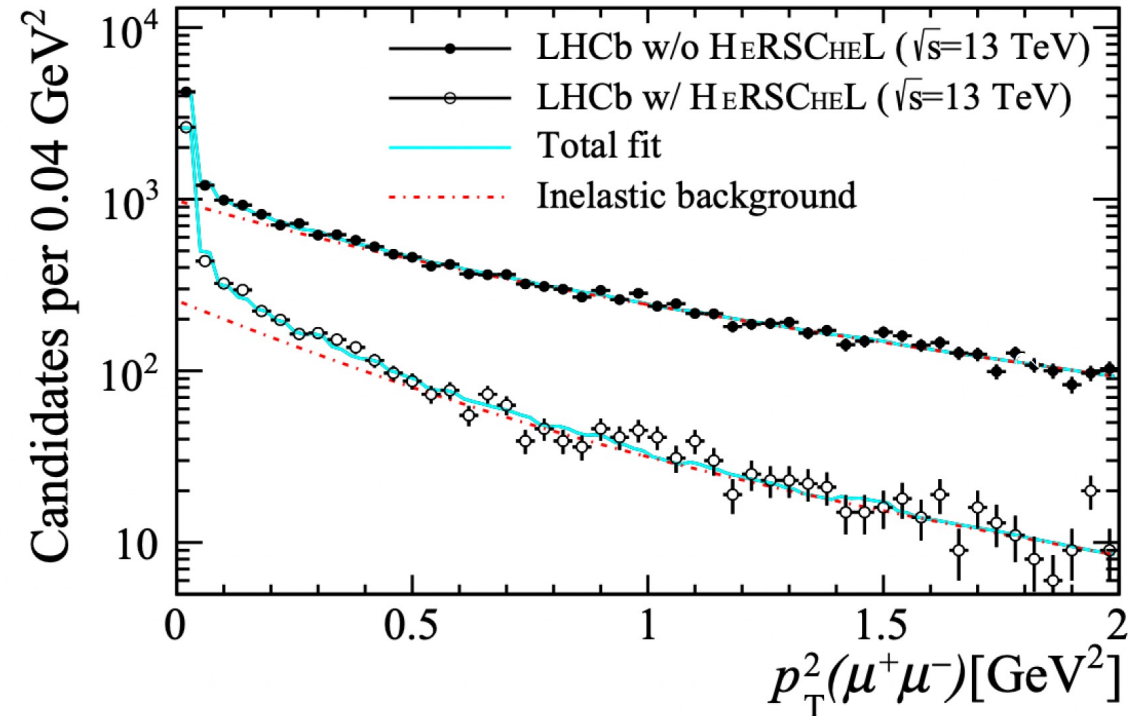
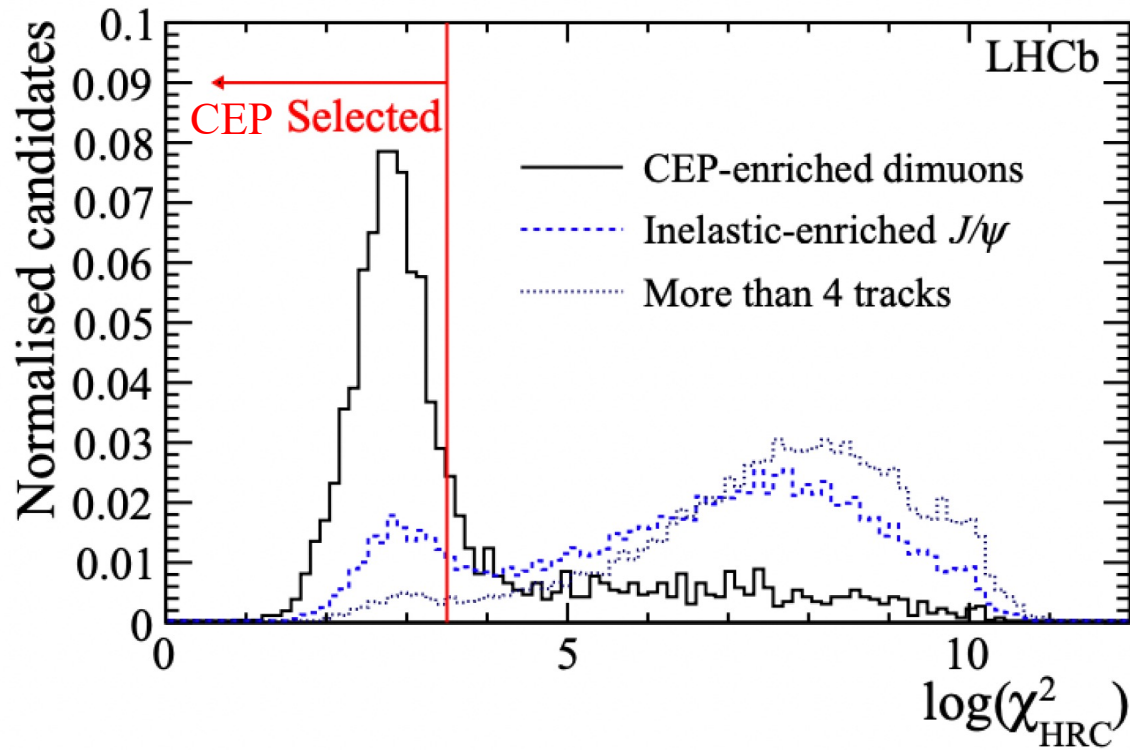
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HeRSChEL Tagging & Discrimination



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- The Figure of Merit (left) is a χ^2 quantity that includes hits from all twenty counters and accounts for correlations among counters based on activity above the noise
 - By subtracting the background, an exclusive sample of signal events is obtained
- The p_T^2 distribution of dimuons (right) with and without the requirement on the $\log(\chi^2)$

Comparison With Theory & Other Results

