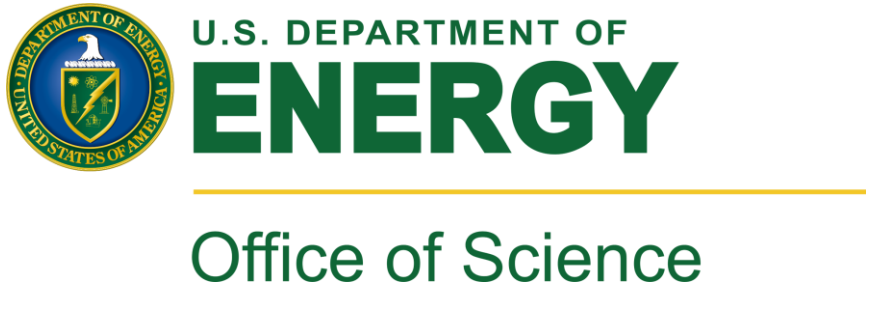
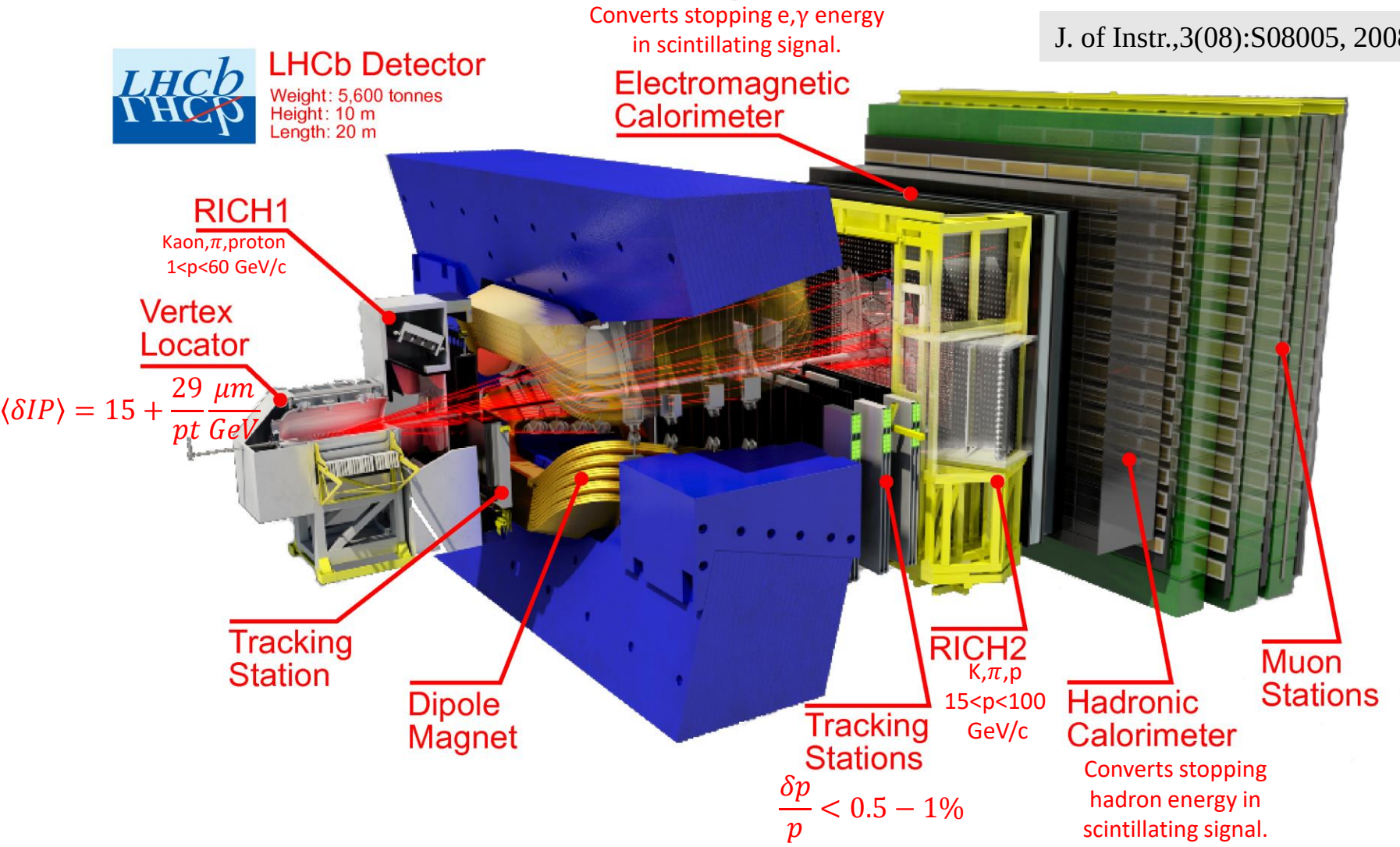
Latest LHCb UPC Results

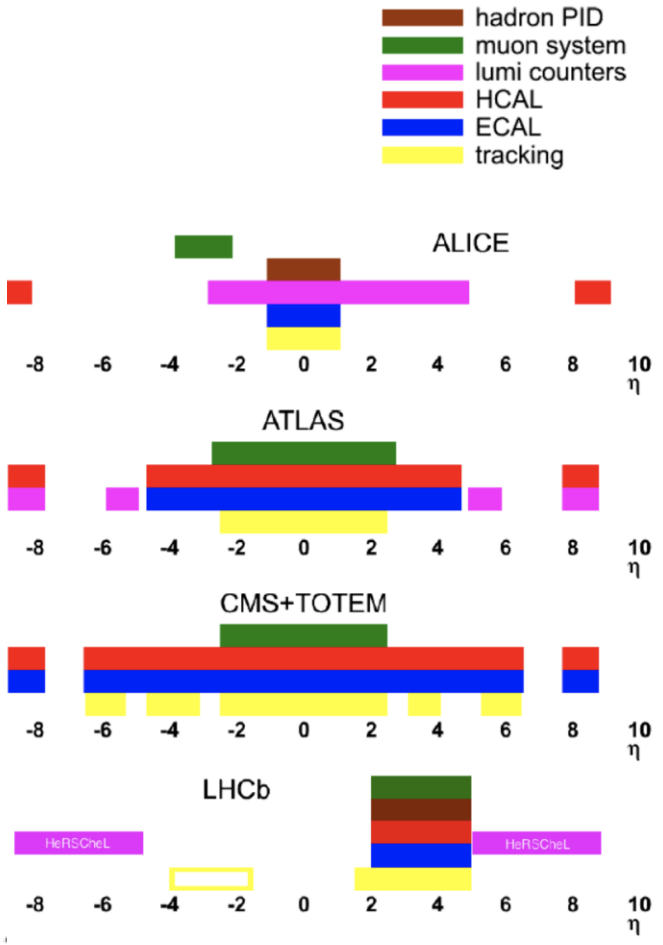
Cesar Luiz da Silva for the LHCb Collaboration
Los Alamos National Lab



The LHC beauty detector Runs 1 & 2



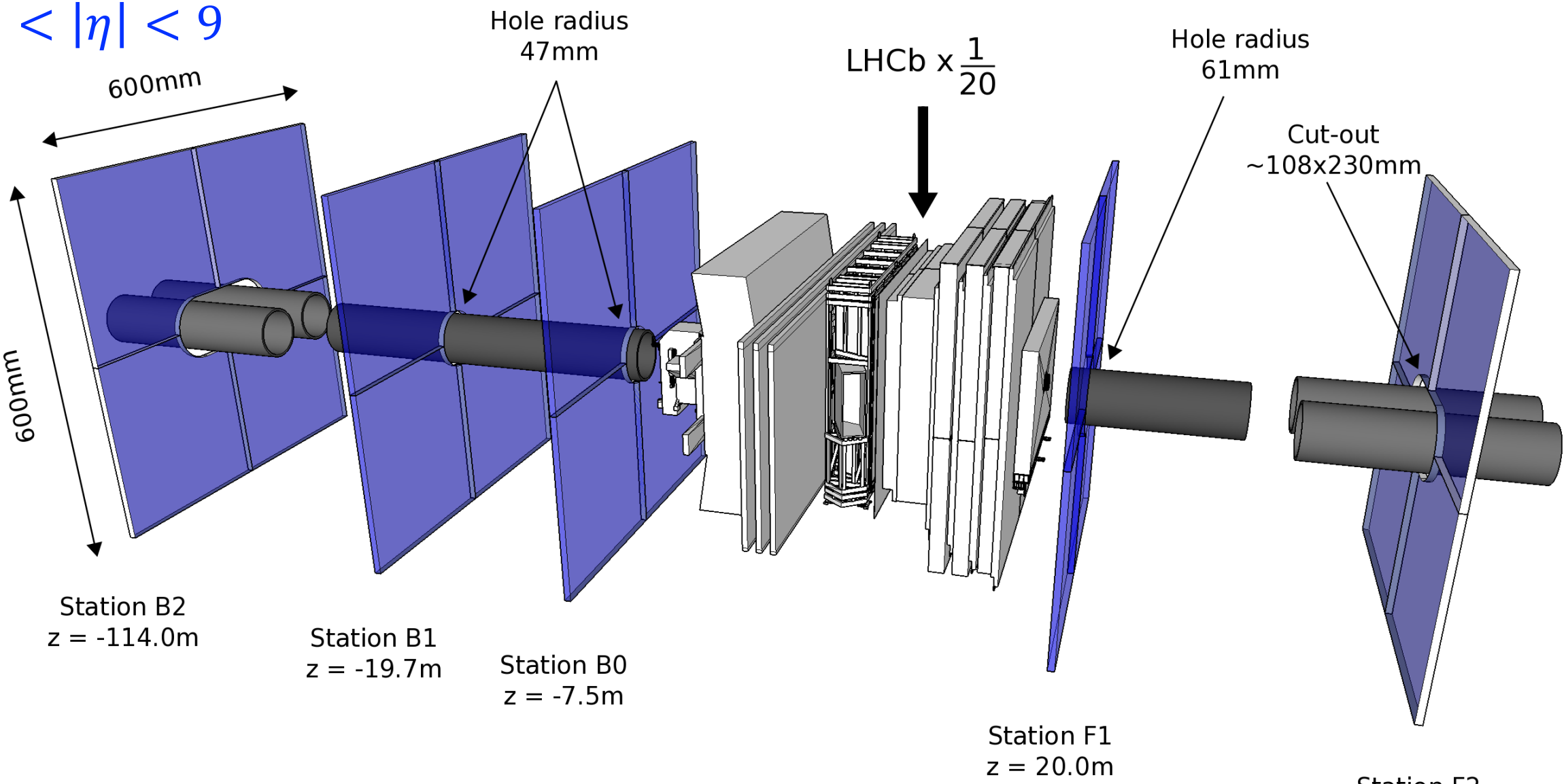
J. of Instr.,3(08):S08005, 2008



- Dedicated to Flavor Physics
- $e, \mu, \pi, K, p, \gamma$, particle identification in 1<p<100 GeV/c
- Unique forward instrumentation for heavy ion physics

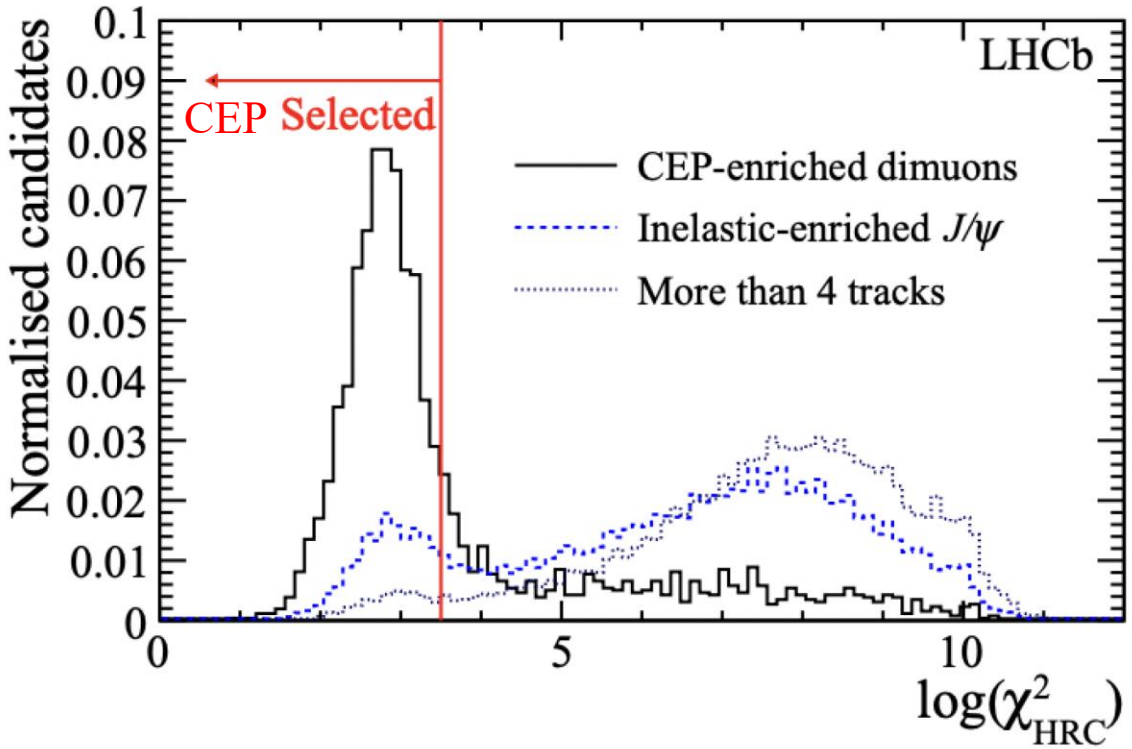
HeRSCheL detector: high-rapidity shower counters for LHCb

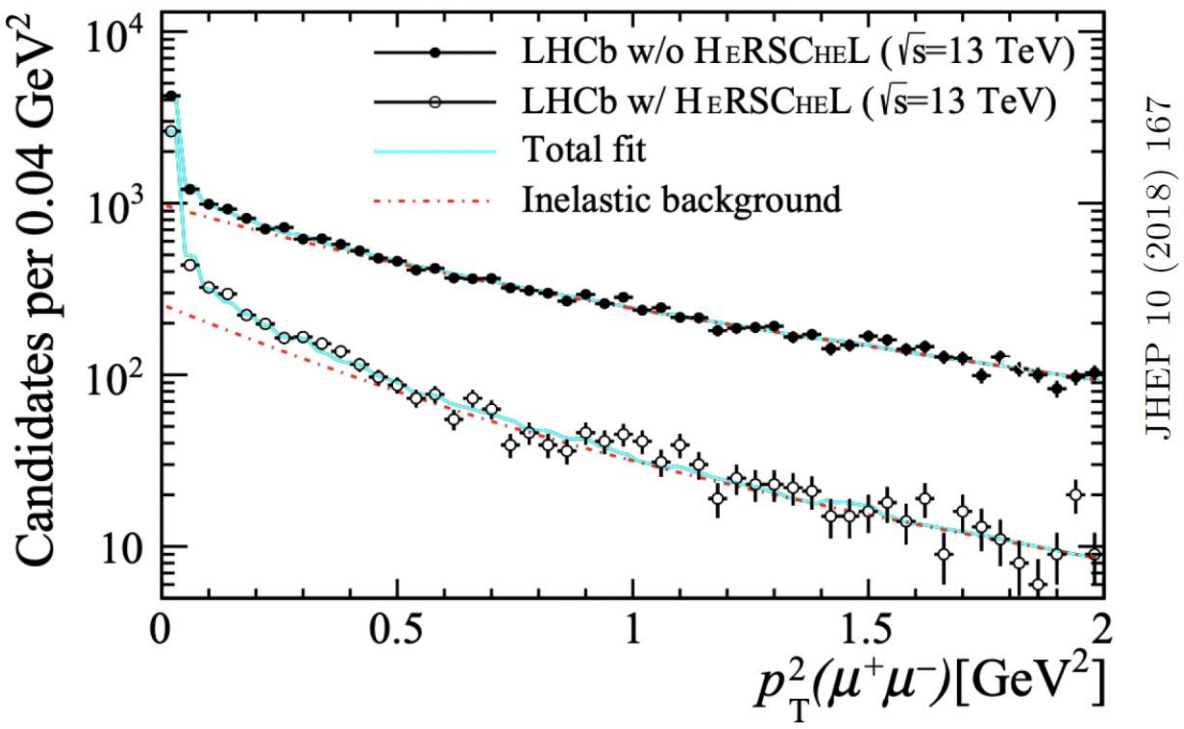
$5 < |\eta| < 9$



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

Herschel Detector Discrimination



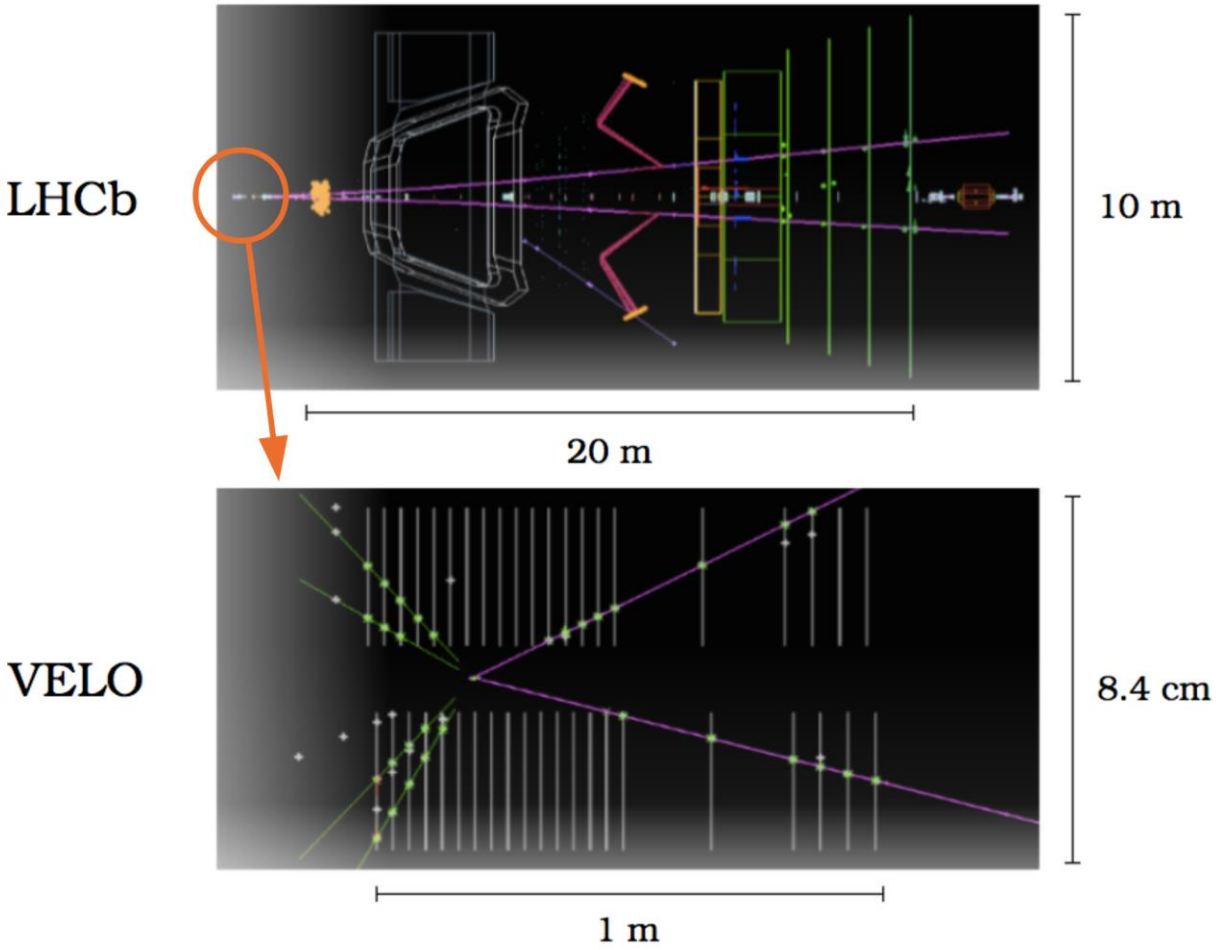


JHEP 10 (2018) 167

- 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 $\log(\chi^2)$

Trigger Conditions for UPC events

- long track (tracks with hits in all tracking detectors) [1,20]
- SPD hits (ECAL raw hits) < 2000
- Event selected by software
- NO pre-scale

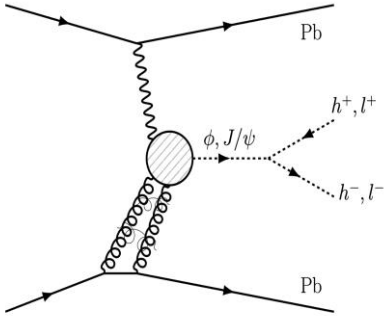


Data sets

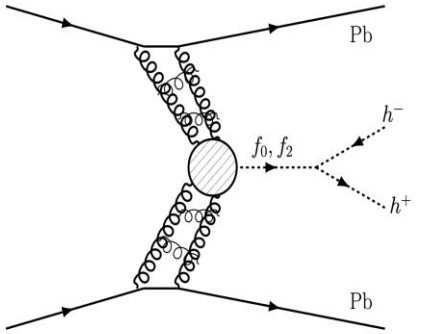
2015 PbPb 5 TeV	4 μb^{-1}
2018 PbPb 5 TeV	214 μb^{-1}
2023 PbPb 5 TeV	~210 μb^{-1}

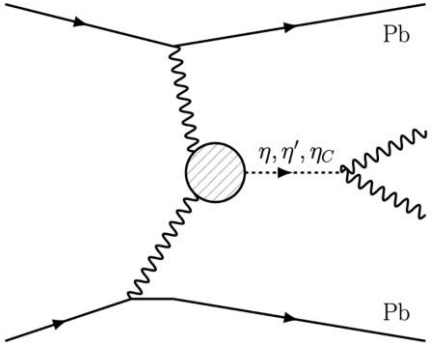
LHCb has detector coverage and particle identification for an entire UPC program

- Photoproduction of vector mesons

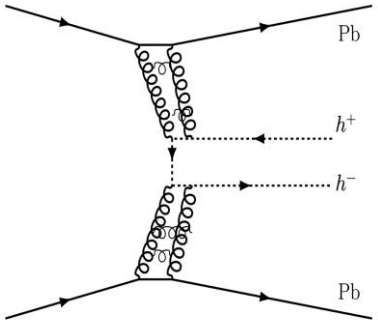


- scalar and tensor mesons from pomeron+pomeron and $\gamma\gamma$ interactions
- Glueball and tetraquark searches

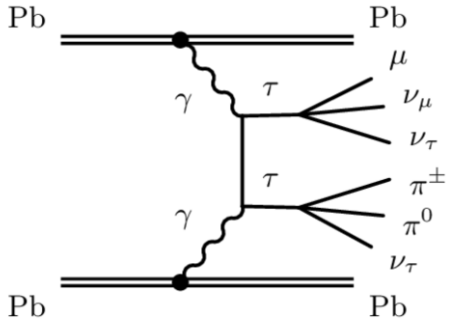




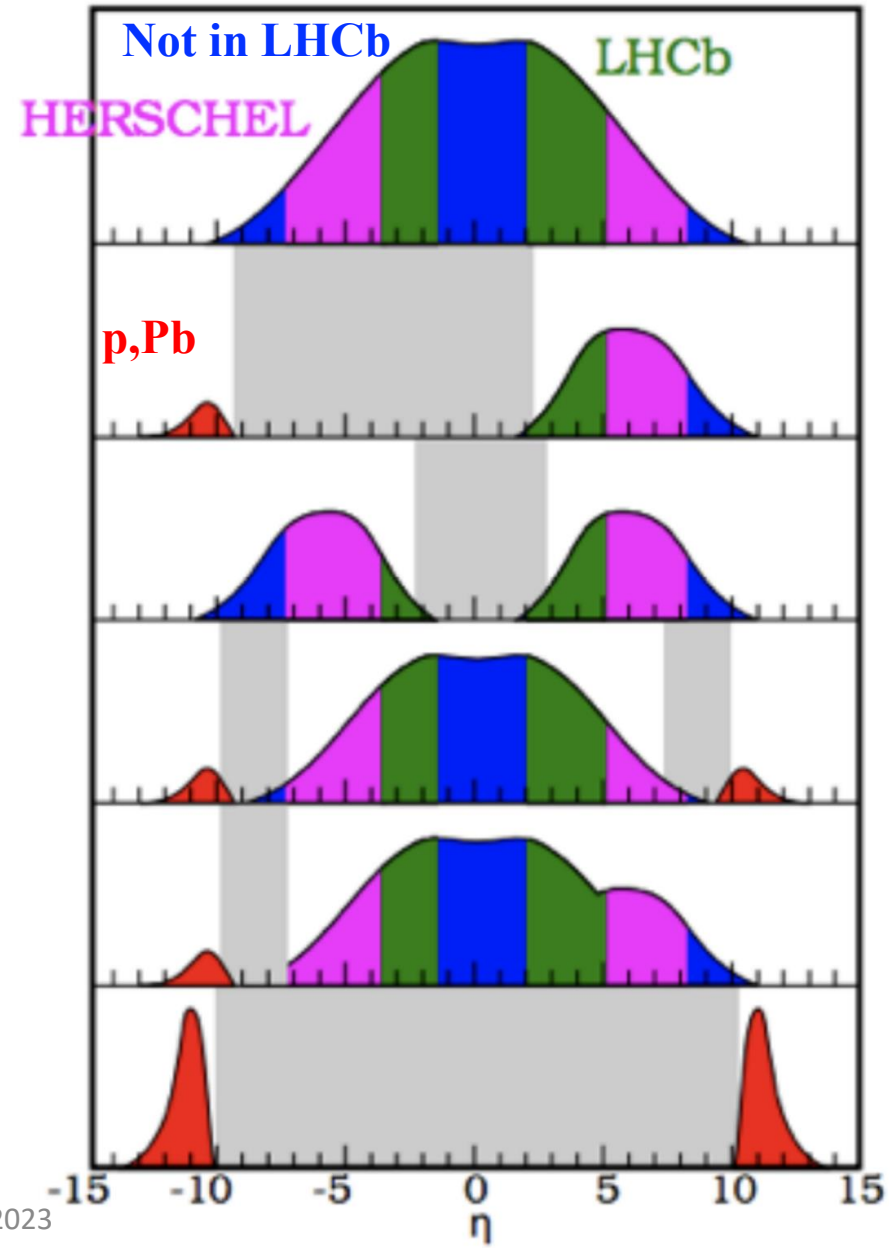
- Non-resonant spectrum

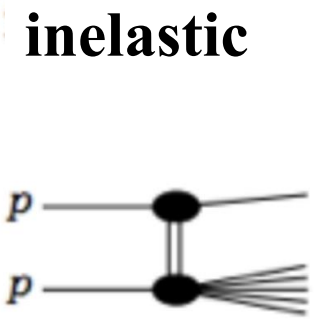


- BSM : τ g-2 with hadron decays and lepton p_T<<5 GeV/c



Rapidity coverage





inelastic

single diffraction

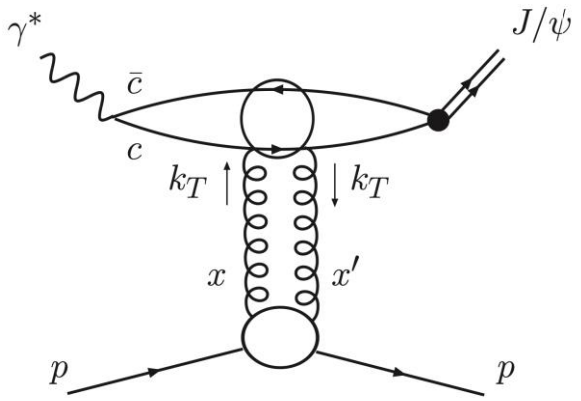
double diffraction

CEP+UPC elastic

CEP+UPC inelastic

Elastic

$J/\psi, \psi(2S)$ Photo-production cross-section in CEP



JHEP11(2013)085

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

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

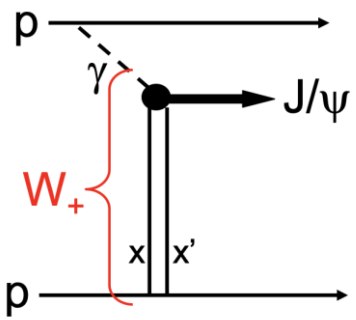
External inputs

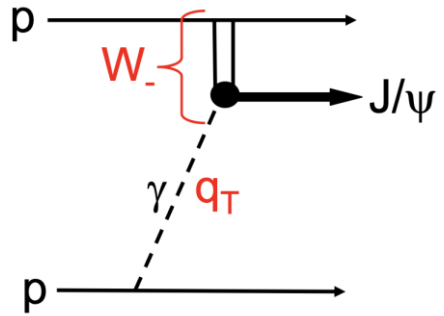
gap survivor, photon flux

Photoproduction result from H1(HERA)

parametrization = $a\left(\frac{W}{90\ \mathrm{GeV}}\right)^{\delta}$

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

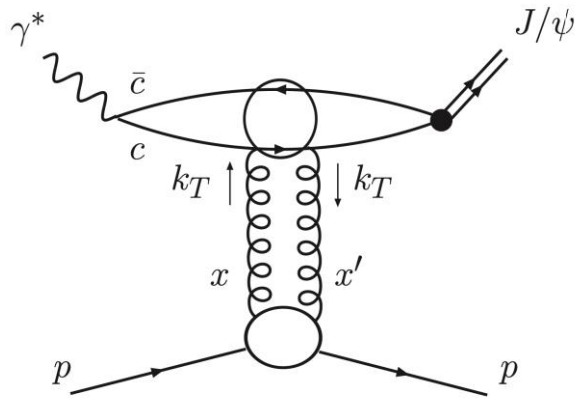




- $\sigma_{pp\to p\psi p}(\mathrm{W})$ has contributions from photon coming from both forward and backward going proton in CMS
- **Goal:** Extract ψ photoproduction cross − section $\boldsymbol{\sigma_{\gamma p\to\psi p}(W)}$ from measured $\boldsymbol{\sigma_{pp\to p\psi p}(\mathrm{W})}$

$W^2 \equiv 2k\sqrt{s}$

$J/\psi, \psi(2S)$ Photo-production cross-section in CEP



JHEP11(2013)085

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

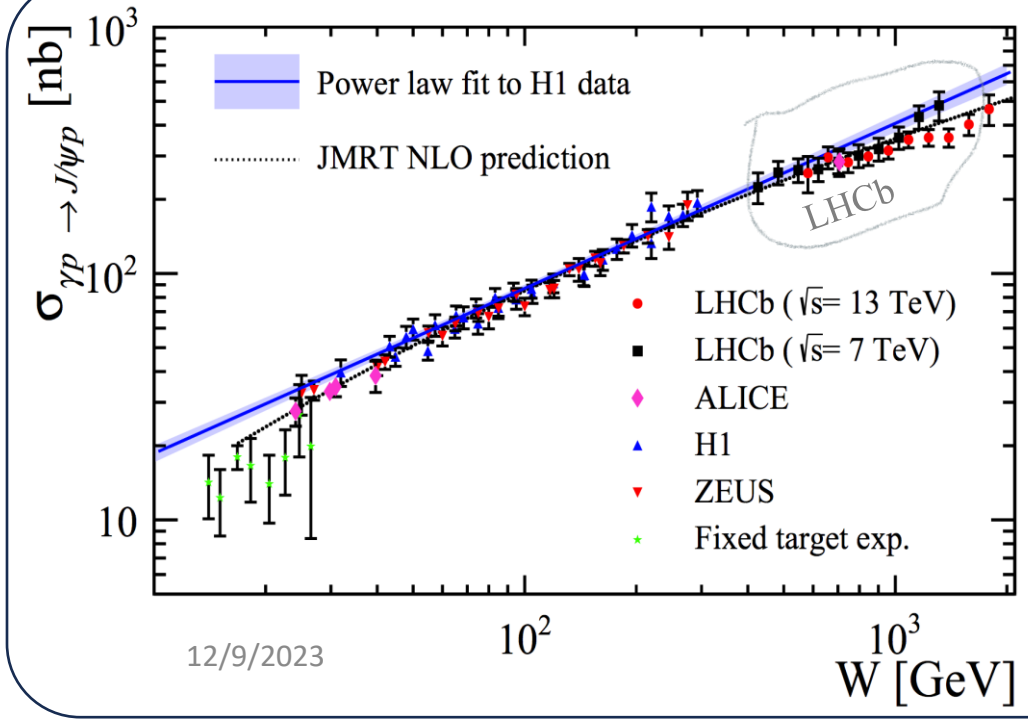
Invariant mass of the photon-proton system
$W_\pm^2 = 2k_\pm\sqrt{s}$

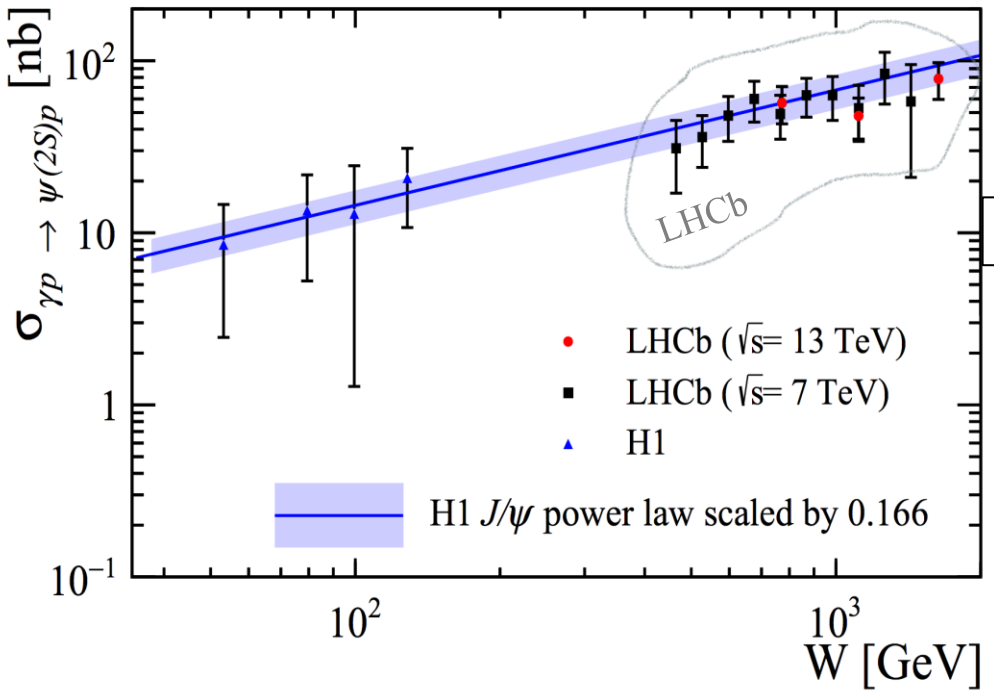
External inputs

gap survivor — photon flux

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

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



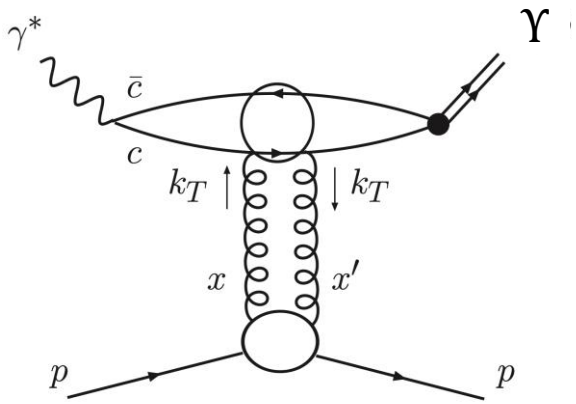


JHEP 10 (2018) 167

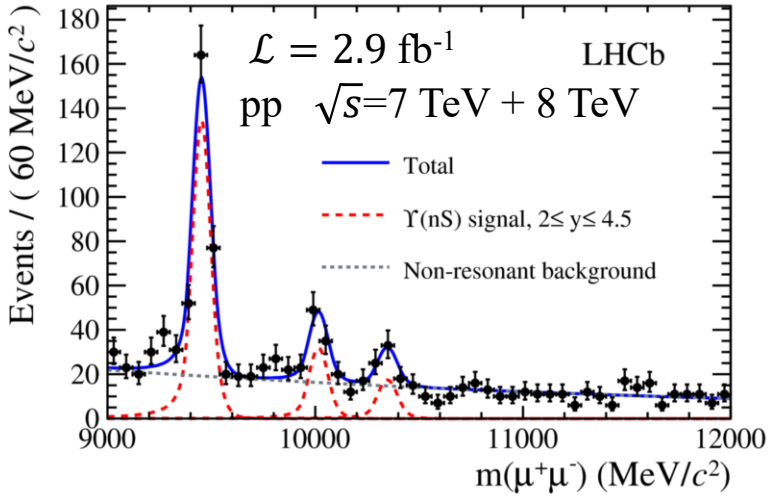
$W^2 \equiv 2k\sqrt{s}$

HeRSCheL sel.

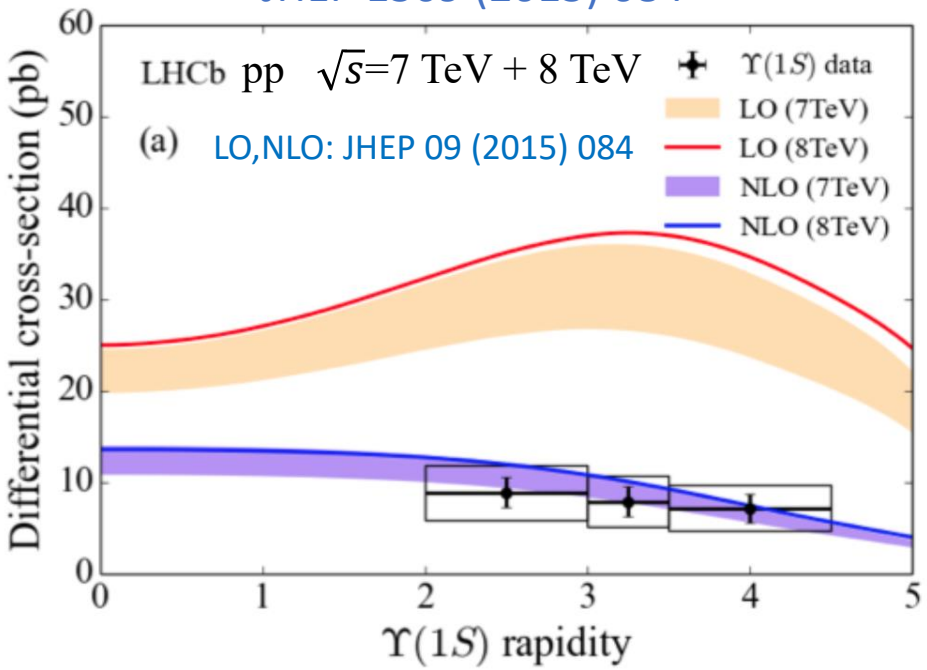
Bottomonia photo-production cross-section in CEP

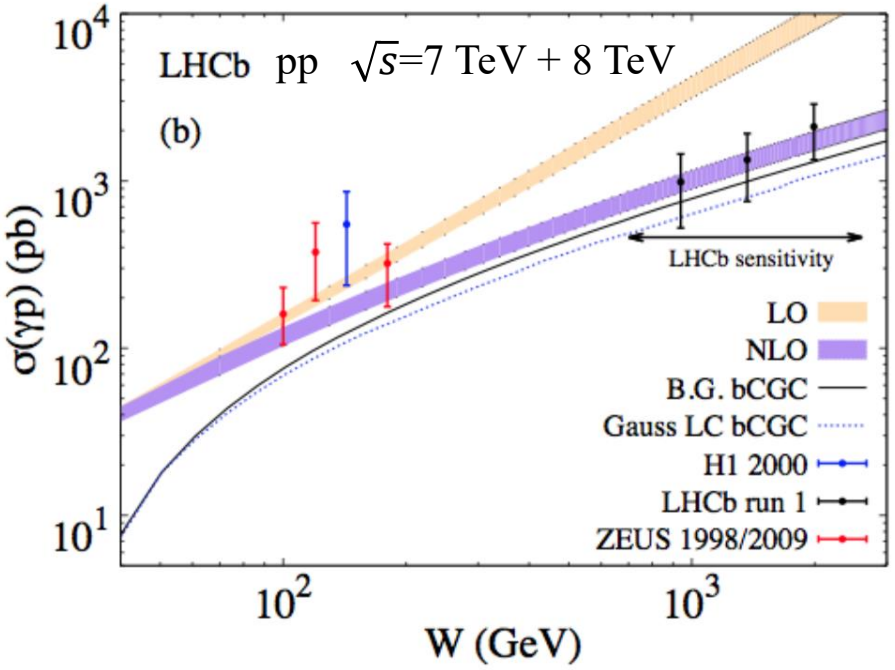


$$Q^2 \approx 25 GeV^2$$

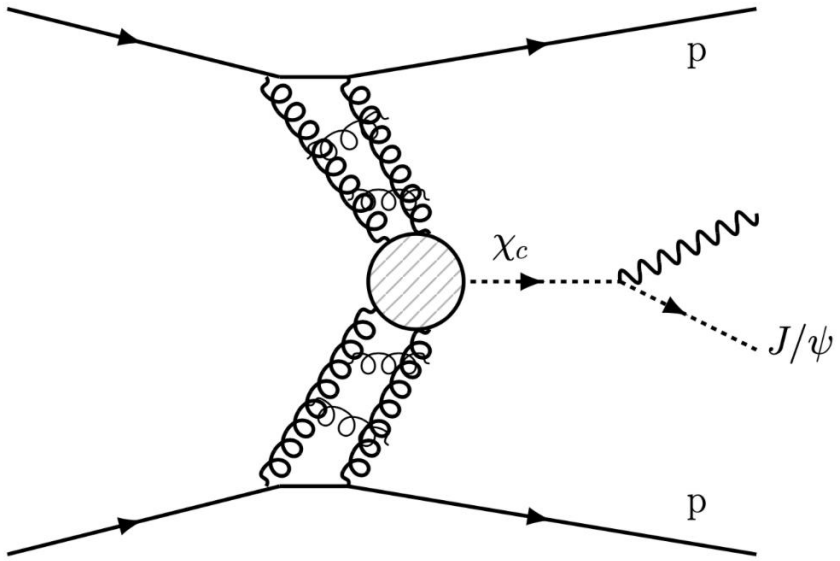


JHEP 1509 (2015) 084

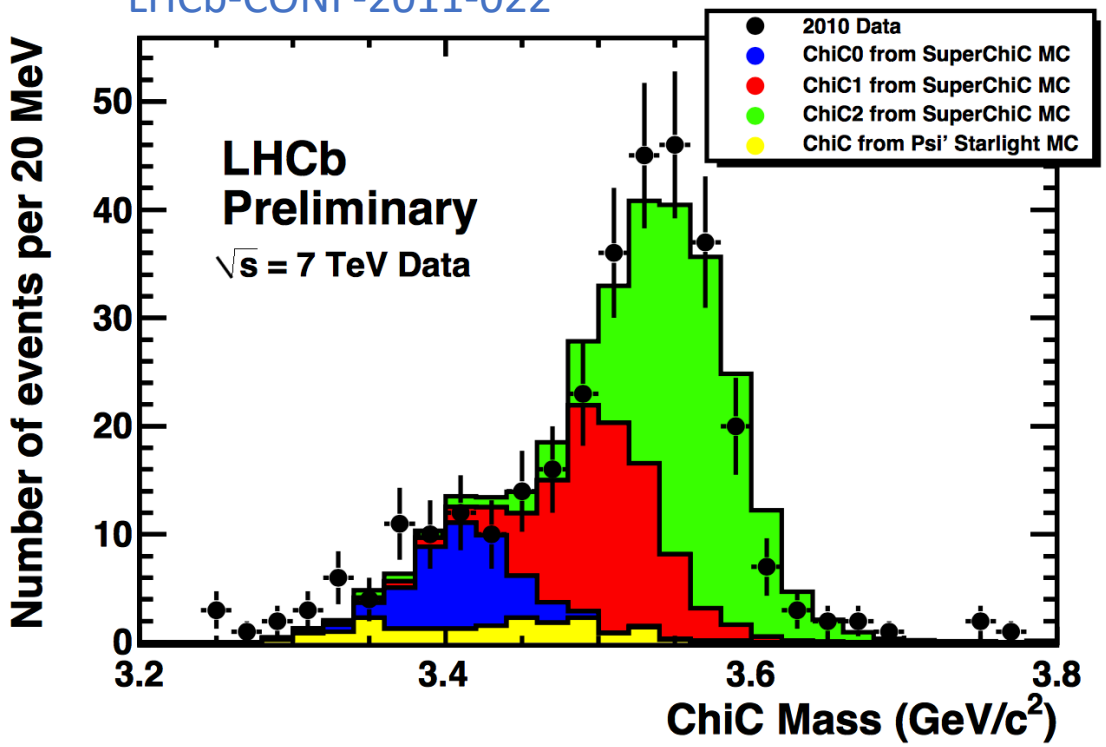




P-wave charmonia



LHCb-CONF-2011-022



Data Result

$$\sigma_{\chi_{c0}\to J/\psi\gamma\to\mu^+\mu^-\gamma}(2<\eta_{\mu+},\eta_{\mu-},\eta_\gamma<4.5)=9.3\pm2.2\pm3.5\pm1.8\ \text{pb}$$

$$\sigma_{\chi_{c1}\to J/\psi\gamma\to\mu^+\mu^-\gamma}(2<\eta_{\mu+},\eta_{\mu-},\eta_\gamma<4.5)=16.4\pm5.3\pm5.8\pm3.2\ \text{pb}$$

$$\sigma_{\chi_{c2}\to J/\psi\gamma\to\mu^+\mu^-\gamma}(2<\eta_{\mu+},\eta_{\mu-},\eta_\gamma<4.5)=28.0\pm5.4\pm9.7\pm5.4\ \text{pb}$$

SuperChic

$\sigma_{\chi c0} = 14\ pb$

$\sigma_{\chi c1} = 10\ pb$ (factor 2 uncertainty)

$\sigma_{\chi c2} = 3\ pb$

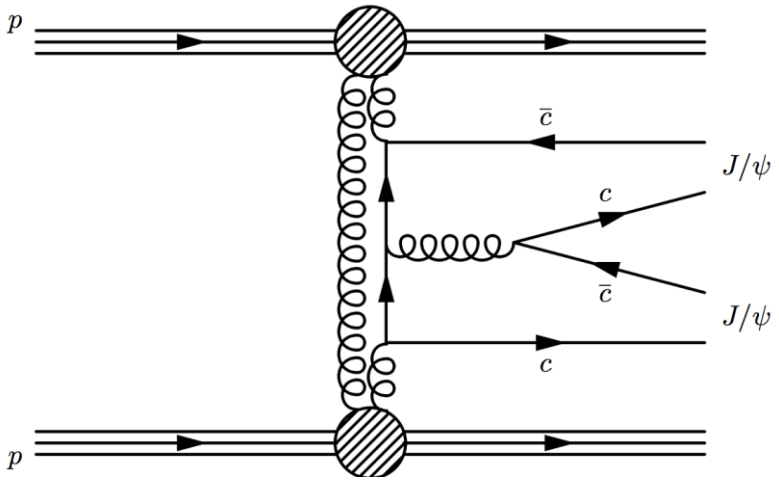
arXiv:hep-ph/0909.4748

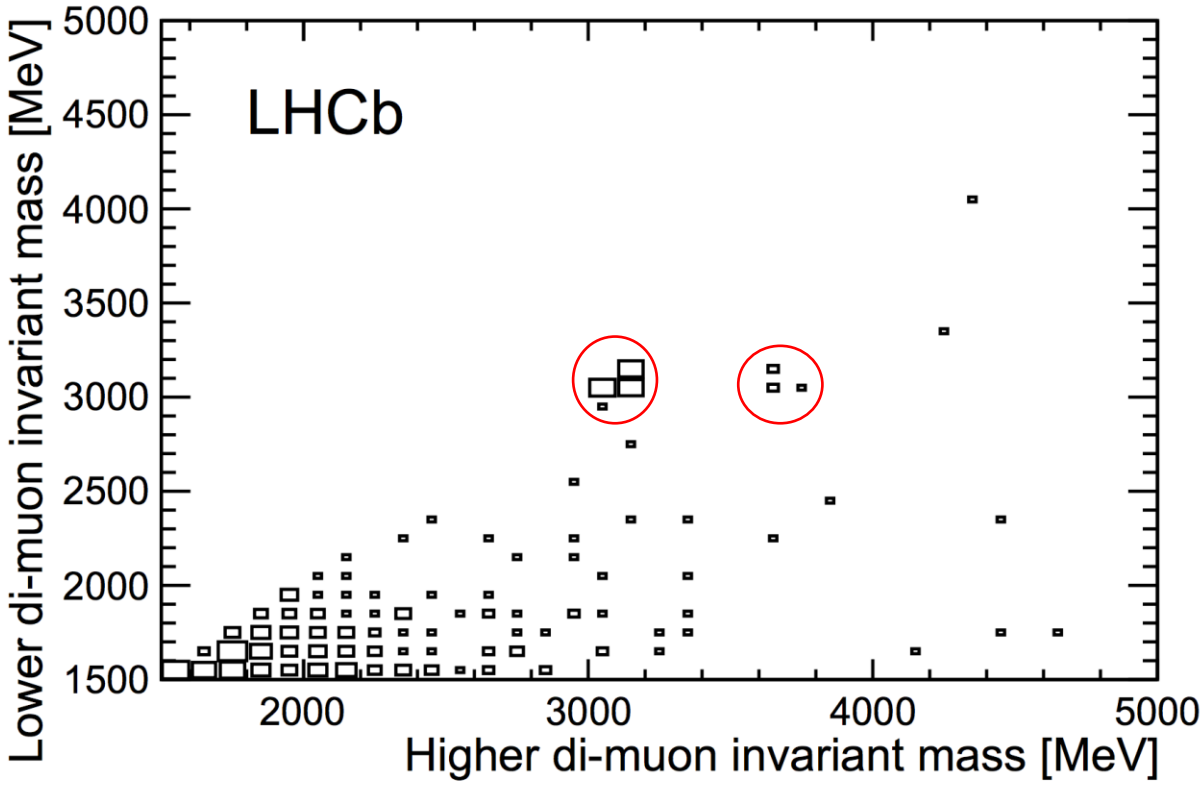
Discrepancy for $\sigma_{\chi c2}$ can come from inelastic contamination.
New measurement using HeRSCheL on target.

Double J/ψ production

J.Phys.G41 (2014)115002

Double pomeron exchange



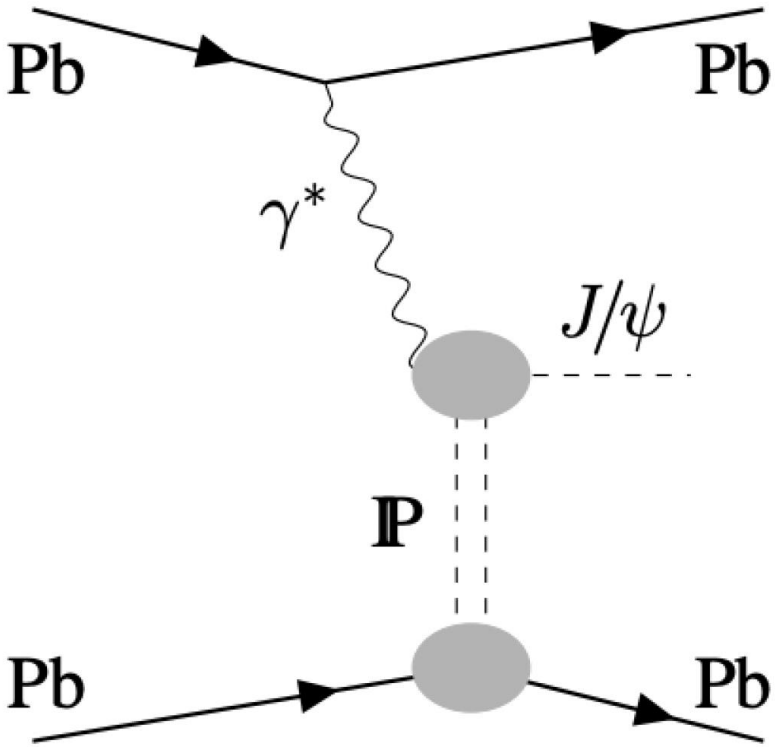


$$\sigma^{J/\psi\,J/\psi} = 58 \pm 10(\text{stat}) \pm 6(\text{syst})\,\text{pb},$$
$$\sigma^{J/\psi\,\psi(2S)} = 63^{+27}_{-18}(\text{stat}) \pm 10(\text{syst})\,\text{pb},$$
$$\sigma^{\psi(2S)\psi(2S)} < 237\,\text{pb},$$
$$\sigma^{\chi_{c0}\chi_{c0}} < 69\,\text{nb},$$
$$\sigma^{\chi_{c1}\chi_{c1}} < 45\,\text{pb},$$
$$\sigma^{\chi_{c2}\chi_{c2}} < 141\,\text{pb},$$

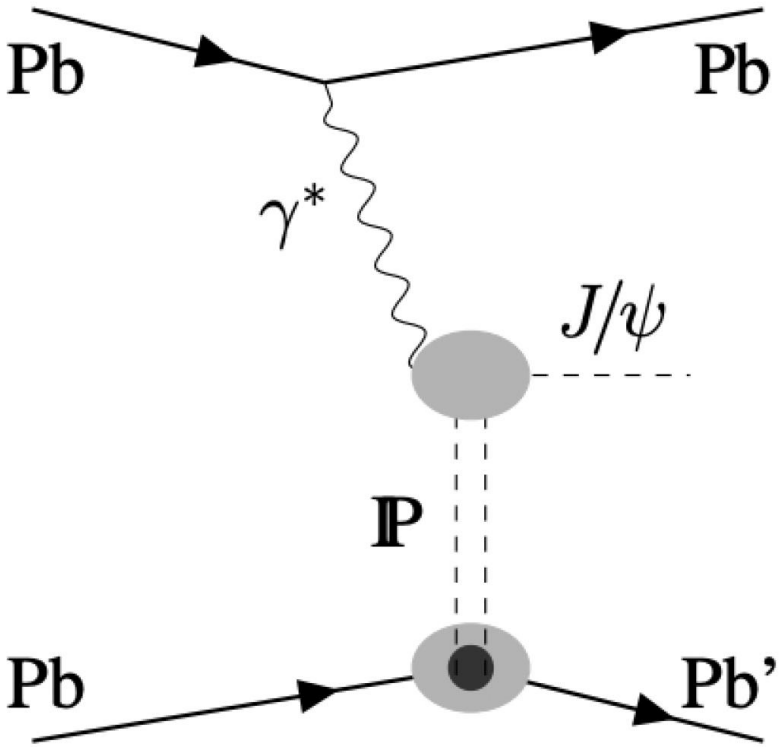
$$\frac{\sigma(J/\psi\,\psi(2S))}{\sigma(J/\psi\,J/\psi)} = 1.1^{+0.5}_{-0.4},$$

Photo-production in PbPb UPC

Coherent

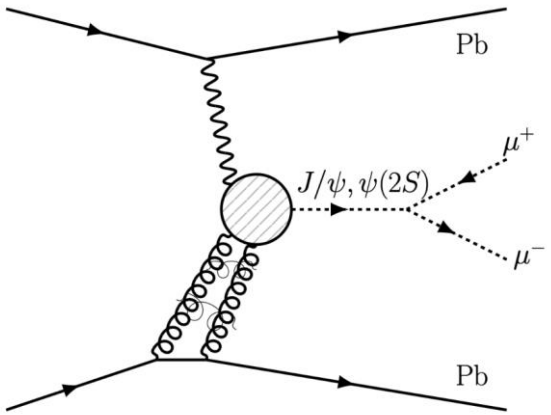


Incoherent

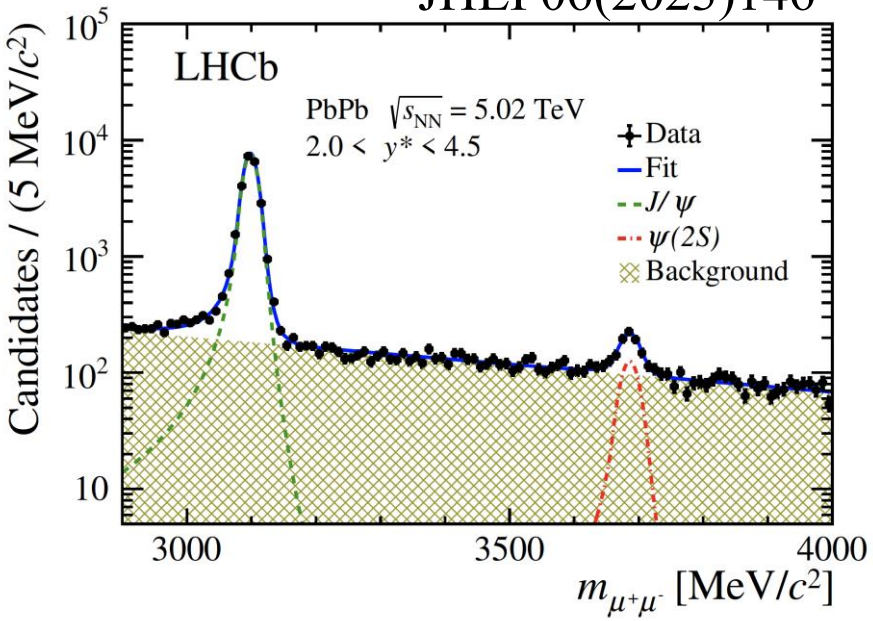


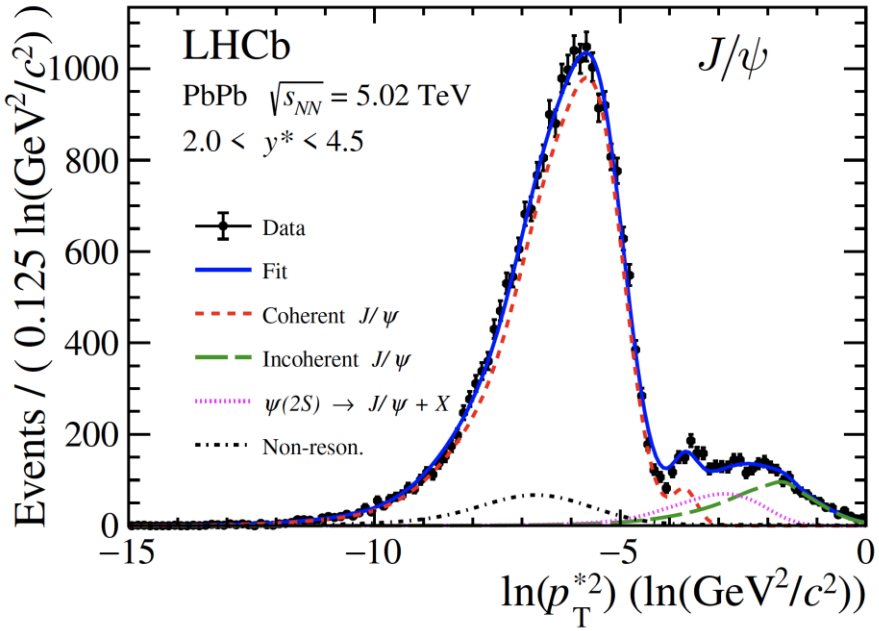
JHEP 07 (2022) 117

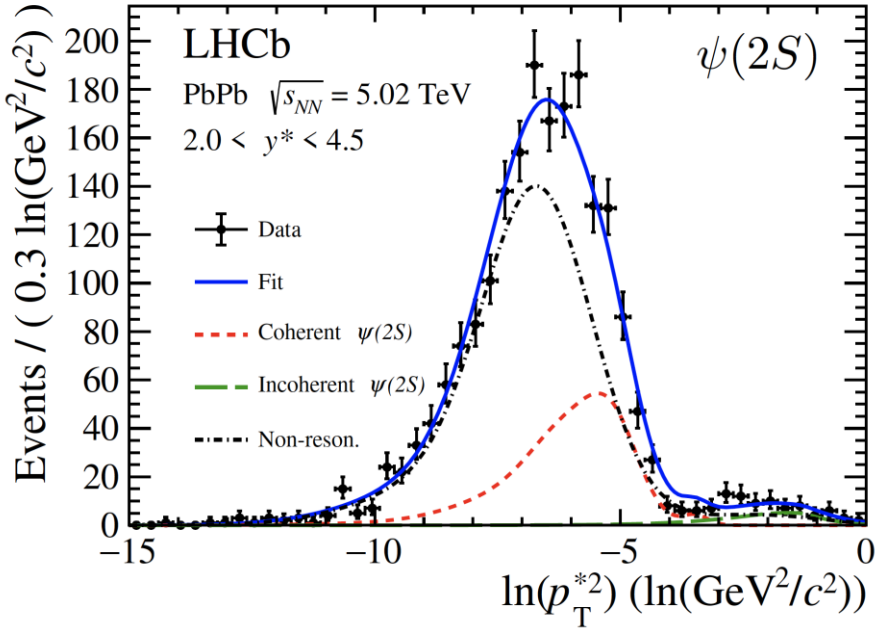
J/ψ, $\psi(2S)$ photoproduction in UPC



JHEP06(2023)146





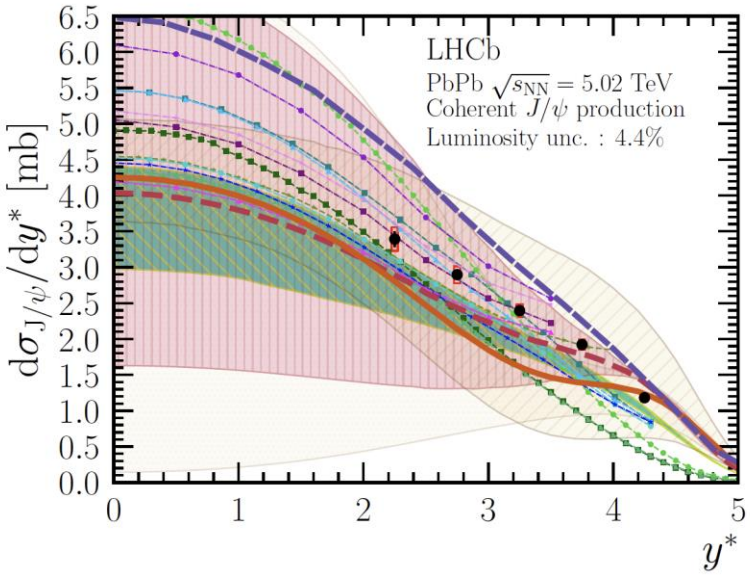


- Excellent separation between coherent and incoherent components, thanks to
  - HeRSCHeL
  - High p_T resolution

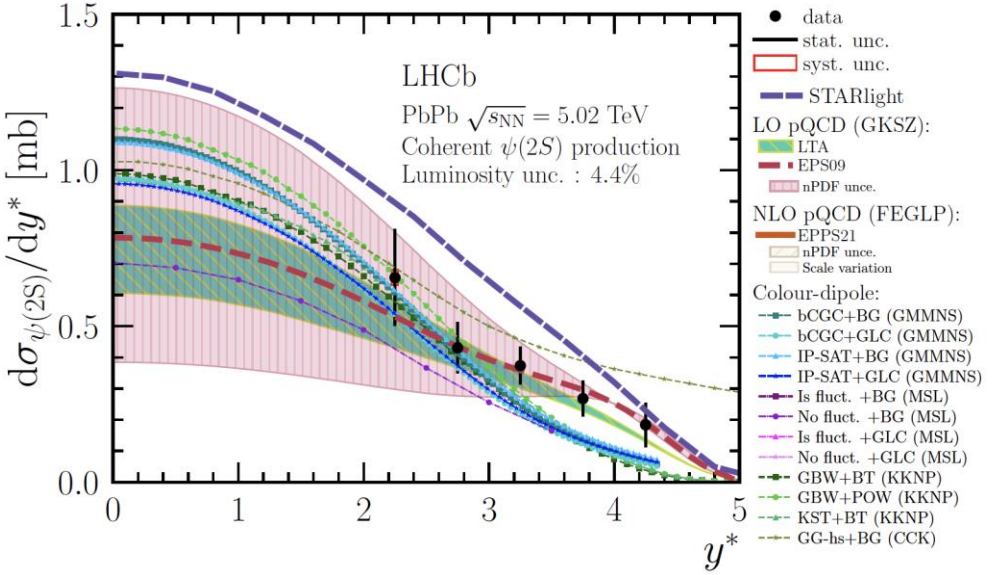
Comparison with theoretical models

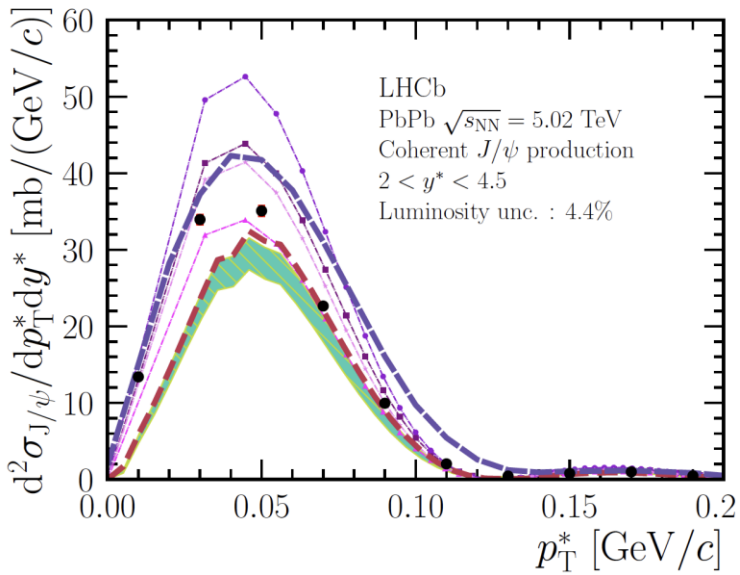
JHEP06(2023)146

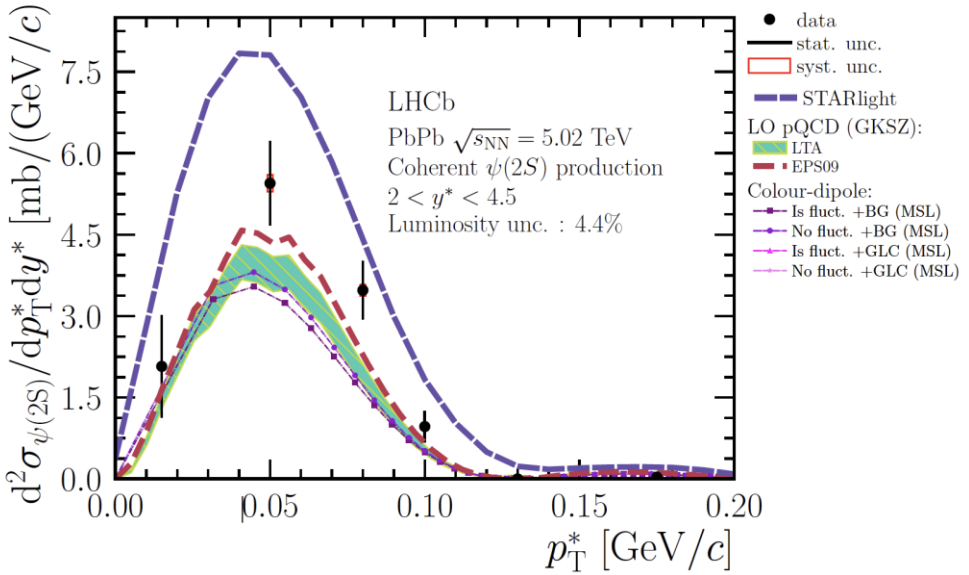
J/ψ



$\psi(2S)$

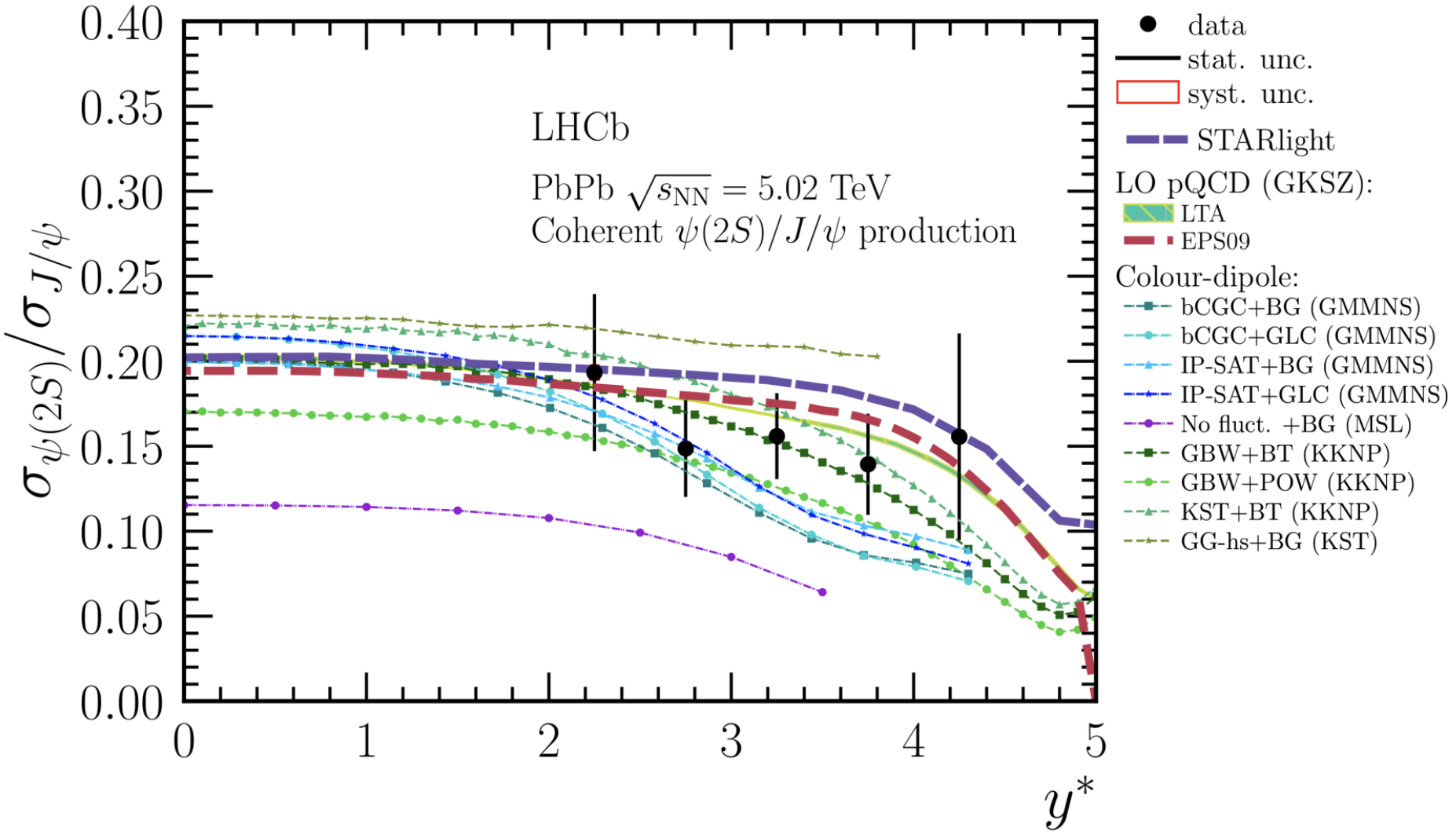






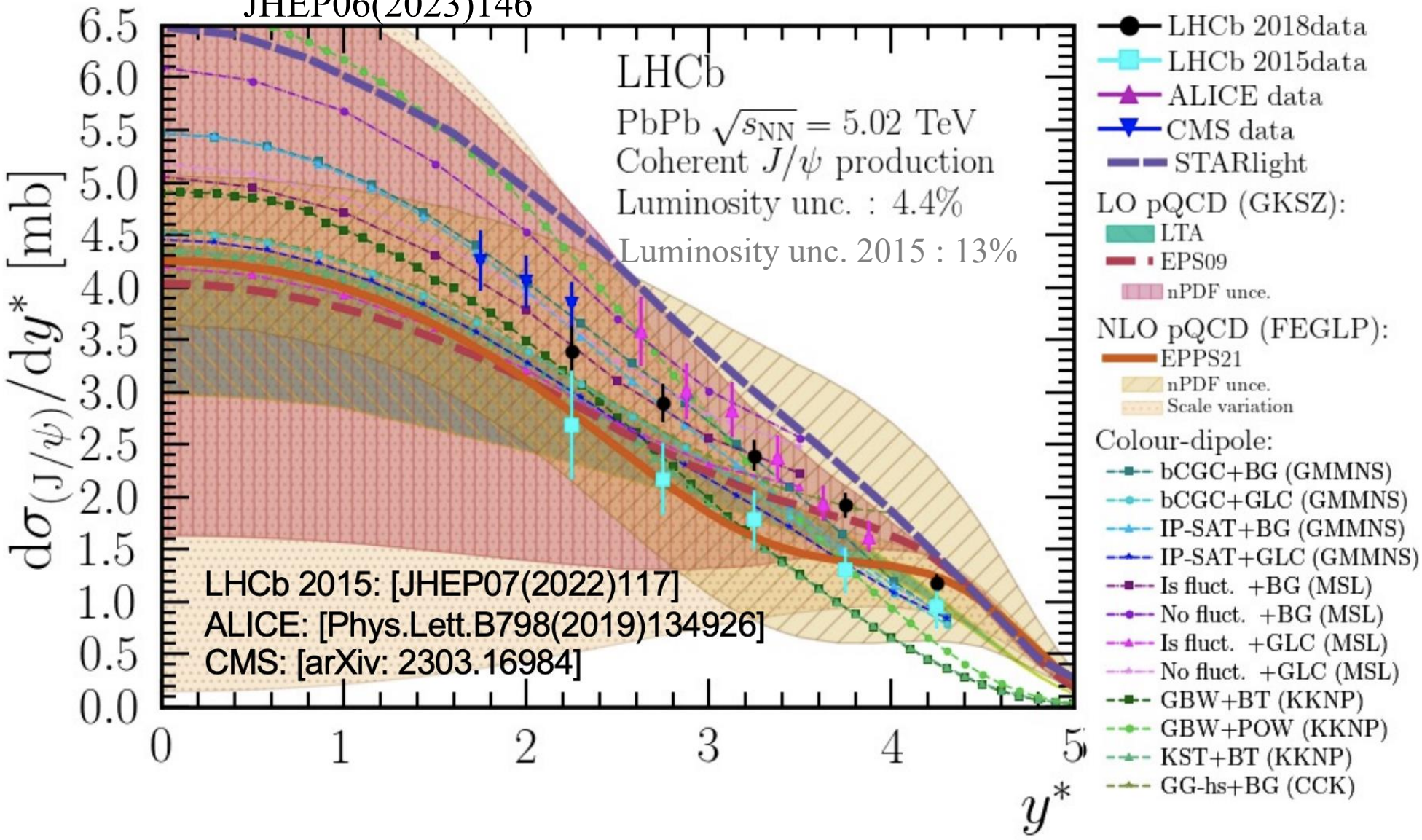
Comparison with theoretical models

JHEP06(2023)146



Comparison with previous results

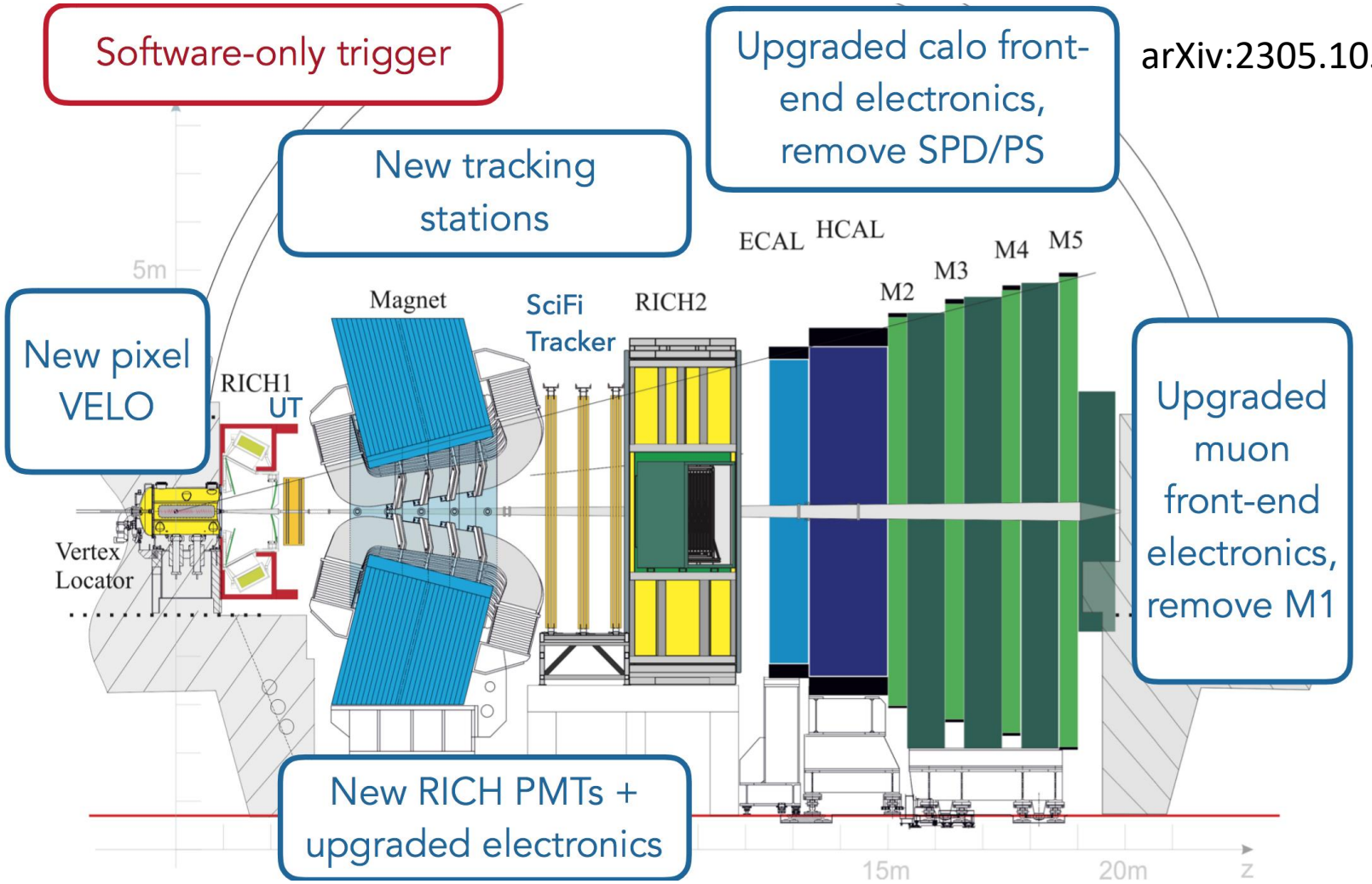
JHEP06(2023)146



Results coming up

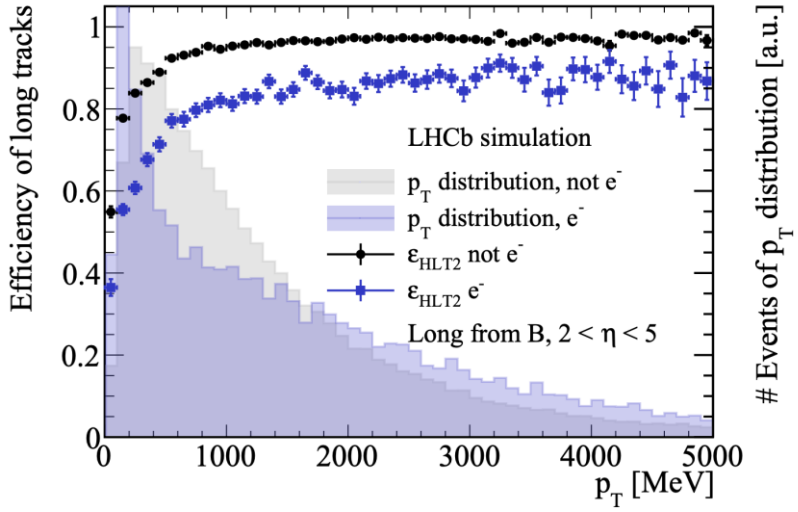
- **Near future**
  - Tetraquark production in CEP $J/\psi + \phi$ events
    - $\gamma + \gamma$, photoproduction, double pomeron interaction
  - Mass spectrum of K^+K^- pairs in UPC
    - Photoproduction, double pomeron interaction, $\gamma + \gamma$
    - Needs theoretical input to identify scalar and tensor meson nonets and glueballs
- **Further future**
  - ϕ photoproduction in UPC
    - Covers gluon density at lower Q^2 and x than J/ψ

The LHCb Upgrade I

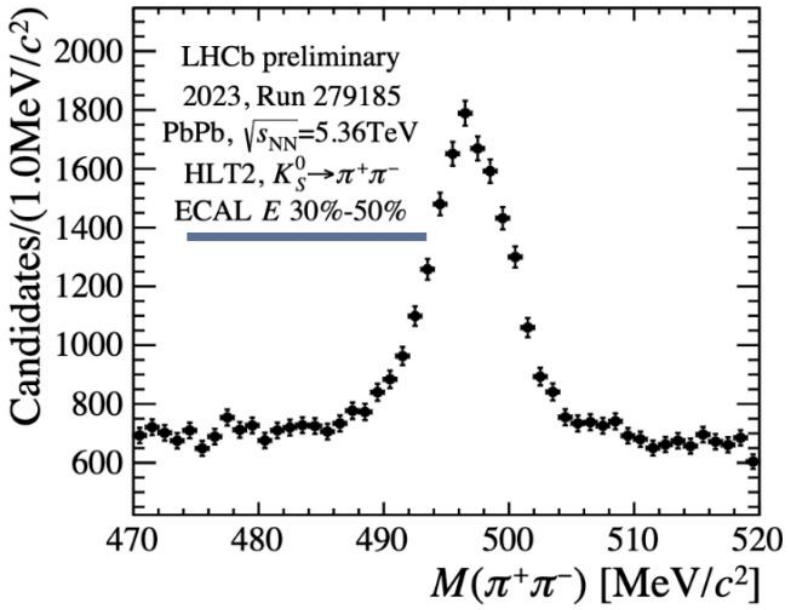


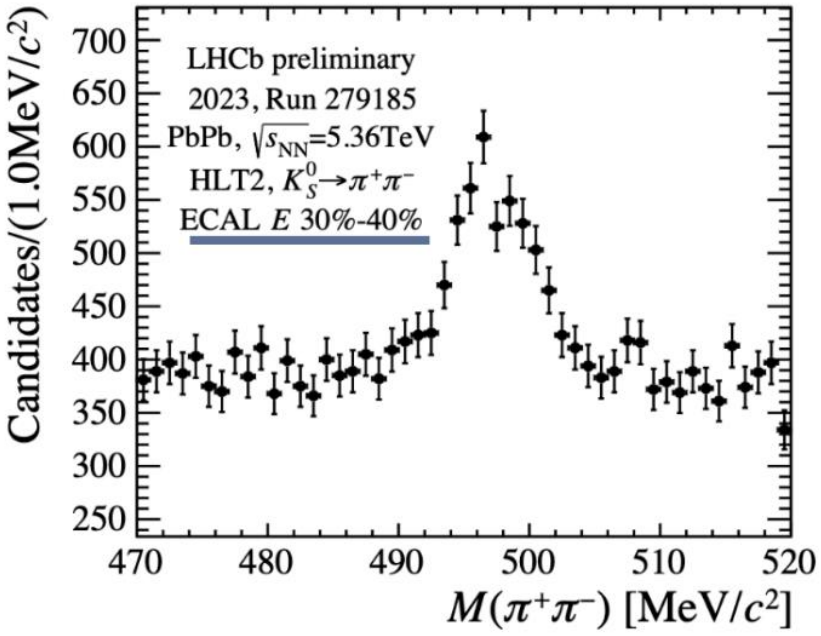
arXiv:2305.10515

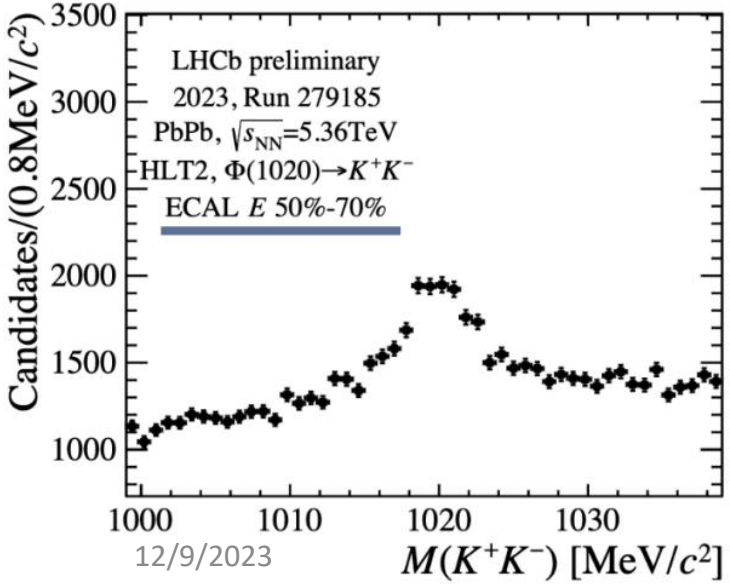
40 MHz data acquisition
No hardware trigger
Real time data reconstruction

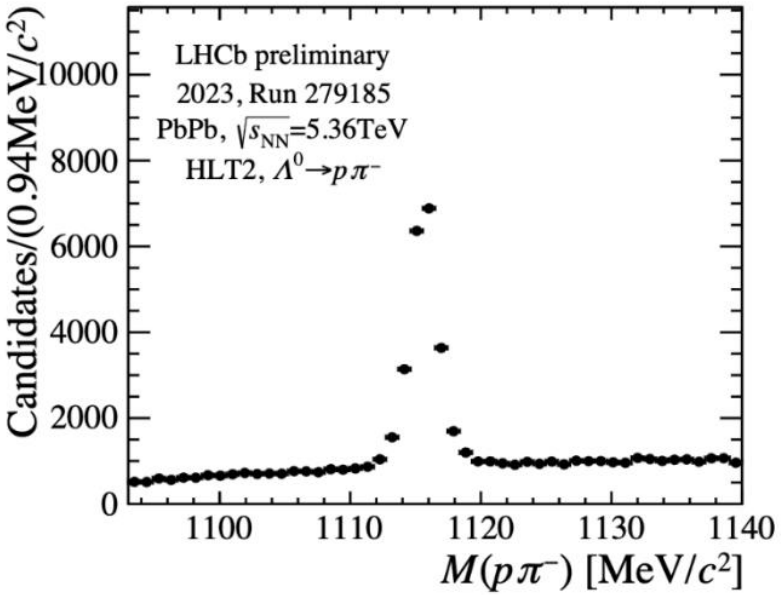


Detector performance in 2023 PbPb run









LHCb can for the first time take PbPb data up to 30% centrality !!

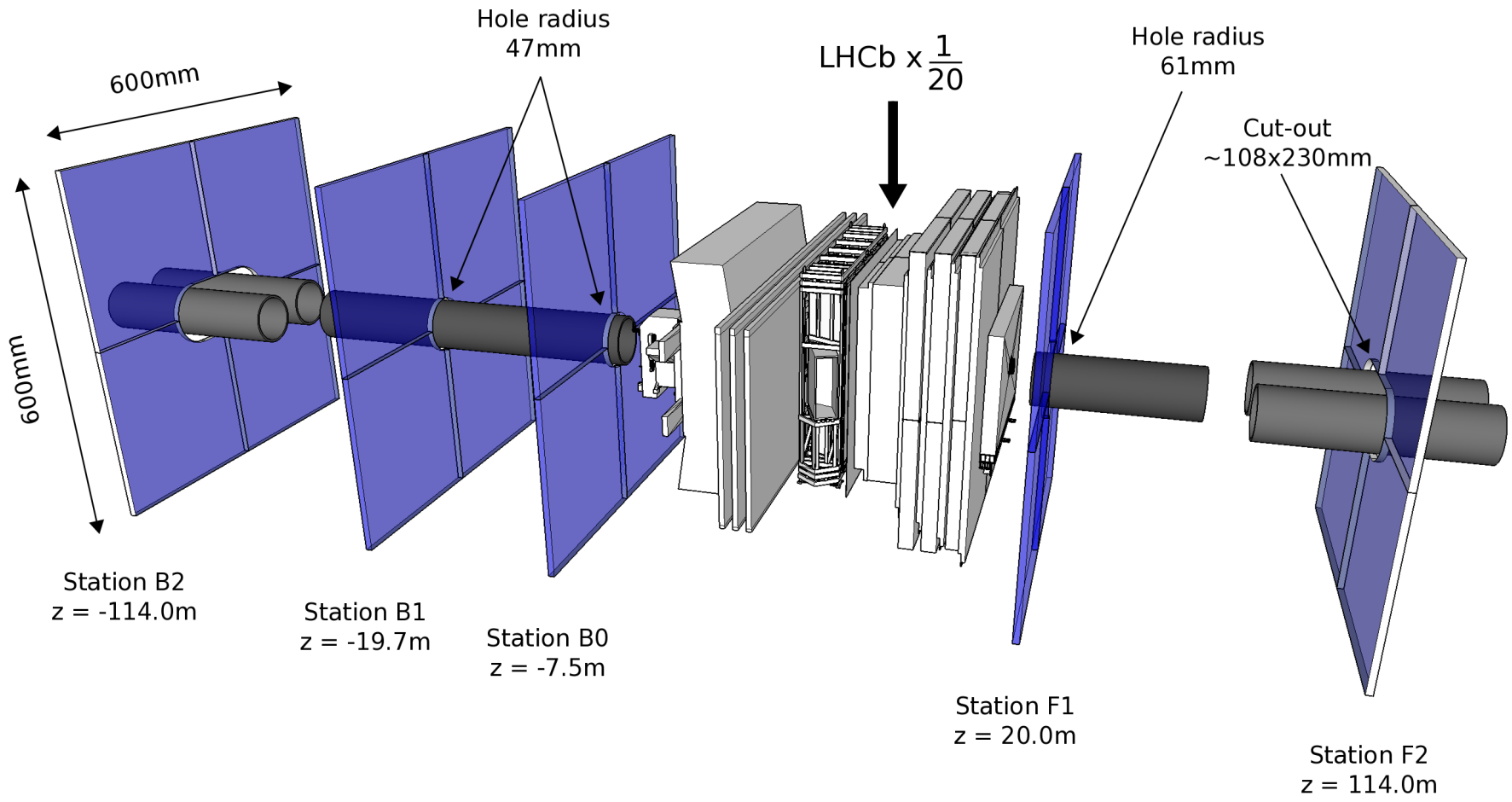
Full centrality in fixed target mode (SMOG)

Peaks from 40 minutes of data taking.

<<1% of the entire data set

Very promising for new UPC results.

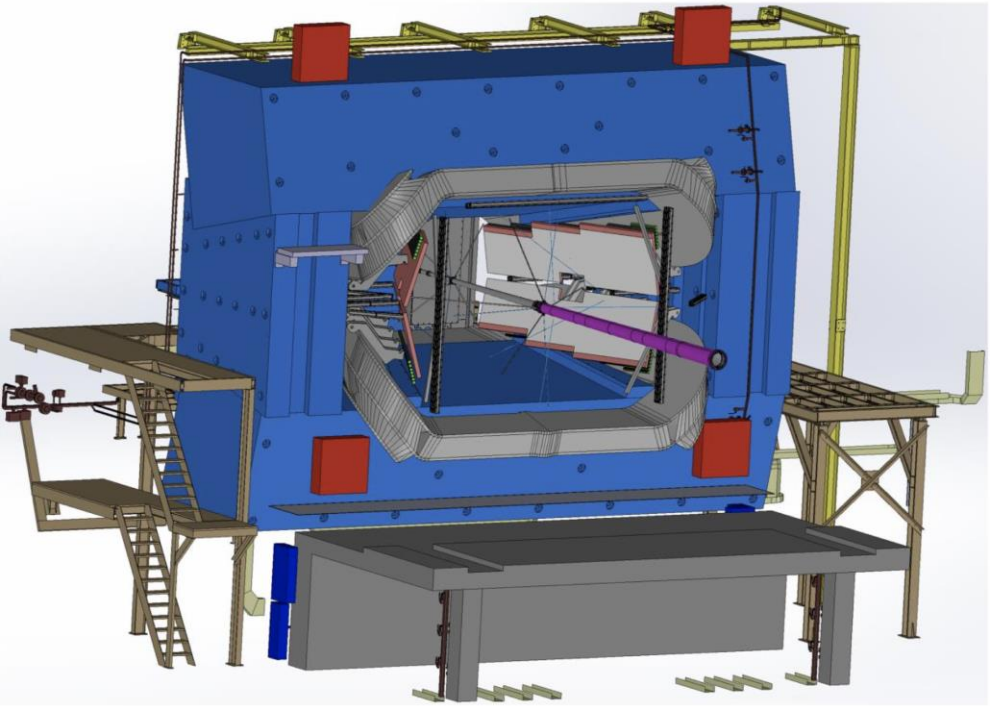
Future Upgrades : New HeRSCheL

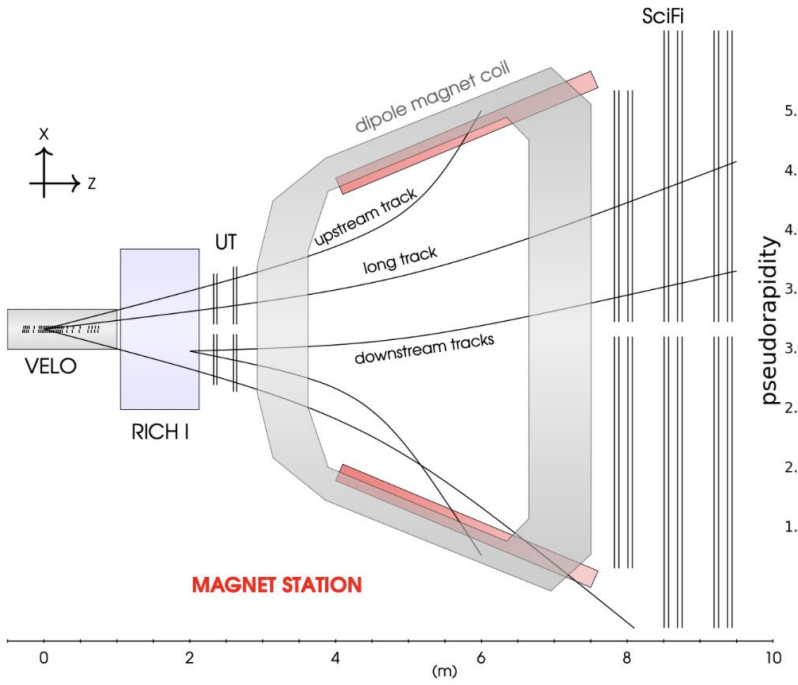


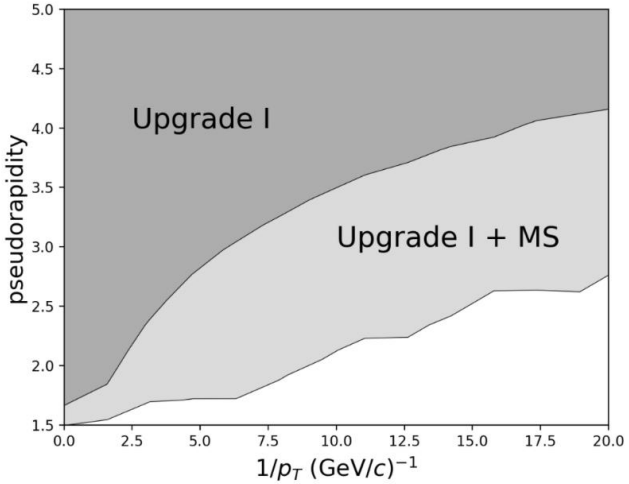
Replace radiation damaged scintillators.

Add another station

Future Upgrades : Magnet Station







- Instrument the internal magnet walls with a scintillator-based soft particle tracker
- tracking 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
- Looking for US institutions to join a DOE proposal, installation starting during LS3

Take away

- LHCb is ideal for UPC studies. The sky is the limit, thanks to
  - Software-based trigger
  - Excellent particle identification
  - Low-p_T tracking
- Results limited to quarkonia photoproduction so far, but other measurements are very close to be released
- LHCb is a new detector now and ready for Run3
- Future upgrades dedicated to UPC
- LHCb heavy ion is a good example of a high data/people ratio
  - Heartbreaking opportunities missing because of the lack of people to do analysis
  - Upgrade 1b and II are very good opportunities to be part of the LHCb HI program and make UPC physics as one of the most relevant in particle physics