LHCb Cagliari yearly report

Francesco Dettori
On behalf of the LHCb Cagliari group

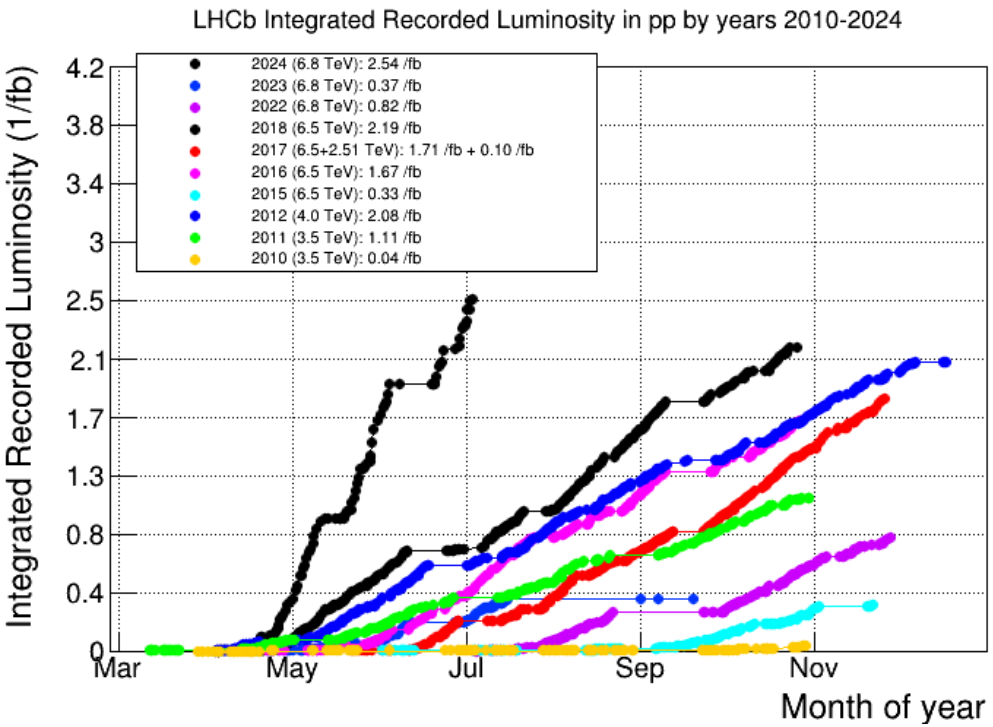
Università degli Studi and INFN Cagliari

Consiglio di Sezione - 05/07/2024

LHCb status: one slide

LHCb Run 3 at full steam

- 2024 luminosity has surpassed all other years
- Last Upgraded subdetector included recently
- Performance plots show massive increase for all channels limited by Run 2 trigger
- First Run 3 physics results coming out soon



Cagliari: Info and general news

- Group Leader: Adriano Lai
- Cagliari is now the largest LHCb group in Italy (19 authors)
- Cagliari chosen to host CKM Conference in 2025 (main international flavour physics conference)

Involvement

- Detector: historically on MUON, now shift towards the VELO (Upgrade II: see Adriano's talk) and Software (RTA)
- Analysis, three lines of research:
  - CP violation
  - Rare decays
  - Heavy ion collisions

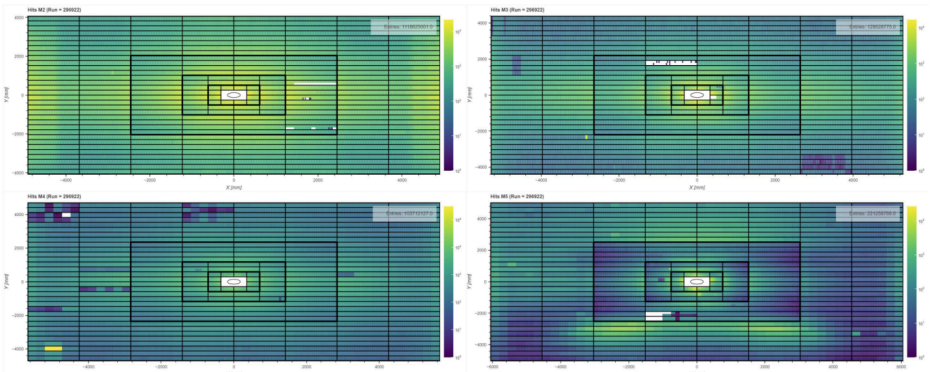
Responsibilities:

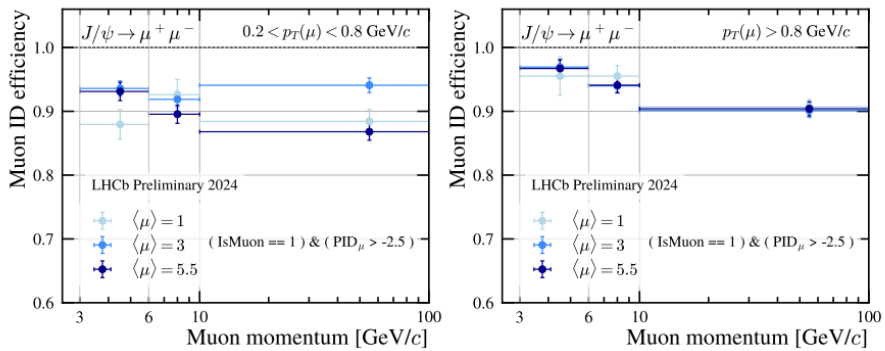
- Muon Deputy Project Leader - Andrea Contu
- Editorial board member - Francesca Dordei
- RTA institutional representative for Cagliari, Bologna, Ferrara - Francesca Dordei
- LHC Heavy-Ion WG convener - Giulia Manca

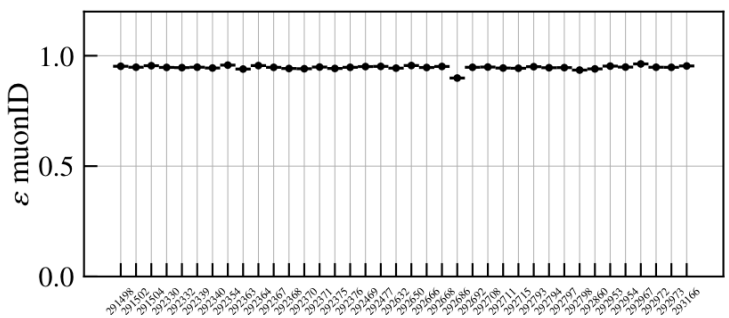
Muon detector

Contu, Brundu, Litvinov (+Shifters: Dettori, Manca)

- Cagliari group heavily involved in commissioning, monitoring and maintenance of the Muon detector
- Intense work during YETS to recover nominal performance by solving DAQ and time alignment issues
- Now the MUON system is running very well, minor adjustments will be performed during the year to recover problematic channels.
- Reached full efficiency ($> 90\%$ efficiency with few permil misID at $\langle\mu\rangle \sim 3$)
- Implemented tools to monitor low- and high-level performance online

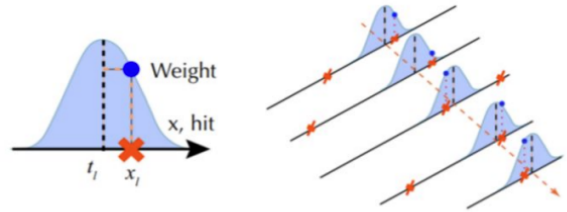




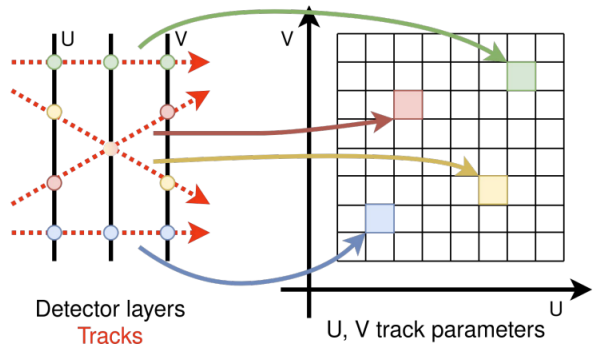


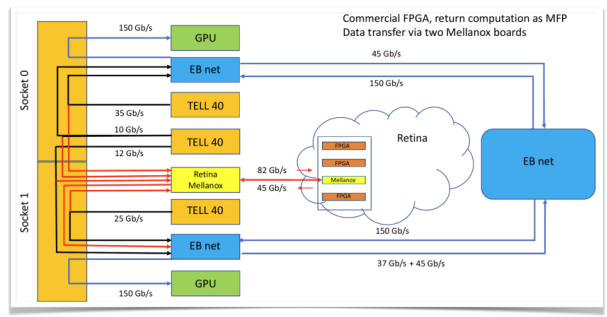
DAQ Upgrade (within RTA)

Contu



- R&D involvement to use event pre-processing with FPGAs using the RETINA algorithm
- Cagliari contributed to integration with existing DAQ infrastructure
- Status:
  - ⋆ RTA endorsement on 30th Nov 2023.
  - ⋆ LHCB-TDR-025 (PCIe400 + DWT).
  - ⋆ Approved by LHCb Technical Board 8th Feb 2024.
  - ⋆ Submitted to the LHCC 27th Feb 2024.
  - ⋆ LHCb-PUB-2024-001 published on 6th May 2024.
  - ⋆ Questions&comments from LHCC arrived 20th May 2024.





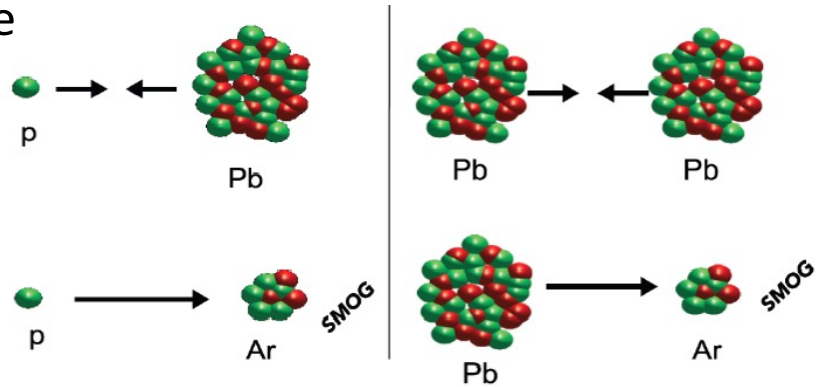
Heavy-Ion activities

DeAngelis, Fabiano, Litvinov, Manca, Sun

- LHCb started Heavy Ion activities in 2015; three setups on top of pp collisions:
  - p/Pb-GAS (SMOG) [NEW], p-Pb [new √s], Pb-Pb [NEW]
  - Cagliari deeply involved in running, trigger, reconstruction,

  data quality and selection studies.

  => Cagliari is doing or has done analyses in <u>all setups</u>.



- Huge potential to study uniquely
  - Quark Gluon Plasma (QGP) in PbPb (χ_c,J/ψ from B) and SMOG (unique √s)
  - Cold Nuclear Matter Effects in pPb

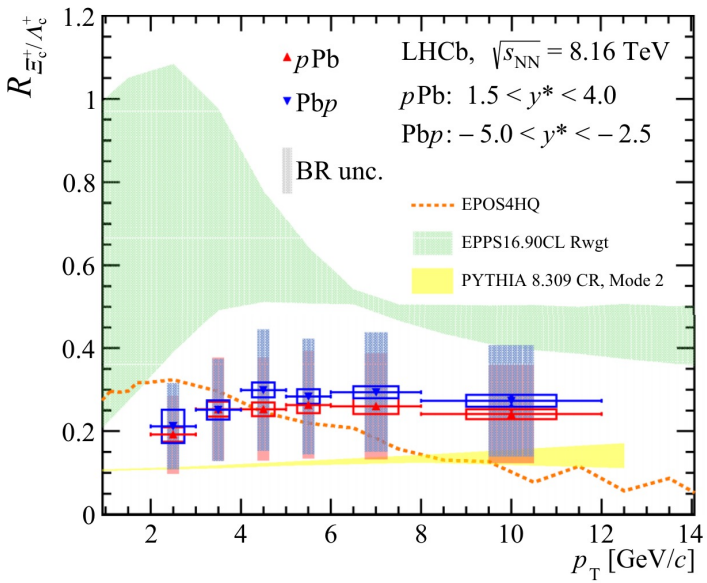
Prompt Ξ_c^+ production in pp collisions

Litvinov, Manca, Sun

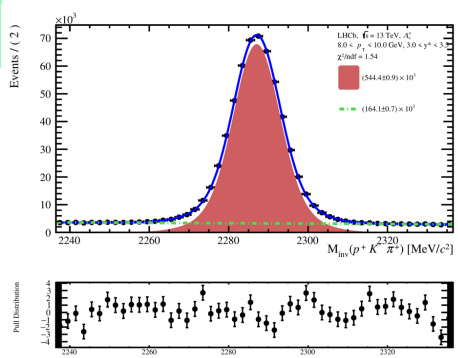
Prompt Ξ_c^+ production in pp collisions

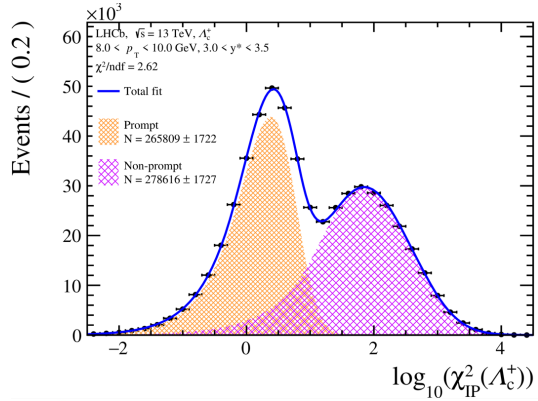
Powerful probe of hadronization:

- charmed baryon formation is not universal and depends on collision system (ref).



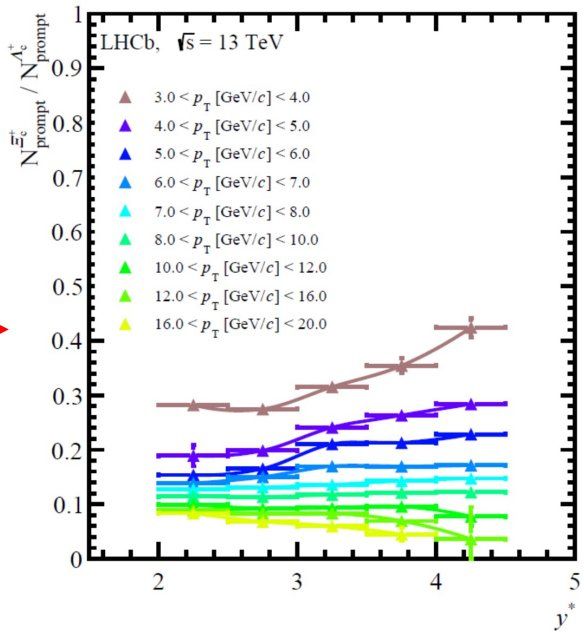
Phys. Rev. C 109, 044901





Analysis in pp collisions at 13 TeV is ongoing:

- LHCb provides extensive studies of charm hadronisation;
- Prompt signal selection is done;



In collaboration with Maastricht

Total charm cross-section in 5.02 TeV *pp* collisions

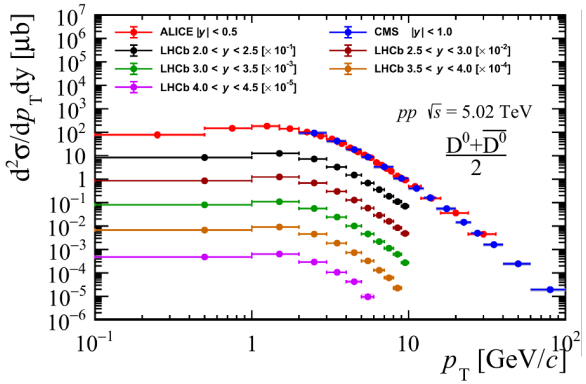
Manca, Sun

- Combination of extensive open charm hadron cross-sections by ALICE, CMS & LHCb
  - Charm baryon data used for the first time
- Pythia8 tuned to match *D*-meson data → extrapolation to full phase space
- Precise result on the upper limit of NLO calculations

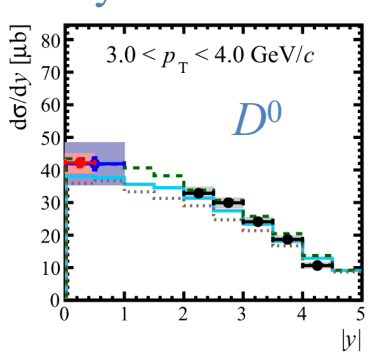
In collaboration with Krakow, Heidelberg, LLR, , C.Bierlich @Lund

Experiment	ALICE	CMS	LHCb
Luminosity (pb^{-1})	$(19.3\pm0.4)\times10^{-3}$	27.4 ± 0.6	8.60 ± 0.33
Hadrons	D^0, D^+, D^{*+}, D_s^+, Λ_c^+, Ξ_c^0	D^0, Λ_c^+	D^0, D^+, D^{*+}, D_s^+
p_{T} coverage (GeV/c)	0–36	2–100	0–10
y coverage	$\lvert y\rvert$ <0.5	$\lvert y\rvert$ <1.0	2.0< y <4.5

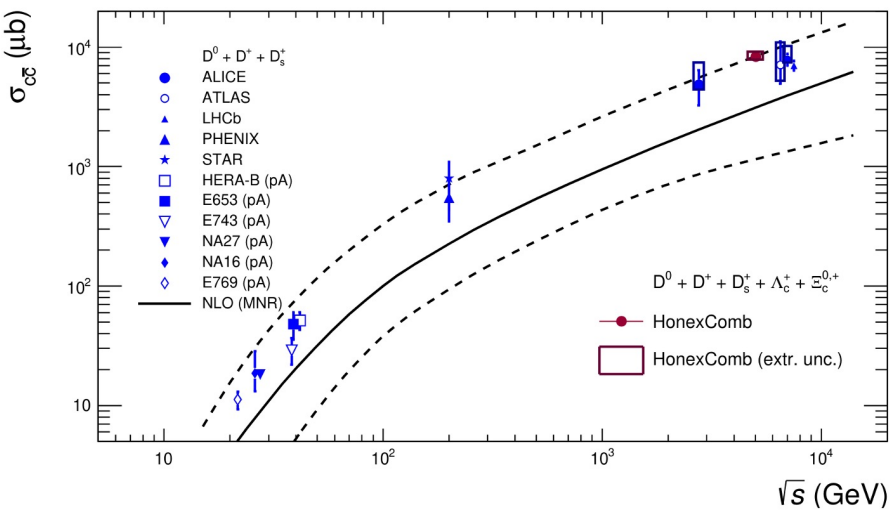
Combined D^0 measurements



Pythia vs. data



Accepted by EPJ Plus!



arXiv:2311.11426

Selected results in *pPb* collisions

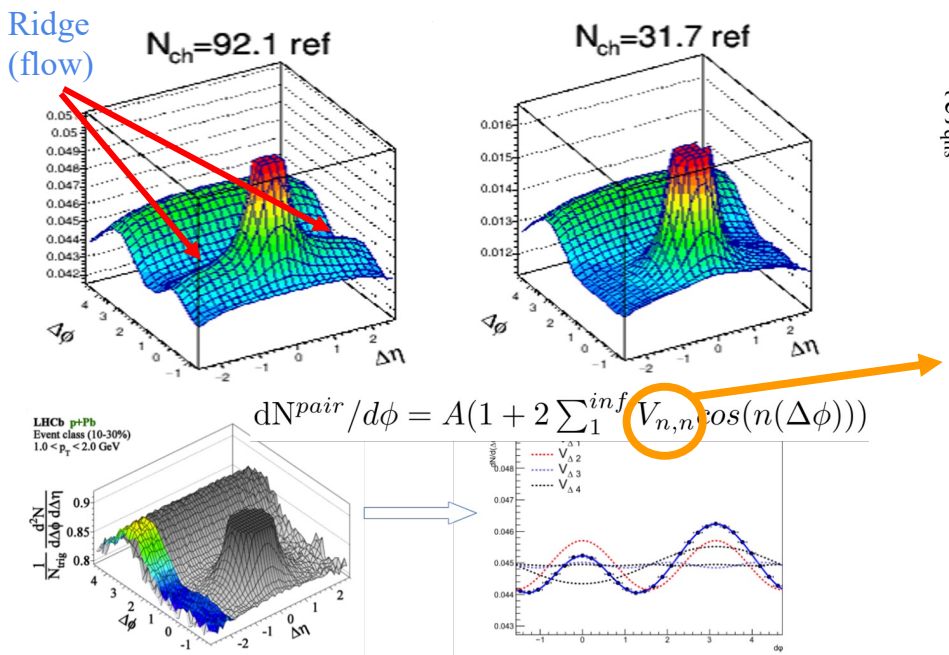
Manca, Sun

Charged hadron flow harmonics in 8.16 TeV *p*Pb collisions

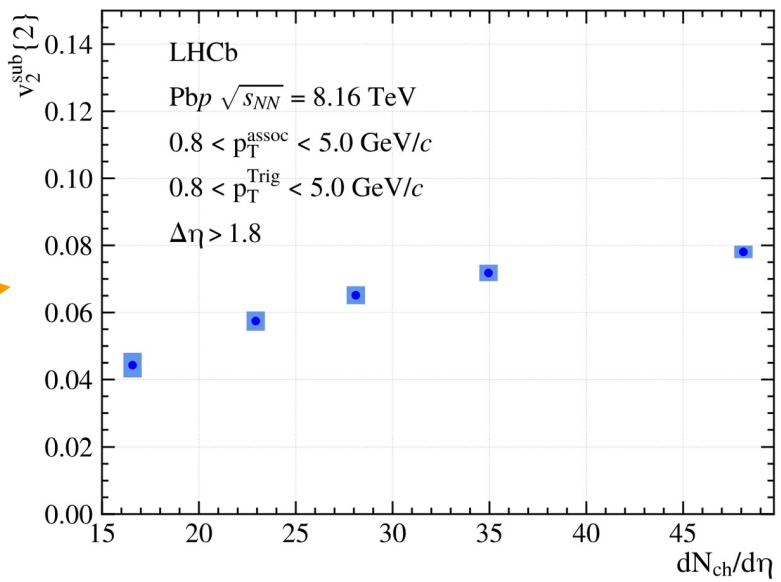
twiki

In collaboration with Santiago

- Angular correlation functions constructed from pairs of charged hadrons
- Visible near-side ridge (flow) in high activity events
- Fourier function fit to the ridge region → derive flow harmonics v_n



Result in IFT WG review. Targeting Hard Probes conference in September!



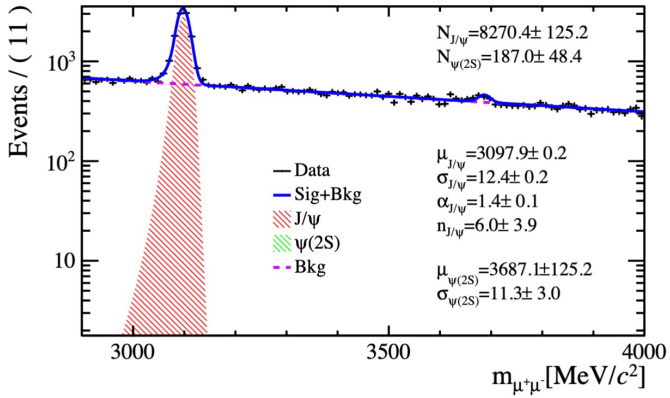
Selected results in *PbPb* collisions

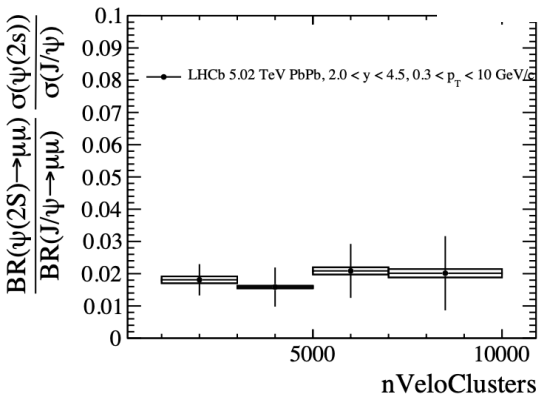
DeAngelis, Manca

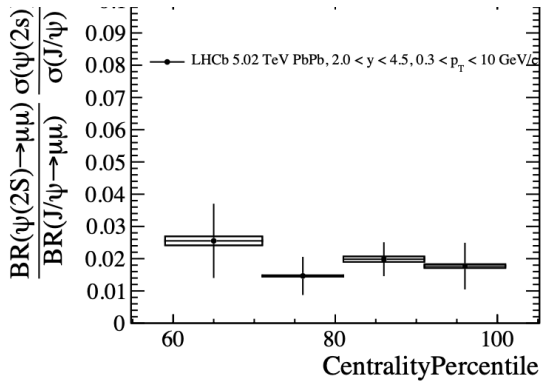
$\psi(2S)/J/\psi$ ratio vs multiplicity in PbPb collisions at $\sqrt{s}$ 20.5 = TeV

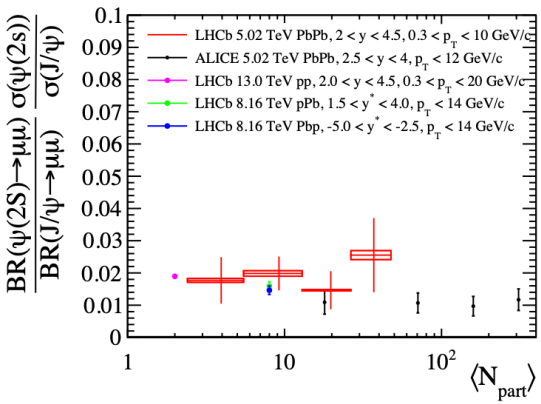
- Quarkonia suppression is a good probe to study QGP formation:
  - **Stronger dissociation expected for ψ(2S) wrt J/ψ** since lower binding energy
  - Relative **quarkonia yield** expected to **change** with different temperatures achieved **in different centrality regions**

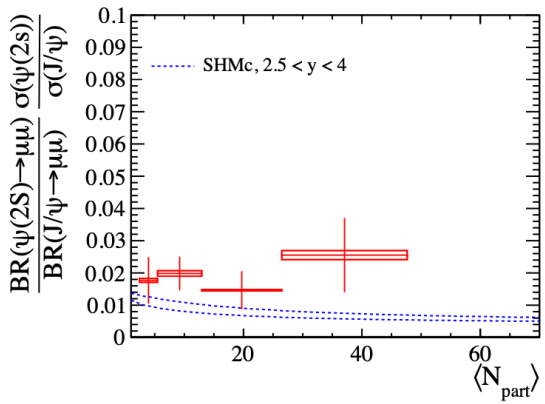
In collaboration with Frascati, LosAlamos and Tsinghua











- **Reasonable agreement with ALICE and LHCb *pp* and *p*Pb results and theory**

- **LHCb-ANA-2024-037 signed-off from the WG on 26/06/2024, RC kick-off meeting foreseen soon.**
- **Targeting Hard Probes in September 2024!**

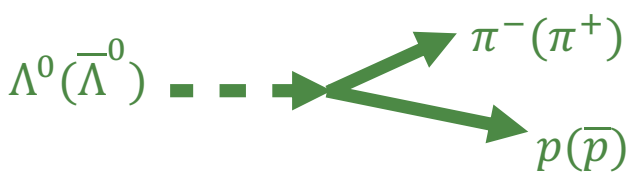
Selected results with SMOG

DeAngelis, Fabiano, Manca

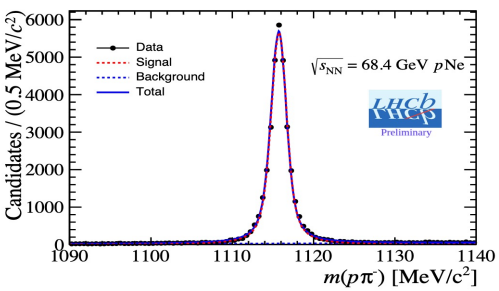
Λ transverse polarization in *p*Ne collisions at $\sqrt{s}$ 5.86 = GeV (CdA,GM)

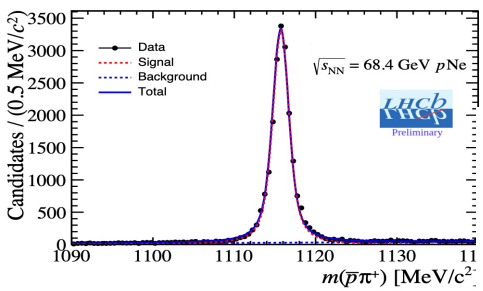
In collaboration with Frascati

- **We measured the polarization in the 2017 SMOG *p*Ne sample:**



Both Λ and $\overline{\Lambda}$ states analyzed

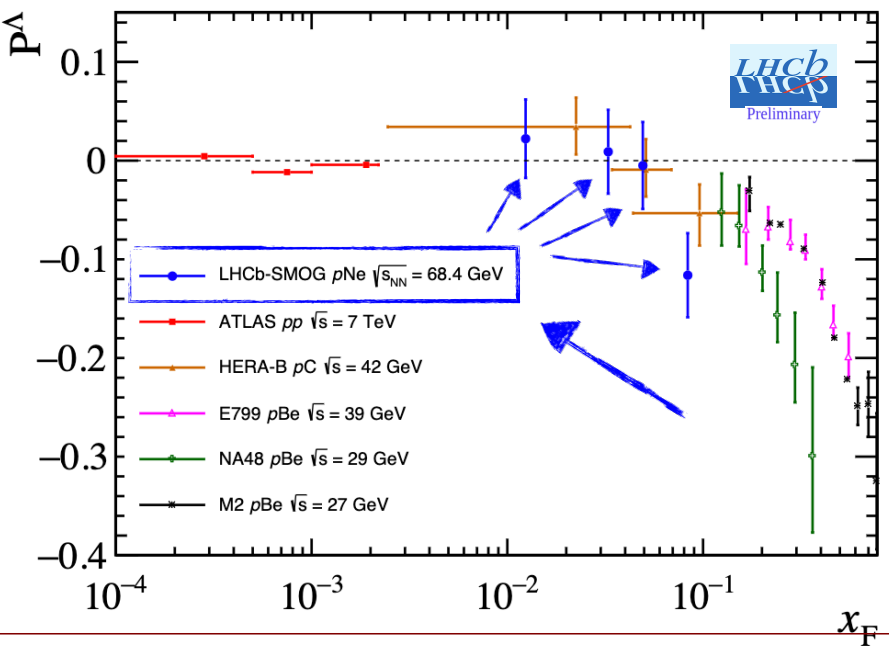




- **LHCb-PAPER-2024-009, arxiv:2405.11324 submitted to JHEP, first minor comments received on 02/07/24!**

- **Decay protons** are preferentially emitted along the spin direction of the Λ
- Polarization accessible measuring the **asymmetry in the proton's angular distribution:**

$$\frac{dN}{d\Omega} = \frac{dN_0}{d\Omega}(1 + \alpha P_n^\Lambda \cos\theta)$$



Selected results with SMOG

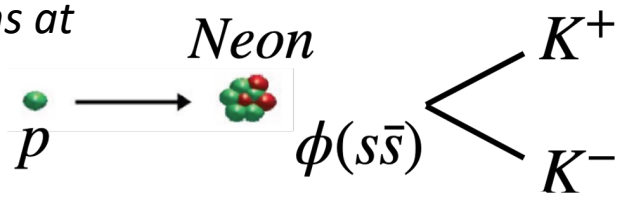
DeAngelis, Fabiano, Manca

Strangeness production in in *p*Ne collisions at $\sqrt{s}$ 68.5 = GeV (FF,GM) *In collaboration with Frascati*

First *measurement of the cross-section in pT, y in pNe collisions at 68.5 GeV*

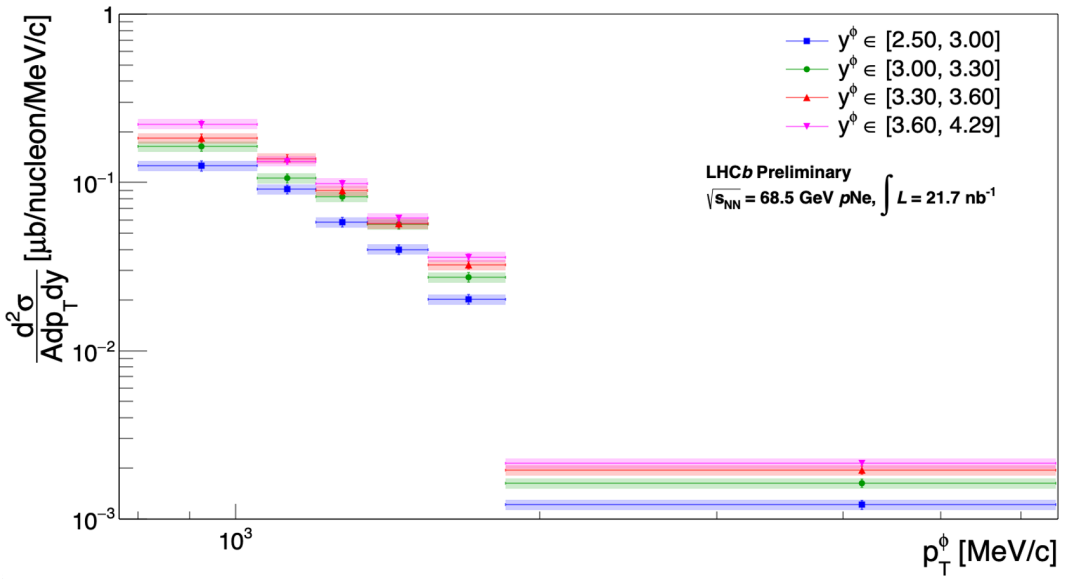
- ***Observable***:

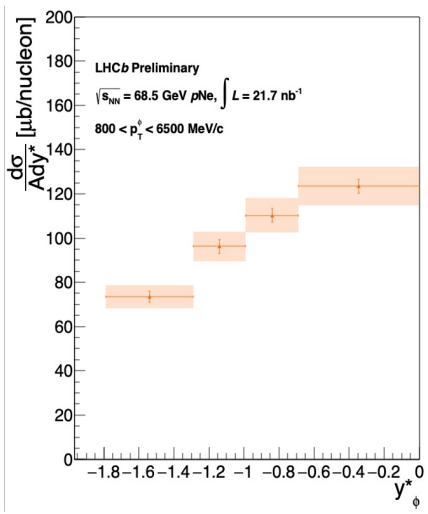
$$\frac{d^2\sigma(p_T, y)}{dp_T\, dy} = \frac{N^{\phi}(p_T, y)}{\mathscr{L}\,\mathrm{BR}\,\epsilon_{tot}(p_T, y)\,\Delta p_T\,\Delta y A_{Ne}}$$

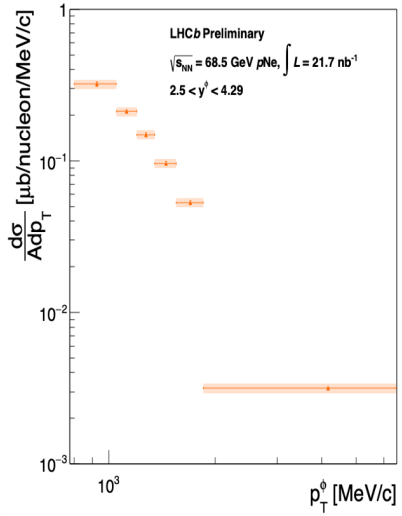


BR = (48.9 ± 0.5)%

Results: ***Double differential cross-section per nucleon in pT,y***







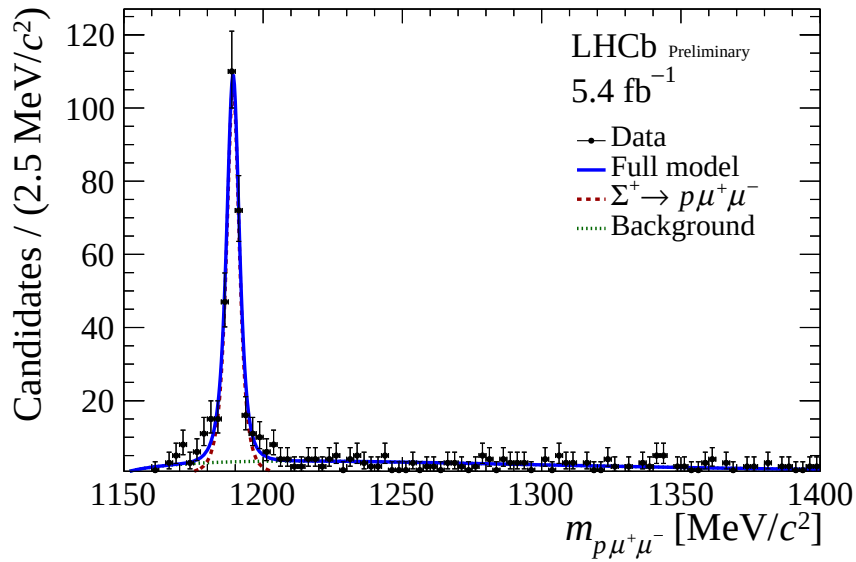
- Analysis in internal LHCb Review, aiming at HP2024 in September!

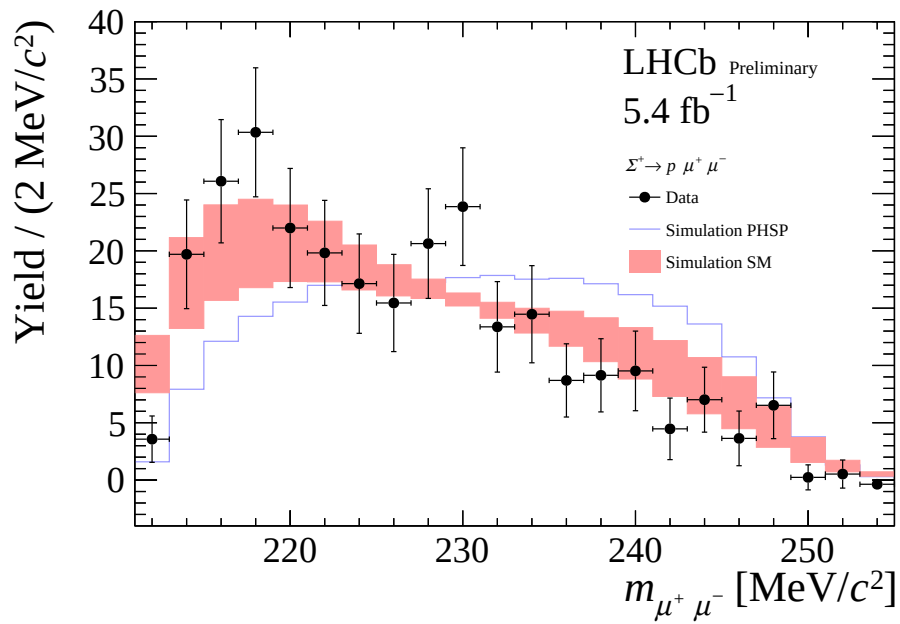
Observation of the $\Sigma^+ \to p\mu^+\mu^-$ decay

Rarest hyperon decay ever observed

Dettori, Dordei, Provenzano

- Rare FCNC with a $\mathcal{B} \sim 10^{-9}$
- Evidence of it at HyperCP showed possible New Physics intermediate state
- Evidence at LHCb in Run1 did not confirm it
- Crucial trigger improvements in Run 2 brought a factor 10 efficiency
- Now observed with full Run 2 statistics LHCb-CONF-2024-002Conf. note out, paper in preparation
- Opens a new branch of analyses in LHCb (including CPV etc) currently the only experiment capable of doing rare hyperon decays



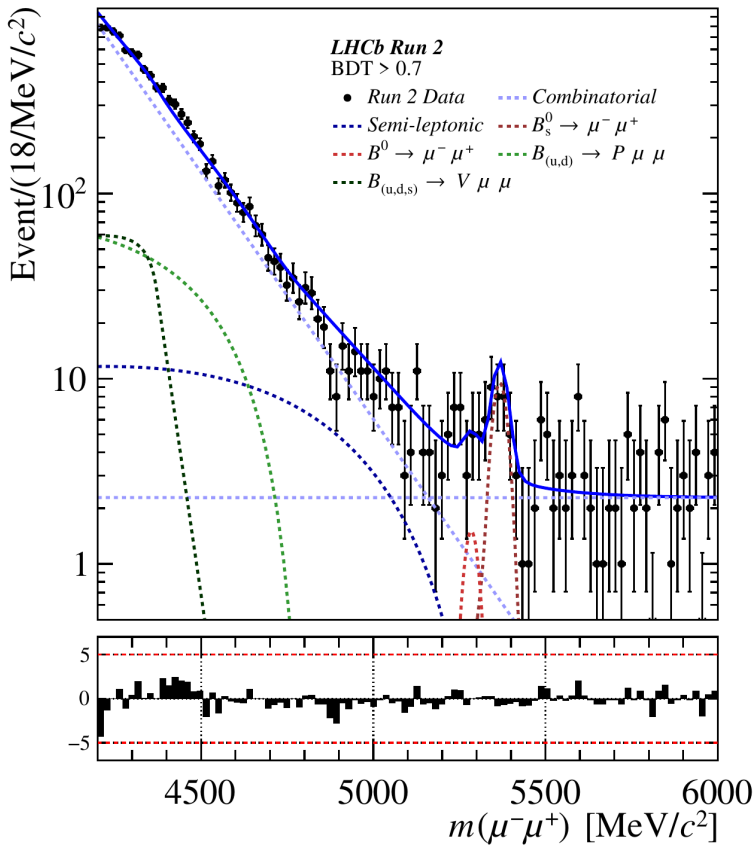


Other rare decay analyses

Contu, Dettori, Saitta, Normand (now at Bristol)

Search for $B_s^0 \to \mu\mu\gamma$ decays

- Sensitive to different new physics couplings than $B_s^0 \to \mu^+\mu^-$
- Partially reconstructed method
- Analysis summarised in Normand's thesis.
- Close to internal review



Search for $B_s^0 \to \tau\tau$ decays

- Next step after $B_s^0 \to \mu^+\mu^-$
- Challenging τ reconstruction
- Current limits at $\mathcal{B}(B_s^0 \to \tau^+\tau^-) < 2.1(6.8) \times 10^{-3}$ can be improved significantly
- Collaboration with Heildeberg

Core CP violation measurements: ongoing activities

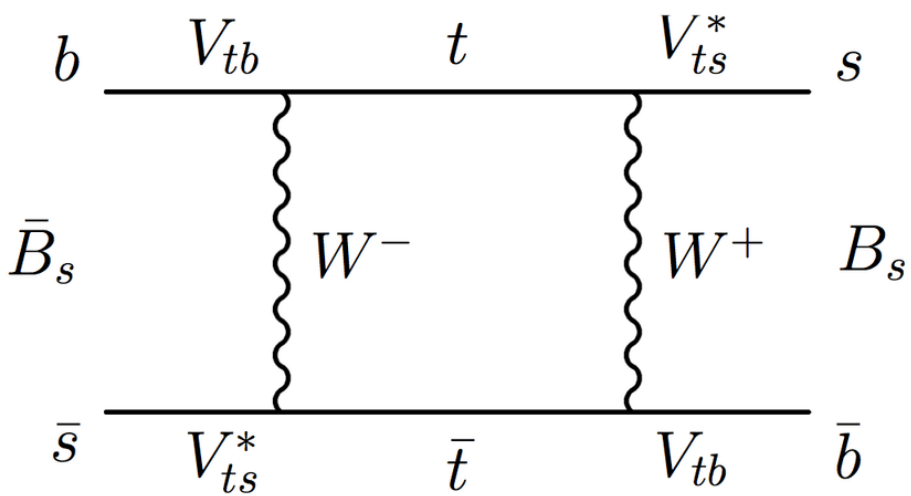
Dordei

Measurement of $\Delta\Gamma_d$ using the channels $B_d \to J/\psi K_S$ and $B_d \to J/\psi K^*$ ongoing with the full Run 2 data.

- Institutes involved Cagliari (main), Heidelberg and Nikhef.
- Important null test of SM (it is expected to be ~ 0 with current uncertainty
- implies profound knowledge of reconstruction performances.
- Soon master's student working on this

Measurement of CP violating phase ϕ_s using $B_s \to J/\psi KK$ in Run 3 (many institutes involved)

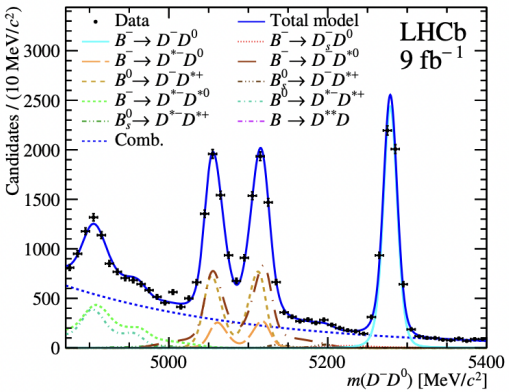
- Cagliari drives the decay time acceptance correction, fundamental for the measurement of $\Delta\Gamma_s$
- Golden analysis of CP violation for LHCb, now starting to look at the first Run 3 samples to validate the new trigger

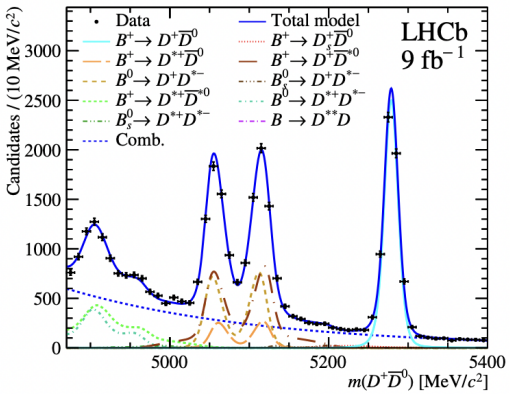


Rolf Oldeman, Fionn Bishop (Cambridge, now Annecy)

Measurement of CP asymmetries and branching fraction ratios of B^- decays to two charm mesons

JHEP09(2023)202
ArXiv ePrint: 2306.09945





Expect small **direct CPV** in decays
From **interference** of tree and loop diagrams

Potentially enhanced by **New Physics**

Analysis of **fully reconstructed** and partially reconstructed decays

90% of work was **calibrating experimental asymmetries**

All results consistent with **zero** and with **SM**

Run 3 data not affected by **CALO trigger asymmetry**

$$\mathcal{A}^{CP}(B^- \to D_s^- D^0) = (+0.5 \pm 0.2 \pm 0.5 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D_s^{*-} D^0) = (-0.5 \pm 1.1 \pm 1.0 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D_s^- D^{*0}) = (+1.1 \pm 0.8 \pm 0.6 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D^- D^0) = (+2.5 \pm 1.0 \pm 0.4 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D^- D^{*0}) = (-0.2 \pm 2.0 \pm 1.4 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D^{*-} D^0) = (+3.3 \pm 1.6 \pm 0.6 \pm 0.3)\%,$$
$$\mathcal{A}^{CP}(B^- \to D^{*-} D^{*0}) = (+2.3 \pm 2.1 \pm 1.7 \pm 0.3)\%,$$

Conclusion

- Cagliari group has prominent role in crucial LHCb detector present and future
- Active in LHCb core physics program (CPV, Rare Decays) as well as exploring new alleys (Ion Physics, Hyperons)
- Most Run 2 legacy analyses done
- Run 3 commissioning progressed well and data-taking at full steam
- Possible extension of LHC Run 3 would be favourable for LHCb