CMS: perspective, wishes, proposals, and views on the working group

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On behalf of the CMS Collaboration

Kickoff meeting of the LPCC working group on heavy-ions

Reflecting on what **achieved** so far and future **expectations**

- **Thermalization and hadronization of heavy quarks**
  - Modification of heavy quark hadronization with D^0, D_s, D^*, B^+, B^0, B_s, Λ_c, Λ_b, B_c
  - Direct detection of charm diffusion: jet-D^0 and γ-D^0 angular correlation
  - DD correlations: studies of heavy quark energy loss mechanism

- **Pinning down uncertainties in initial state and extraction of QGP properties at various scales**
  - Electroweak boson production
  - Photon- and Z-tagged jets
  - Quarkonia and observation, e.g., of Υ(3S) production
  - Jet substructure as a tool for the study of QGP constituents
  - Top quark production as novel tool in pPb/PbPb

- **Initial-state effects and QGP formation in small systems**
  - Flow correlation in high statistics peripheral PbPb collisions
  - Search for jet quenching in high-multiplicity pp, pPb, pO and OO collisions

- **Study of exotic particles and search for BSM physics**
  - Probe the inner structure of X(3872) and other exotic states (for example $f_0(980)$) with QGP
  - Light-by-light scattering and ALP searches

- **New MTD capabilities**
  - Charge and baryon number fluctuation capability with large acceptance detector (up to |eta|<4) and MTD (PID)
  - Jet hadronization

CMS **welcomes the group implementation!**

- **About time**
  - Experiments: large enough data sets while preparing for the “boost” from Runs 3 & 4
  - Accelerator front: valuable running experience gained
  - Theory community**:** improved modeling but need experimental input (observables, common format, uncertainties...)

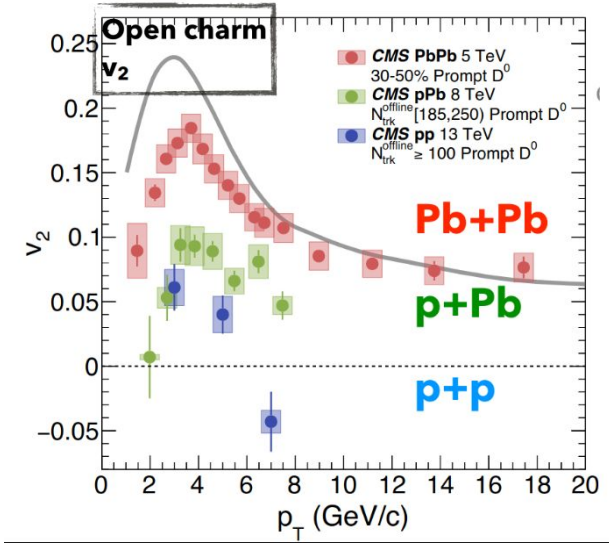
- Following up on past experience from other LHC working groups (some of them already since early Run 1)
  - we could envisage some **interaction** with them at least for the beginning?
    - milestones they reached and challenges they faced
  - **mandate of the group** yet to be formed, e.g., approval process, treatment of confidential information...

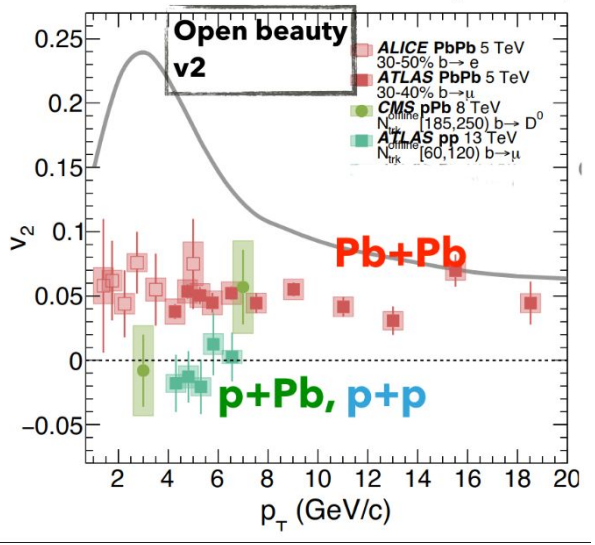
- Organization wise, we think acting in a transparent and efficient way means:
  - **splitting** into working subgroups
  - **frequent** closed meetings
    - key persons, e.g., generator experts, can be invited
  - **regular** (e.g., biannual?) open plenary meetings
  - **web page** (twiki/foswiki) with formed recommendations and updated results, and links to documentation
    - a logo could promote/advertise the common effort too

First things first: **Summary Plots**

- A series of LHC measurements that can be included
  - **subgroups** can identify and propose their lists
  - a **common repository** for code sharing and easy reproduction to be formed
- Summary plots (so far custom made) to be
  - **provided by** the LHC HI Working Group
  - **for the benefit** of the LHC Collaborations
  - **reproduction** of the figures allowed as specified in a Creative Commons license

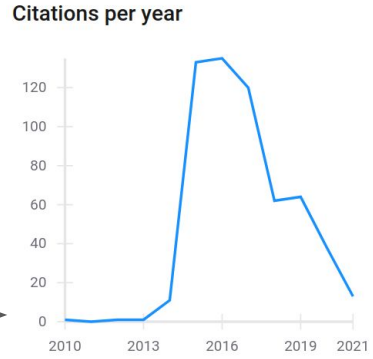
C. Mironov (HP2020)





Past combination efforts: **What is the gain?**

- CMS performed 6 joint **publications** so far
  - All with **Run 1 data**
    - experiments priority is first to understand and publish with their own data
  - **5** with ATLAS (2 in HIG with 1000+ citations & 3 in TOP groups)
  - **1** with LHCb ($B_S \rightarrow \mu\mu$, in Nature with 500+ citations)
- Combination efforts lead to
  - **improved** final uncertainty and probably **most precise** measurements to date
  - first definitive **observations** in cases where neither of the individual results have sufficient precision
  - **highly cited publications** → motivation to "counterbalance" the extra internal review time



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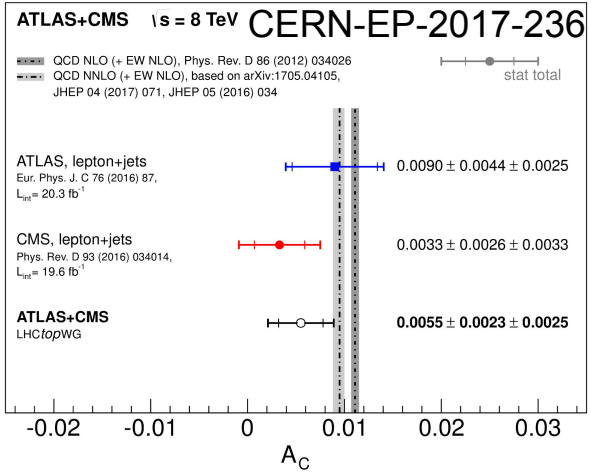
CERN-PH-EP-2015-075



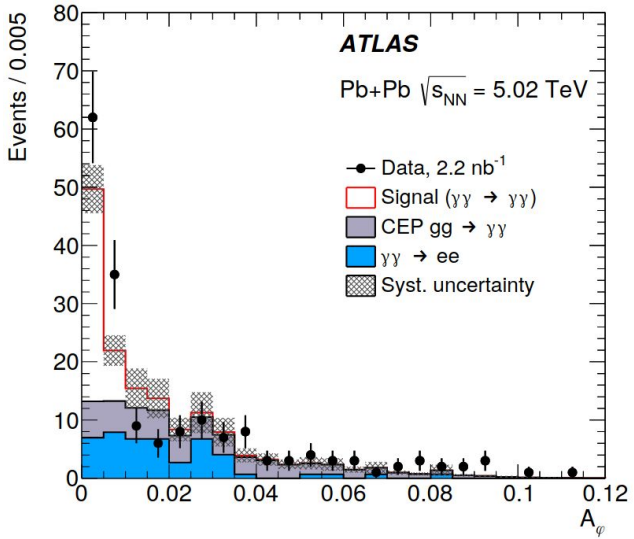
A representative **example I**: Light-by-light (LbL) scattering

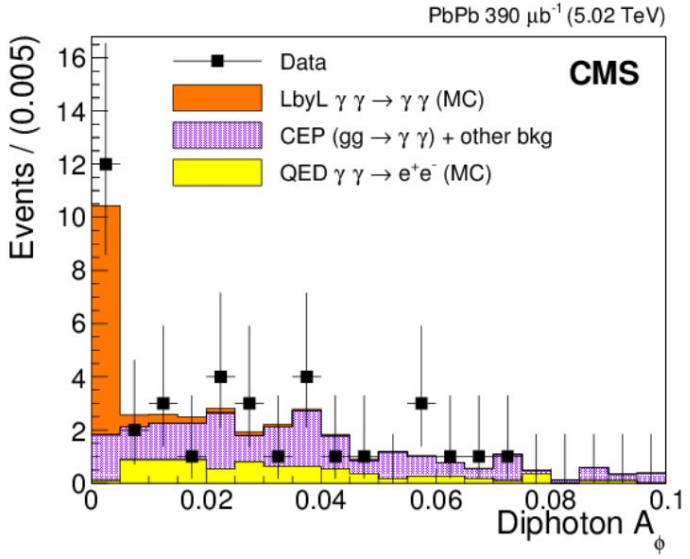
- Four available measurements in PbPb (so far)
- ATLAS
  - 2015 data, 0.49 nb-1, CERN-EP-2016-316
  - 2018 data, 1.73 nb-1, CERN-EP-2019-051
  - **2015+18 data**, 2.2 nb-1, CERN-EP-2020-135
- CMS
  - **2015 data**, 0.39 nb-1, CERN-EP-2018-271

How a **combined measurement** will

- compare to theory?
- impact reinterpretation, ALP limits?

- Ongoing work in the realm of **HonexComb** → see also Giulia's presentations

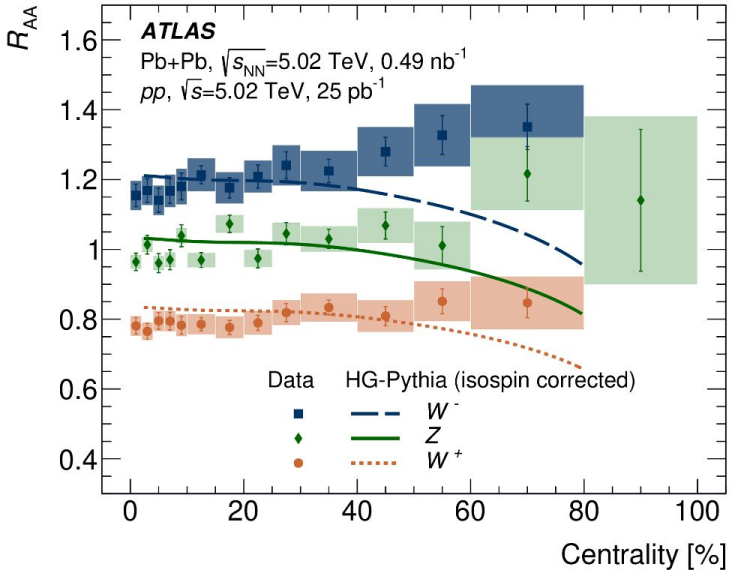


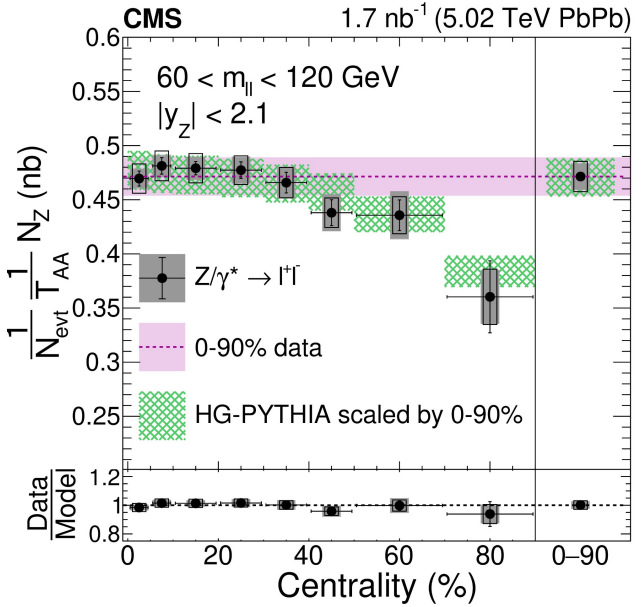


A representative **example II**: Electroweak boson production

- For the latest two measurements in PbPb
  - ATLAS
    - 2015 data, CERN-EP-2019-182
  - CMS
    - 2018 data, CERN-EP-2021-039
  - some tension exists (~3 sigma)
    - data show an indication of an **opposite** centrality dependence

Selection-driven or related to different MC Glauber modelling?

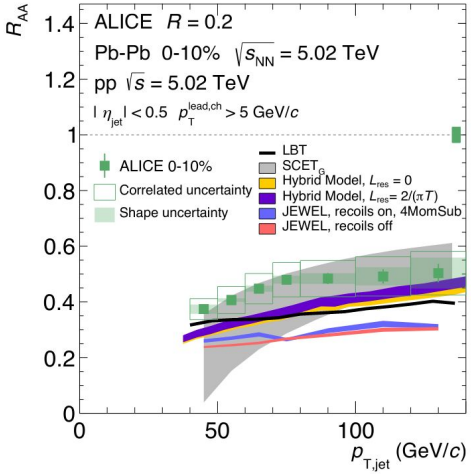


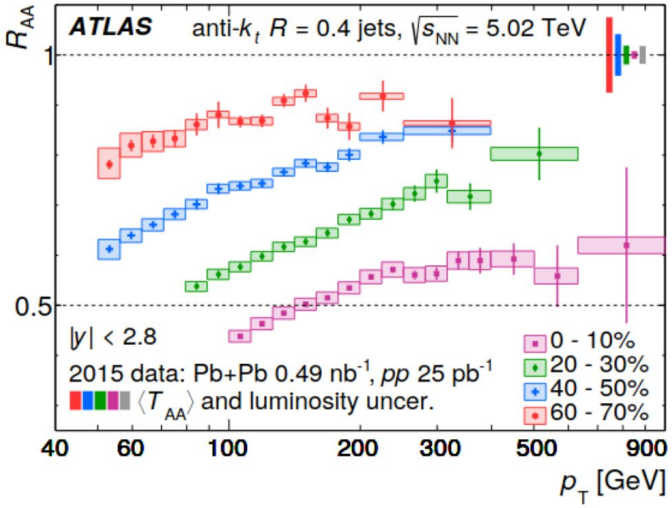


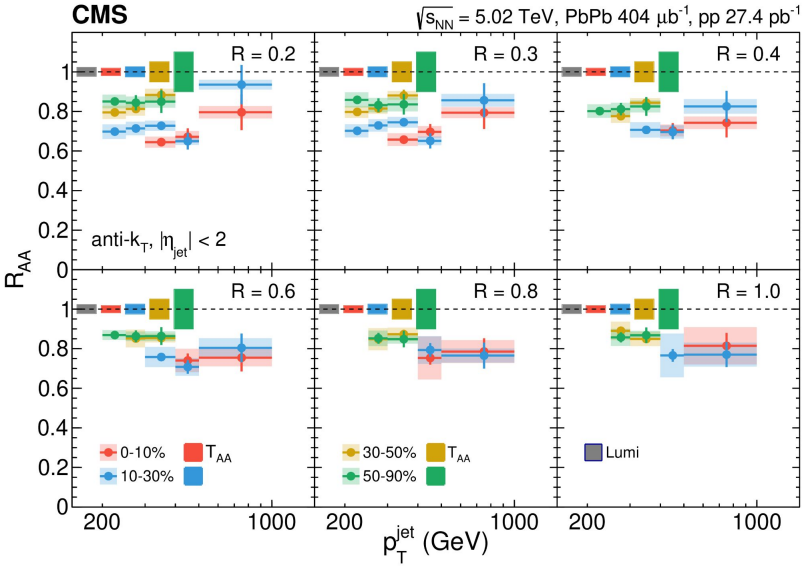
A representative **example III**: Inclusive Jet R_{AA}

- For the latest measurements in PbPb (2015 data)
  - ALICE: lower p_T jets (CERN-EP-2019-200)
  - ATLAS: higher p_T jets (CERN-EP-2018-105)
  - CMS: higher p_T jets, up to large R (0.2 ~ 1.0) (CERN-EP-2020-226)

Towards a universal description of jet suppression as a function of p_T and R





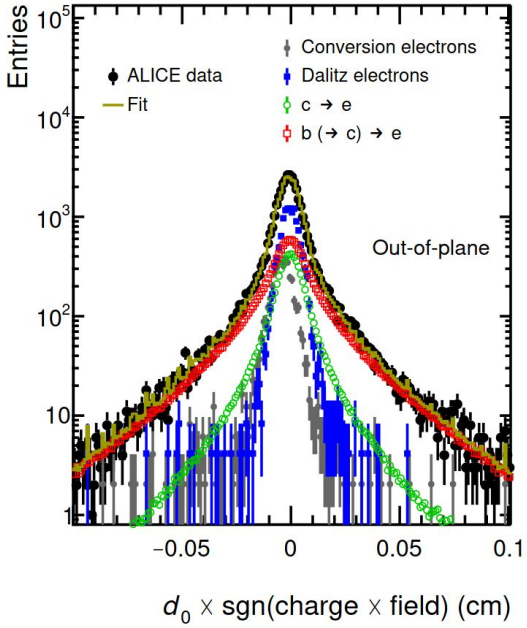


Common ground I: **Observables** and **techniques**

- We think that **common work** or close definition on
  - **global-event variables** (e.g., centrality in small systems, charged particle multiplicity, etc)
  - **analysis techniques** (e.g., correlations and nonflow treatment, (sub)jet reconstruction, **simulation settings**, Glauber MC, UPC simulation for pO/OO, binning of distributions, phase space region, etc)
- would help identify spurious selection effects and comparison with theory

Prompt/nonprompt fraction in HF flow

CERN-EP-2020-085



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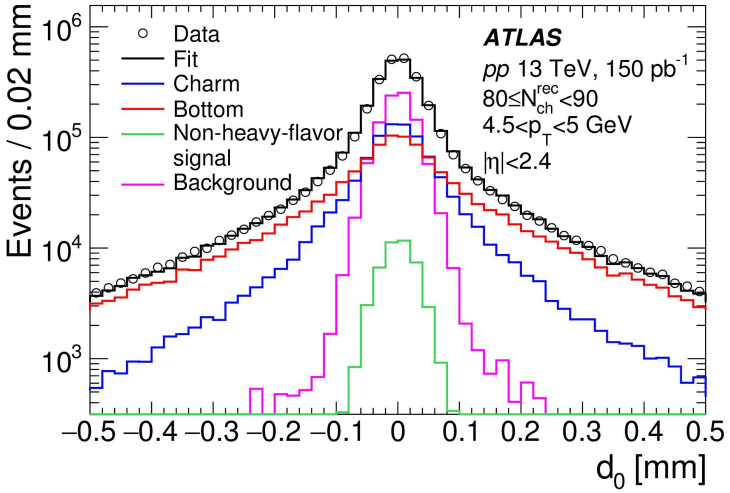

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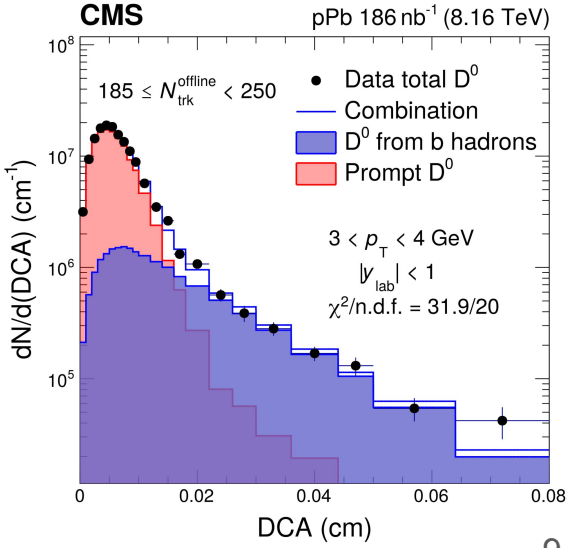
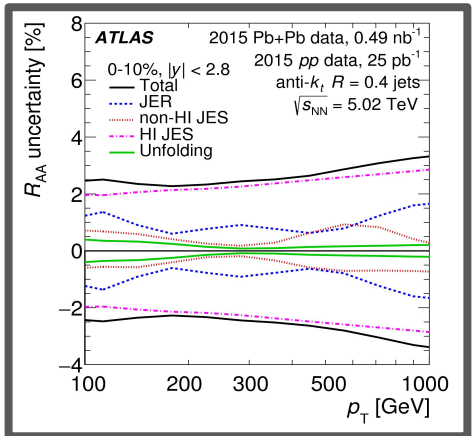
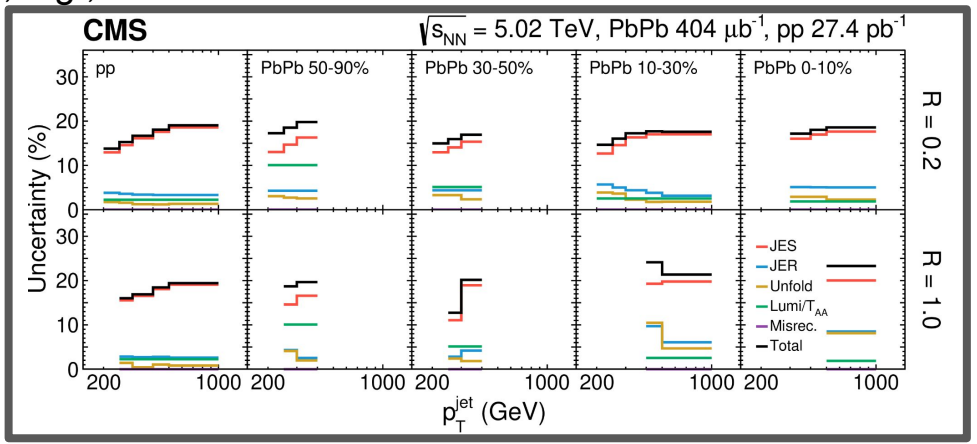


Common ground II: **Corrections** and **systematic uncertainties**

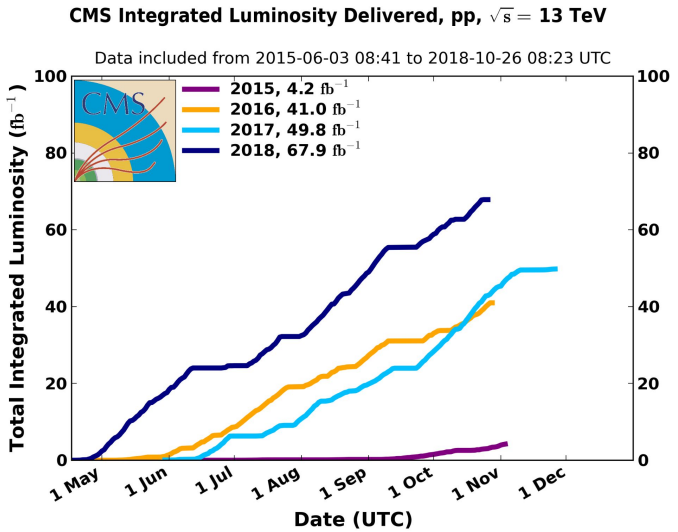
- We think that some corrections can be **harmonized** among experiments
  - e.g., the determination of the background, and its subtraction → relevant for unfolding
  - definition and quoting of **theory** uncertainties
- Same holds true for a set of systematic uncertainties
  - could be quite **different** for experiments, e.g., method or level of splitting of systematic components
- Often hard to get an idea of **correlations**
  - Fraction coming from MC modeling and from the detector? Correlated vs. uncorrelated? Source-by-source? Across measurements (e.g. across different centrality from same paper)?
  - Luminosity - what fraction of total uncertainty is correlated among experiments?
- Good to come up with mapping of uncertainties, and
  - uncertainty correlations **publicly available**, e.g., on HEPData

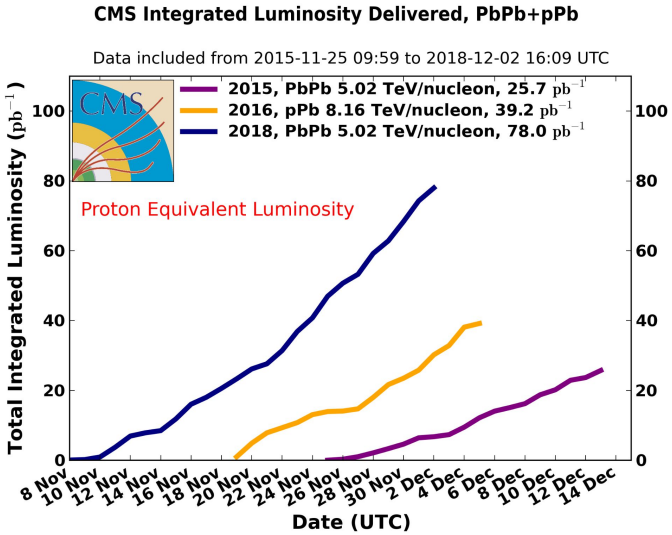




A good place for “pre-discussion” on **running schedule**?

- Before going to LHCC we think the LPCC HI Working Group can serve as basis for discussion on
  - considerations on **running schedule**
  - expected **performance** and recipes for **mitigations** if need be, e.g., beam transmutation in OO
  - setting **common goals** → higher chances **for increased allocated HI time?**



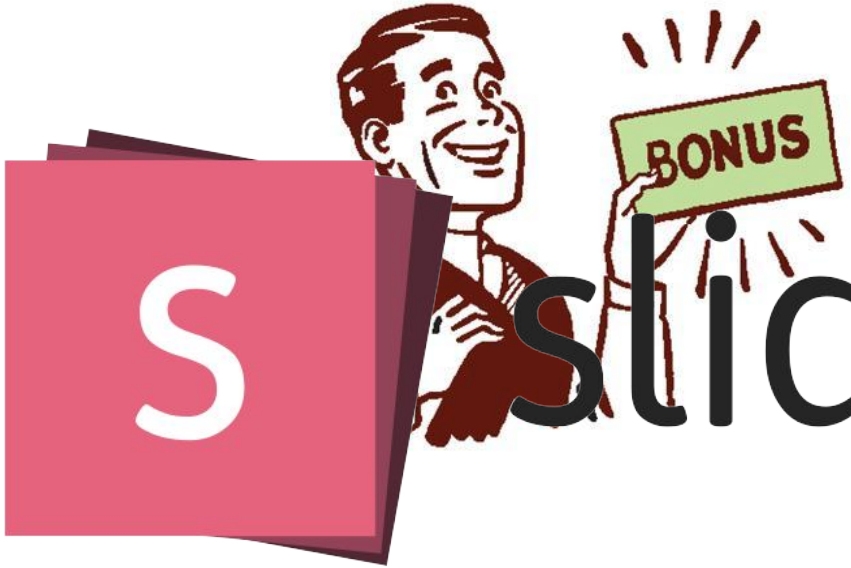


A natural place for communicating/interacting with **theory** community

- While the work remains experimental in nature, **close contact** with the theory community too
  - We expect the theory conveners to steer the effort
- It is important to come up with a standard on the theoretical predictions and request process
  - For instance, experiments depending on their needs request a set of theoretical predictions
  - This “on demand” process may not necessarily result to **identical predictions**
    - e.g., different parameters could have been used for the different requests or updated prescriptions could have become available
  - A **standard set** of predictions on various phase space regions covered by LHC experiments would be beneficial
- After subgroups identify a list of “higher priority observables to be combined” this procedure can be of **higher relevance and wider/immediate applicability**

Outlook

- CMS welcomes the effort for the **official formation** of the LHC HI Working Group(!)
  - initial practicalities: mandate and central web page (twiki) to be formed
  - knowledge sharing with other Working Groups can be beneficial
- Depending on experiments' involvement, we think **subgroups** will efficiently steer the effort
  - while the work remains experimental in nature, close contact with the **theory community** too
- First things first
  - **summary plots** a good/promising starting point for the Working Group mandate
- CMS is **open to** combination efforts building upon successful **past experience**
  - a list of topics with relative priority presented and exemplary analyses highlighted
- Important to cover a **common ground**
  - observables and techniques
  - corrections and associated systematic uncertainties
- The Working Group is
  - potentially a good basis for discussions related to **running schedule**
  - a natural place to standardize the procedure on requesting **theoretical predictions**
- Once agreements reached and common formats obtained we can **extend them** to
  - Open data
  - Combinations with extra-LHC, e.g., RHIC measurements



slides