<u>Heavy Ions and Hidden Sectors</u>

Dec. 4-5, 2018

Concluding Remarks

Andrea Giammanco, CP3

Disclaimers

- This is not a summary
  - Biased selection
  - Take it just as my workshop-inspired flux of consciousness
- Not every speaker will be cited
  - (but I cite the source talk to help a-posteriori navigation to the original discussion)

Why is it interesting to use Heavy Ions for new physics?

- Heavy-ions collisions have 2 important drawbacks:
  - – Low sqrt(s): PbPb runs at 5.5 TeV compared to 14-TeV pp [×2.5 less]
  - – Low lumis: $L_{PbPb} = A^2 \cdot 6 \cdot 10^{27}\ cm^{-1}s^{-2} = 2.5 \cdot 10^{32}\ cm^{-2}s^{-1} << L_{pp} = 2 \cdot 10^{34}\ cm^{-2}s^{-1}$ [×100 less]

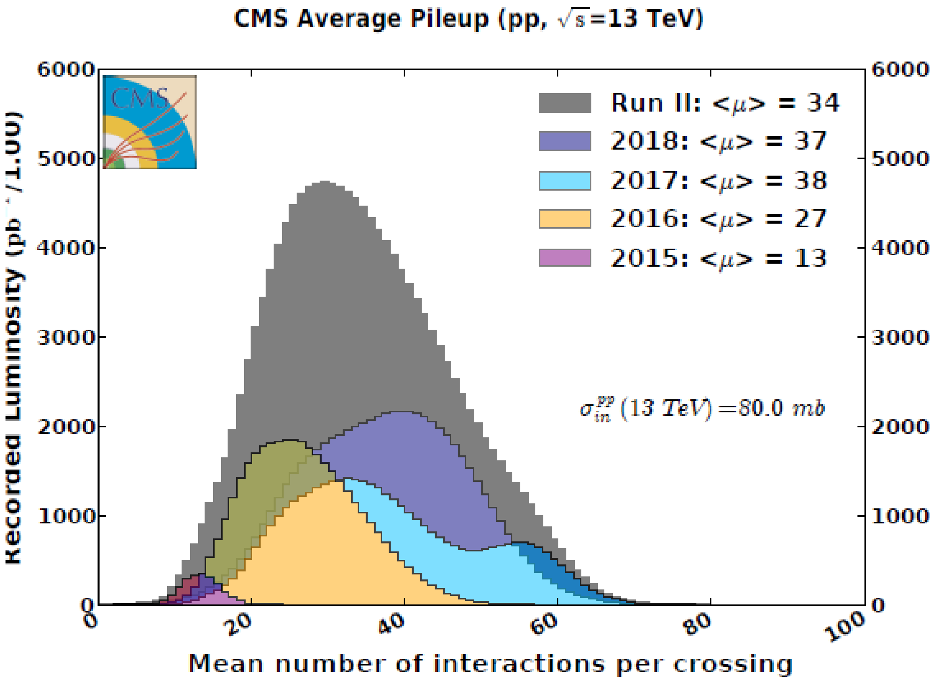
[integrated: $\times 10^3$ less]

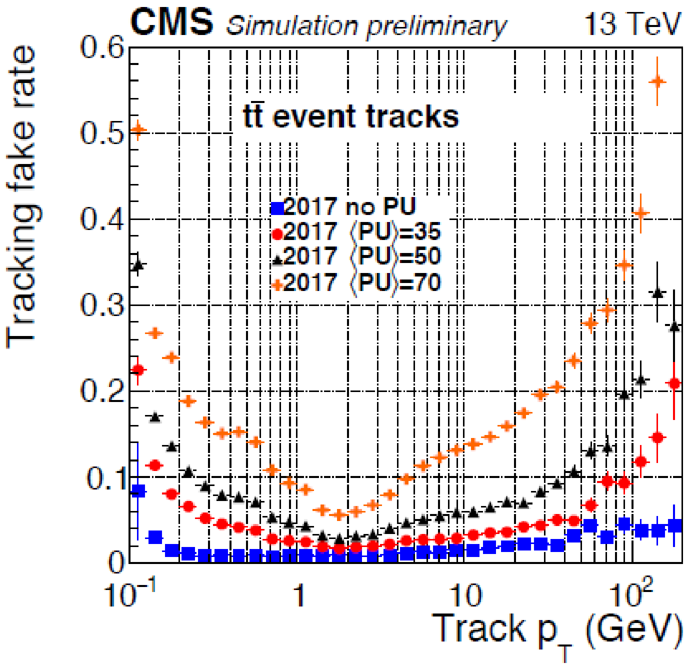
- Heavy-ions collisions have 2 advantages:
  - – No pileup: Excellent vertexing, Lower kin. trigger thresholds [×2? lower p_T values]
  - – Large γ lumis: $L_{pbPb}(\gamma\gamma)/L_{pp}(\gamma\gamma) = Z^4 \times L_{pbPb}/L_{pp} = 4.5 \cdot 10^7 \times (6 \cdot 10^{27}/2 \cdot 10^{34}) \sim 12$ [×10 more]

David D'Enterria

Pileup sorrows (in pp runs)

– No pileup: Excellent vertexing, Lower kin. trigger thresholds [×2? lower p_T values]

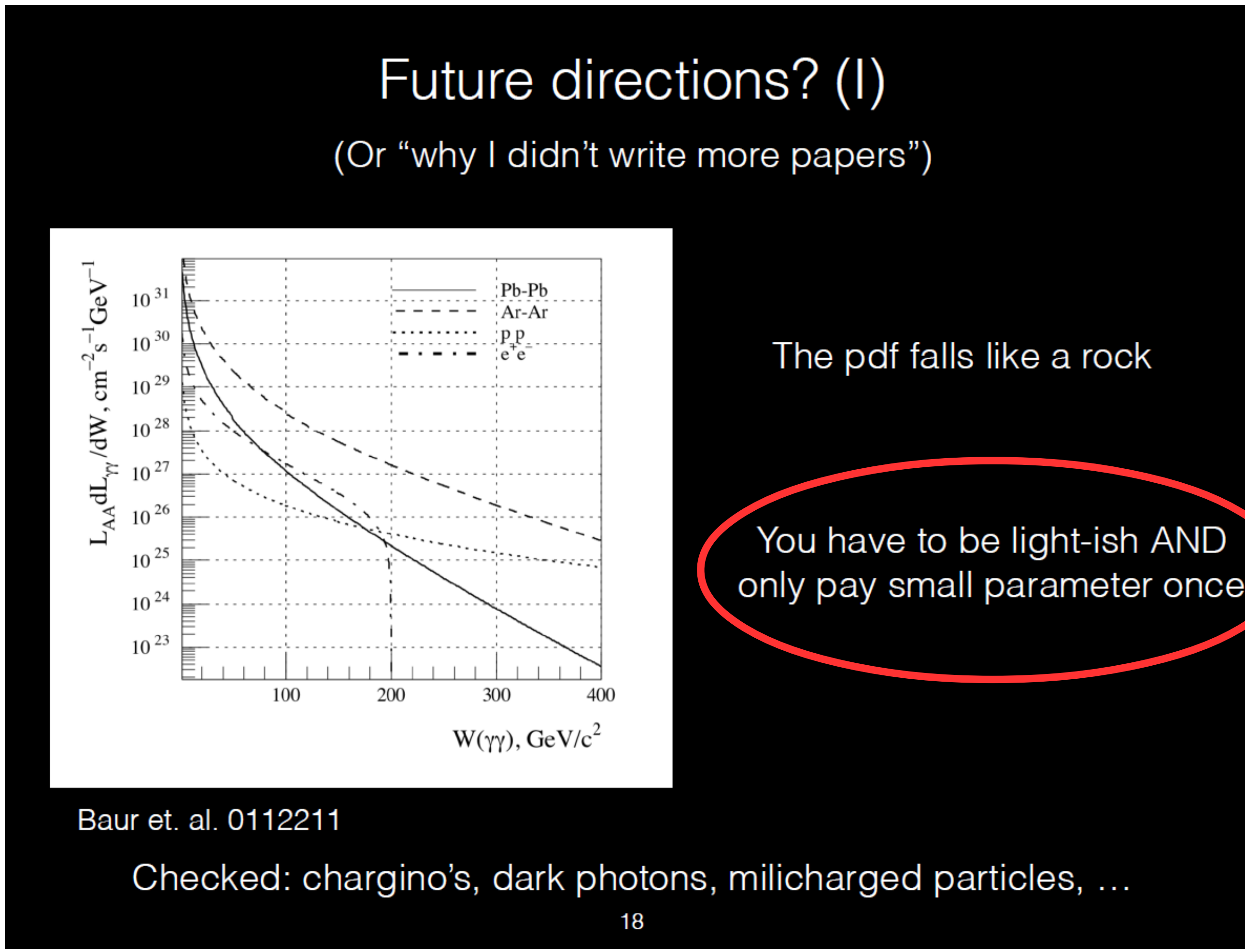




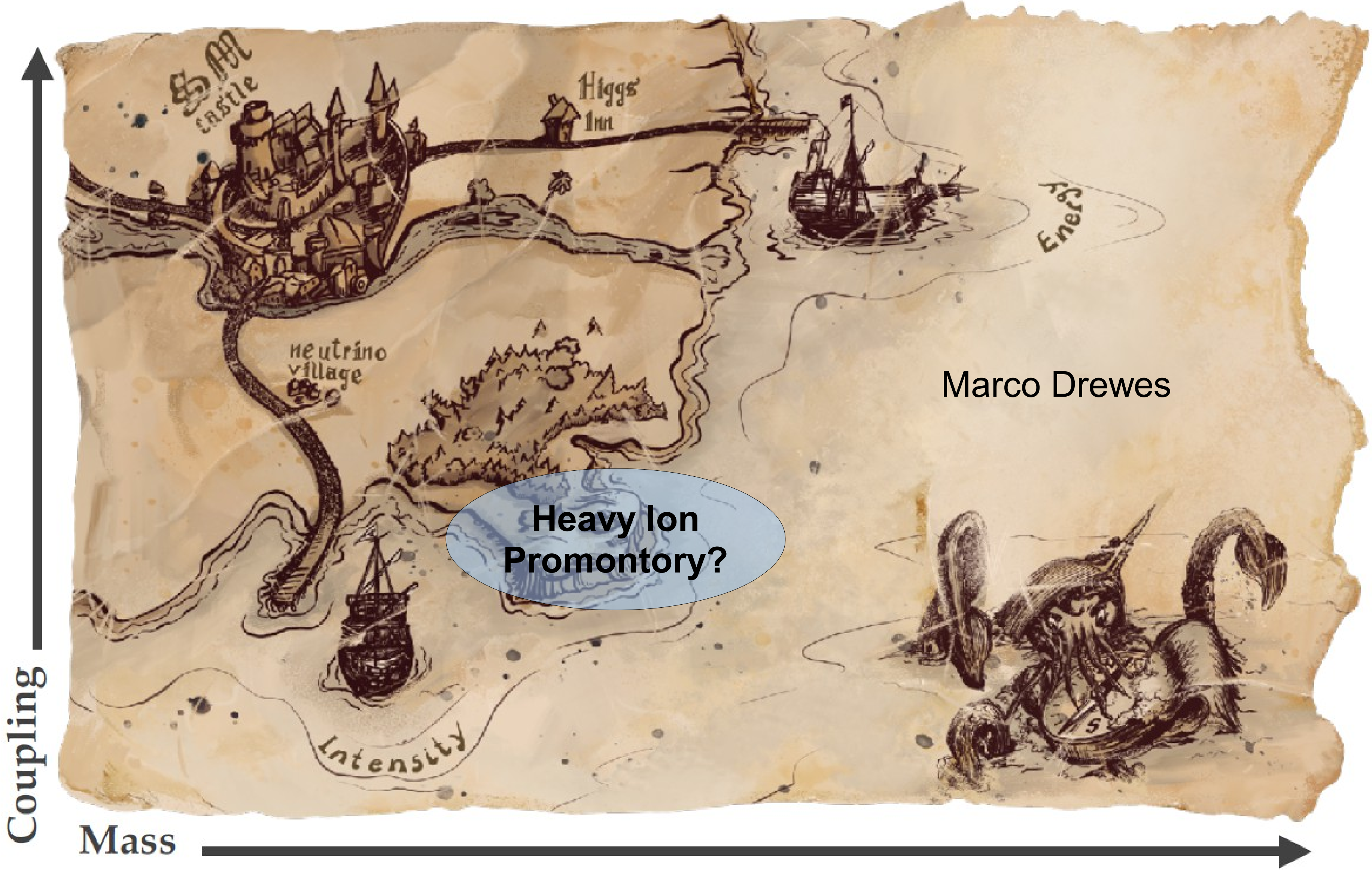
Jessica Prisciandaro

When is it interesting to use Heavy Ions for new physics?

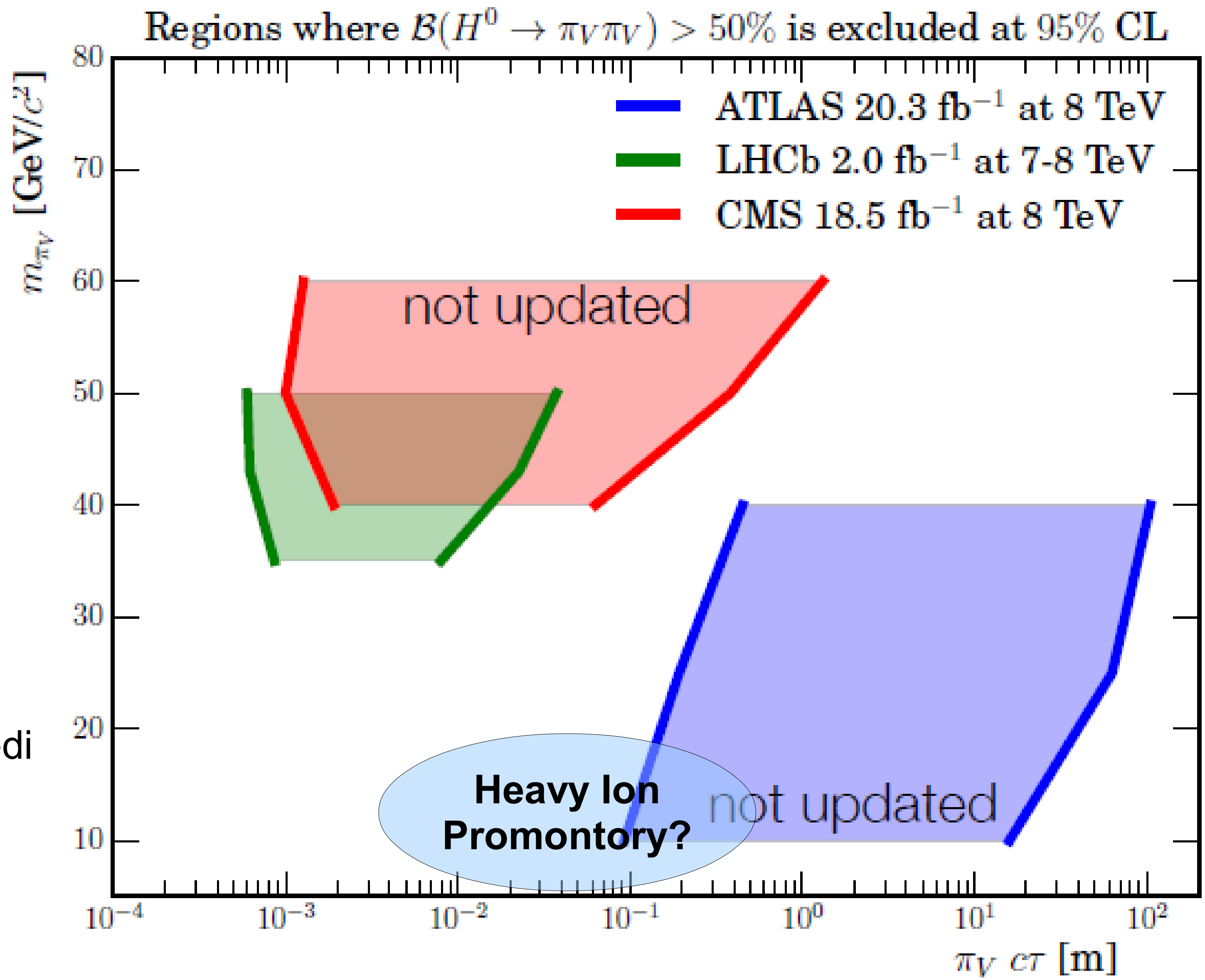
Simon Knapen



WHERE IS THE NEW PHYSICS HIDING?



Federico Redi



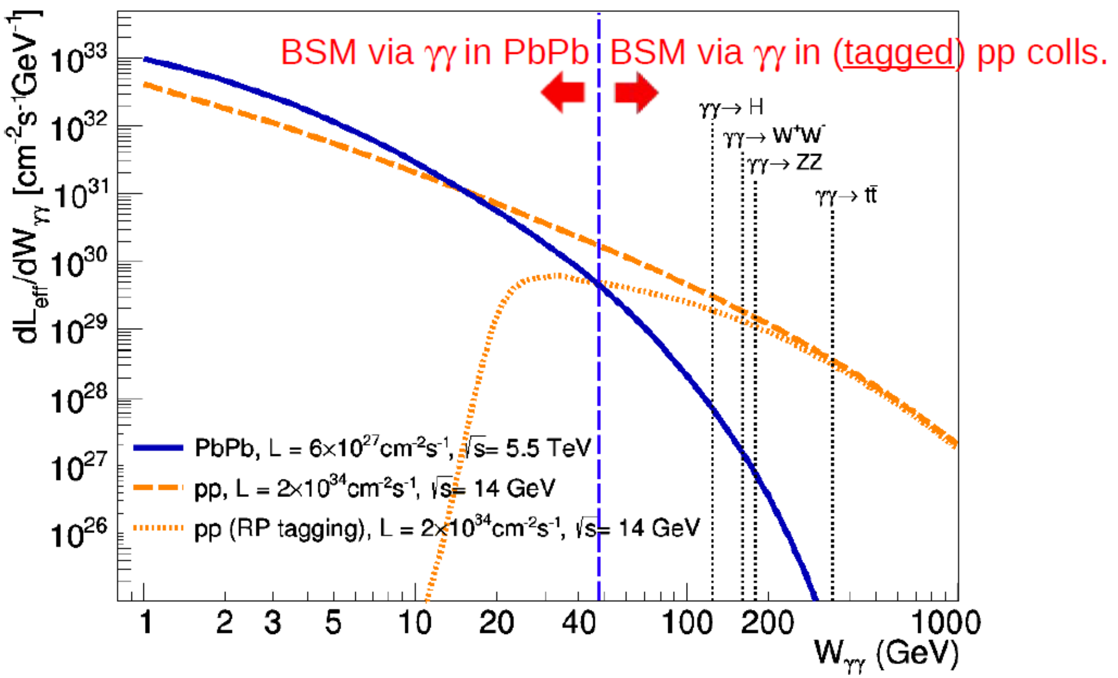
Eur. Phys. J. C77 (2017) 812

When is it interesting to use Heavy Ions for new physics?

Effective γγ luminosities at the LHC

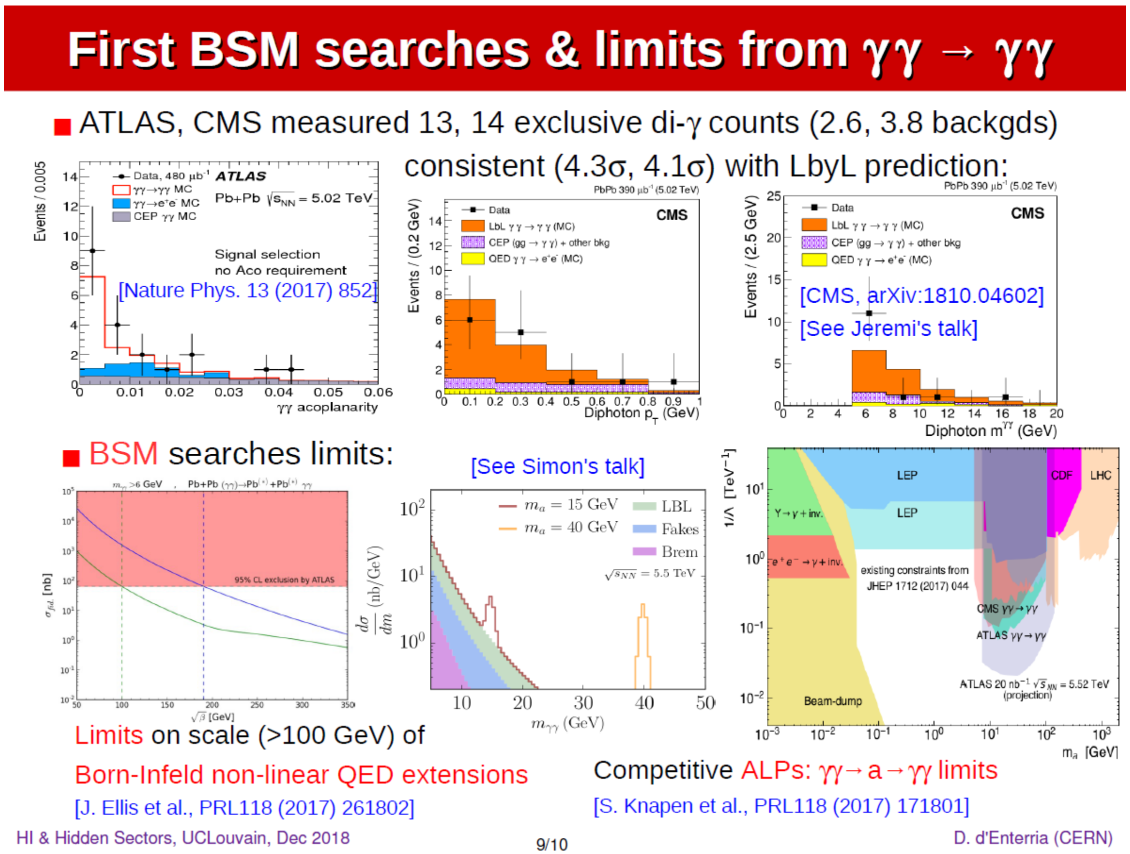
- Competitive mass range for BSM searches in UPCs PbPb collisions: $W_{\gamma\gamma}$ ~ 0.5–45 GeV ($W_{\gamma\gamma}^{min}$~0.5 GeV for ALICE/LHCb, 4 GeV for ATLAS/CMS)

David D'Enterria

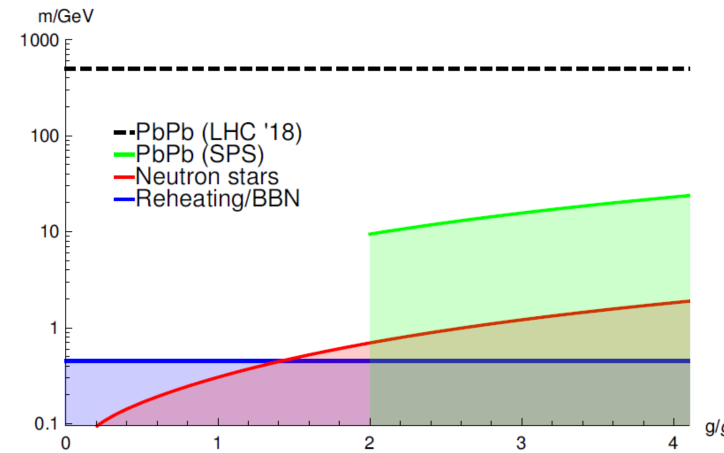


HI & Hidden Sectors, UCLouvain, Dec 2018 7/10 D. d'Enterria (CERN)

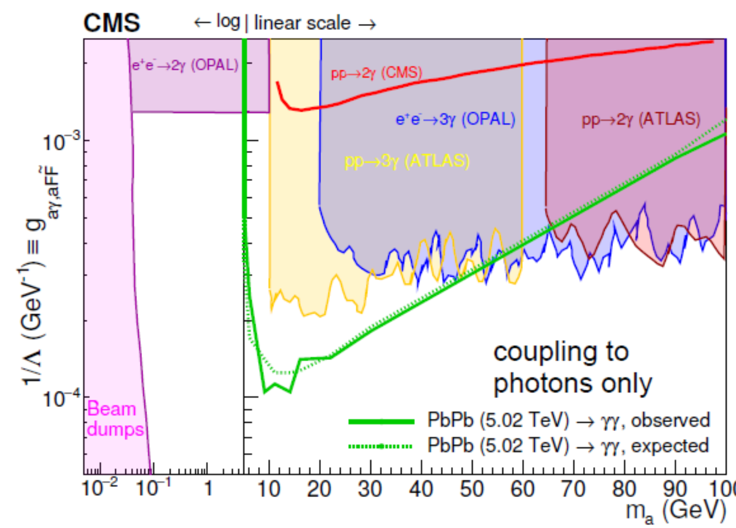
Where we stand (1)



David D'Enterria

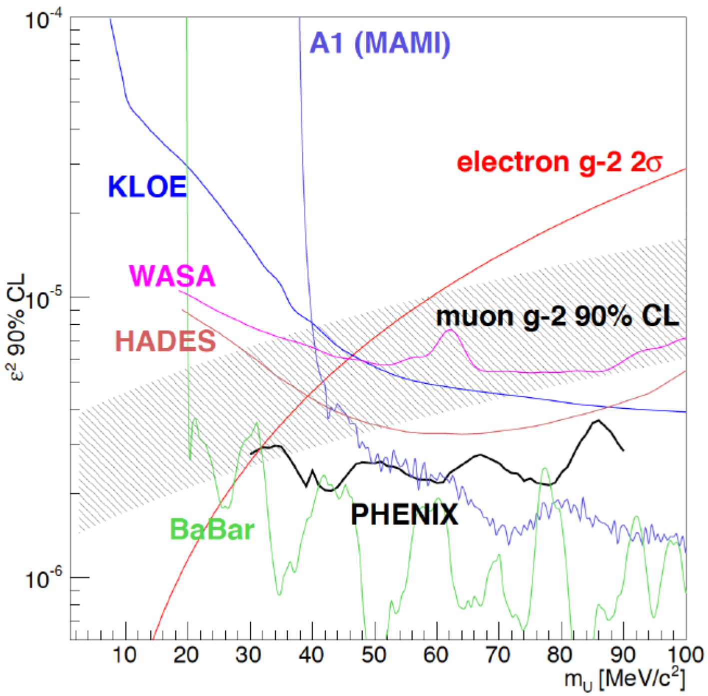


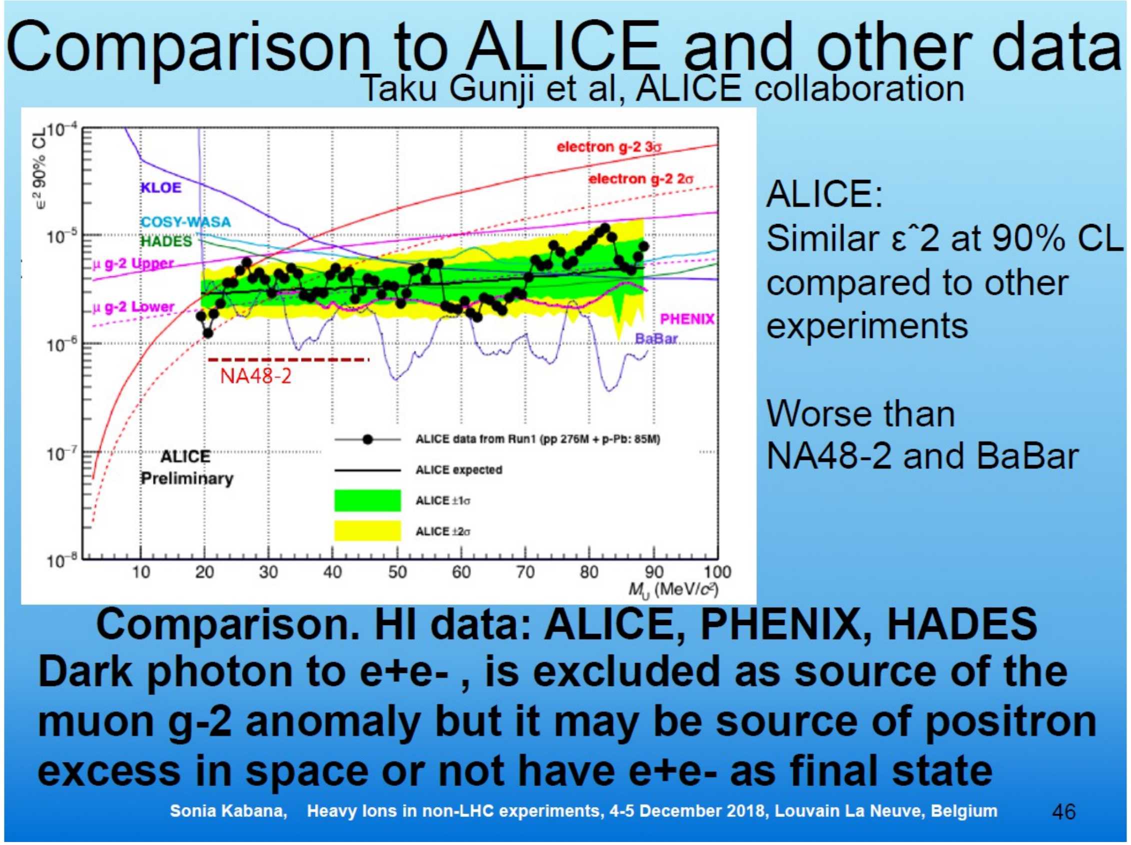
Oliver Gould



Jeremi Niedziela

Where we stand (2)

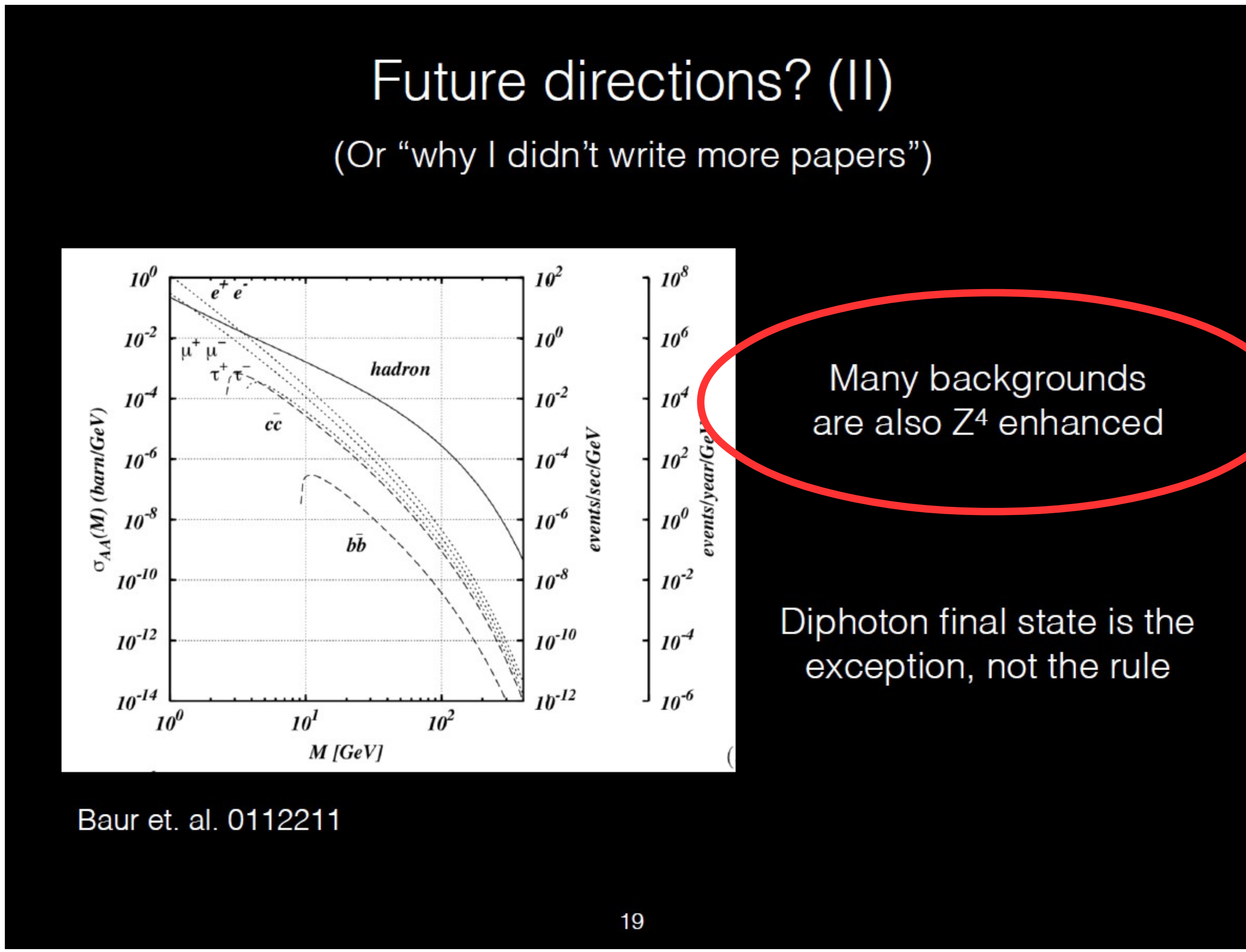




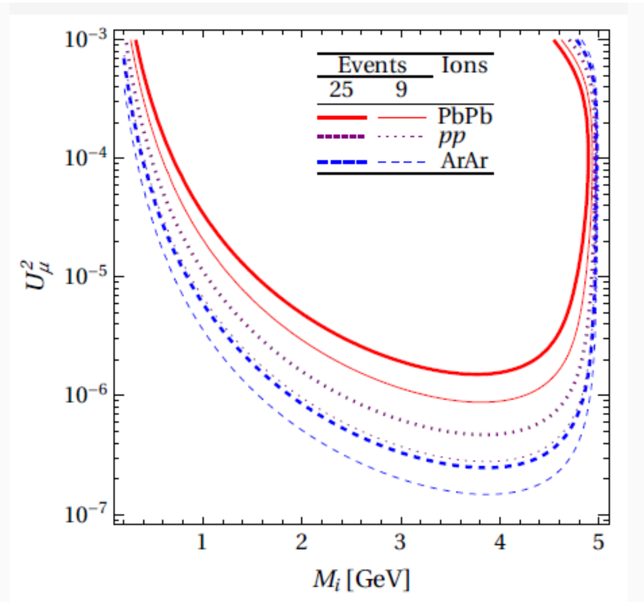
Sonia Kabana

The problem with UPCs

Simon Knapen



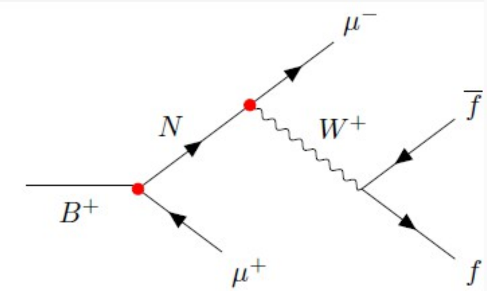
LLPs from b hadrons

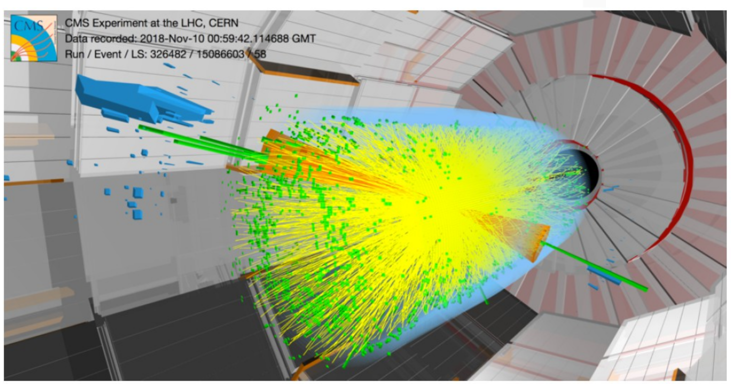


Jan Hajer

B-meson mediator

- lower trigger possible: e.g. $p_T > 3\,\text{GeV}$
- already probed at LHCb
- considered by CMS using parked data.





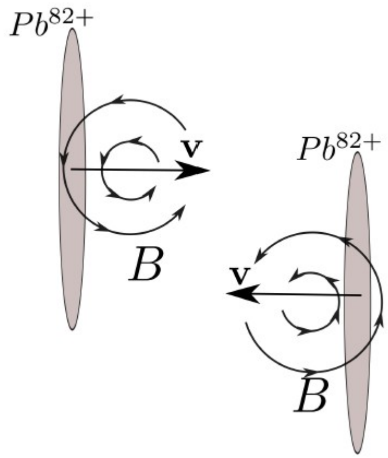
Jets from b's in HI (Pieter David)

Discussion:

- Considering generic b quarks: gain statistics
- Or stick to specific hadron(s) but apply mass cuts to reduce backgrounds (if any)
- Consider same-sign muons: much much cleaner, but theorically controversial?

Magnetic Monopoles

Magnetic fields in heavy-ion collisions are the strongest known in the universe, $O(10\mathrm{GeV}^2) = O(10^{16}\mathrm{T})$ at LHC energies.



Oliver Gould

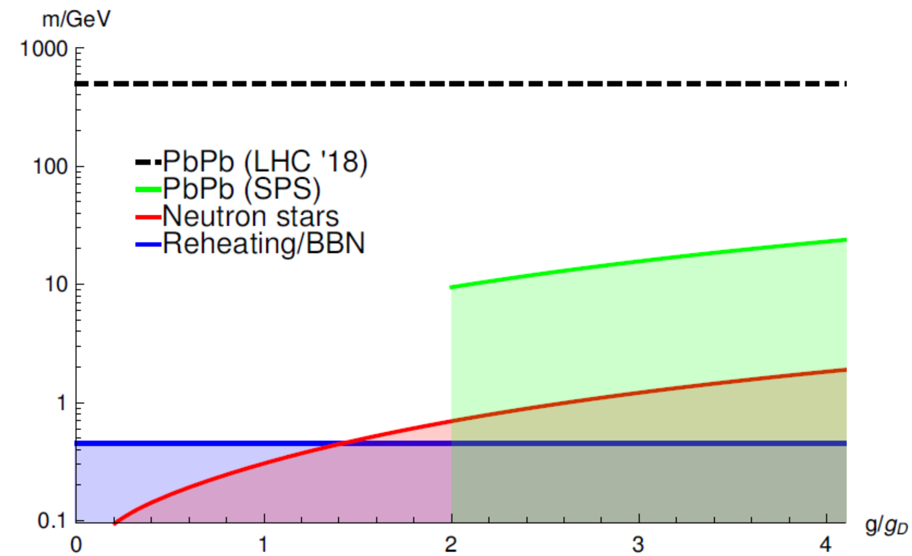


Figure: adapted from OG & Arttu Rajantie '17.

1. If **composite** magnetic monopoles exist, how can they be created?

   ~~pp collisions~~, ~~e^+e^- collisions~~ . . .

   $PbPb$ collisions ✓, $AuAu$ collisions ✓,. . .

2. If **elementary** magnetic monopoles exist, how can they be created?

   pp collisions? e^+e^- collisions? . . .

   $PbPb$ collisions ✓, $AuAu$ collisions ✓,. . .

Discussion:
- How do we trigger on that?
- Parabolic tracks; a problem? (UPC: few tracks anyway)

Sexaquarks

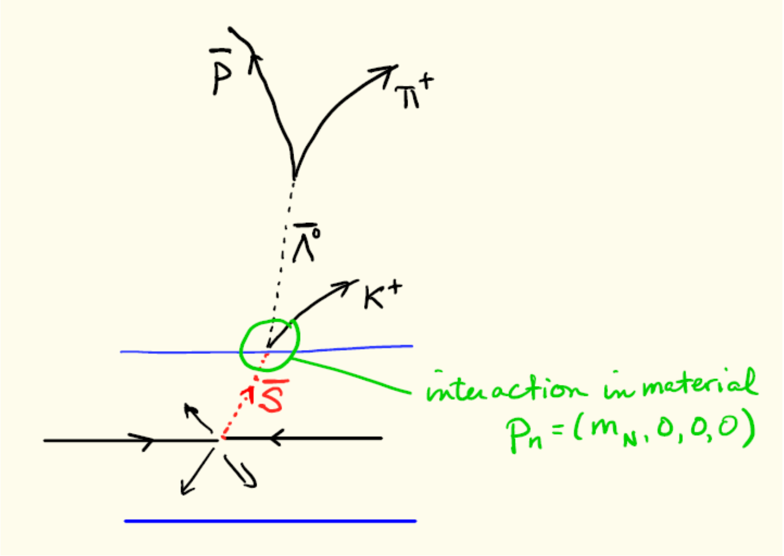
Glennys Farrar

Prediction: Ω_{DM} / Ω_b = 4.5 ± 1

determined by *stat mech*, *quark masses* & *temp* of *QGP-hadronization transition*

(Ω_{DM} / Ω_b observed = 5.3 ± 0.1)

- Heavy ion collisions produce more particles — feasible to reconstruct ???

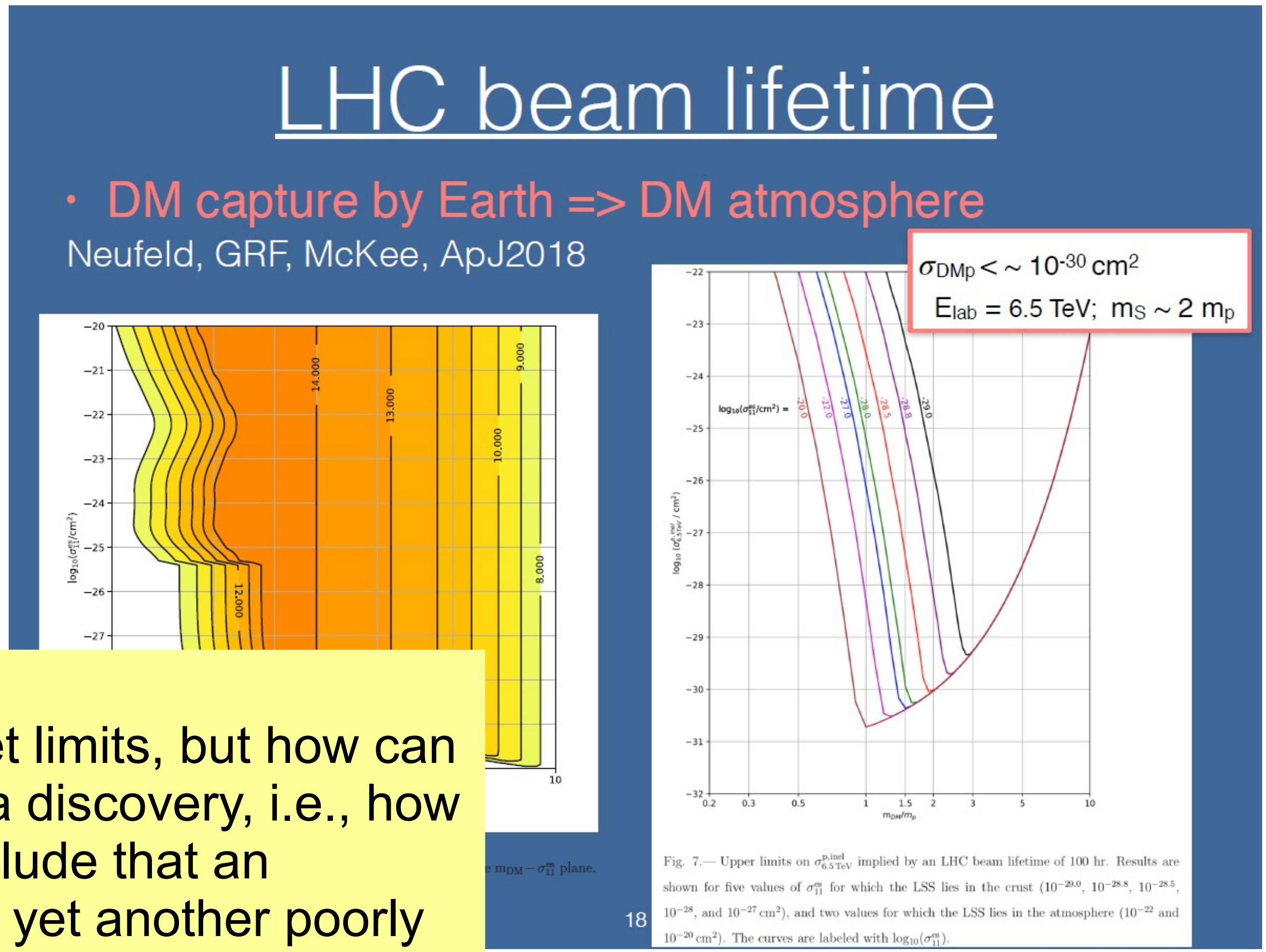


Discussion:

- LHCb and ALICE have very good hadron-id, should be able to distinguish π, K, p

Is the LHC beampipe's vacuum actually full of sexaquarks?

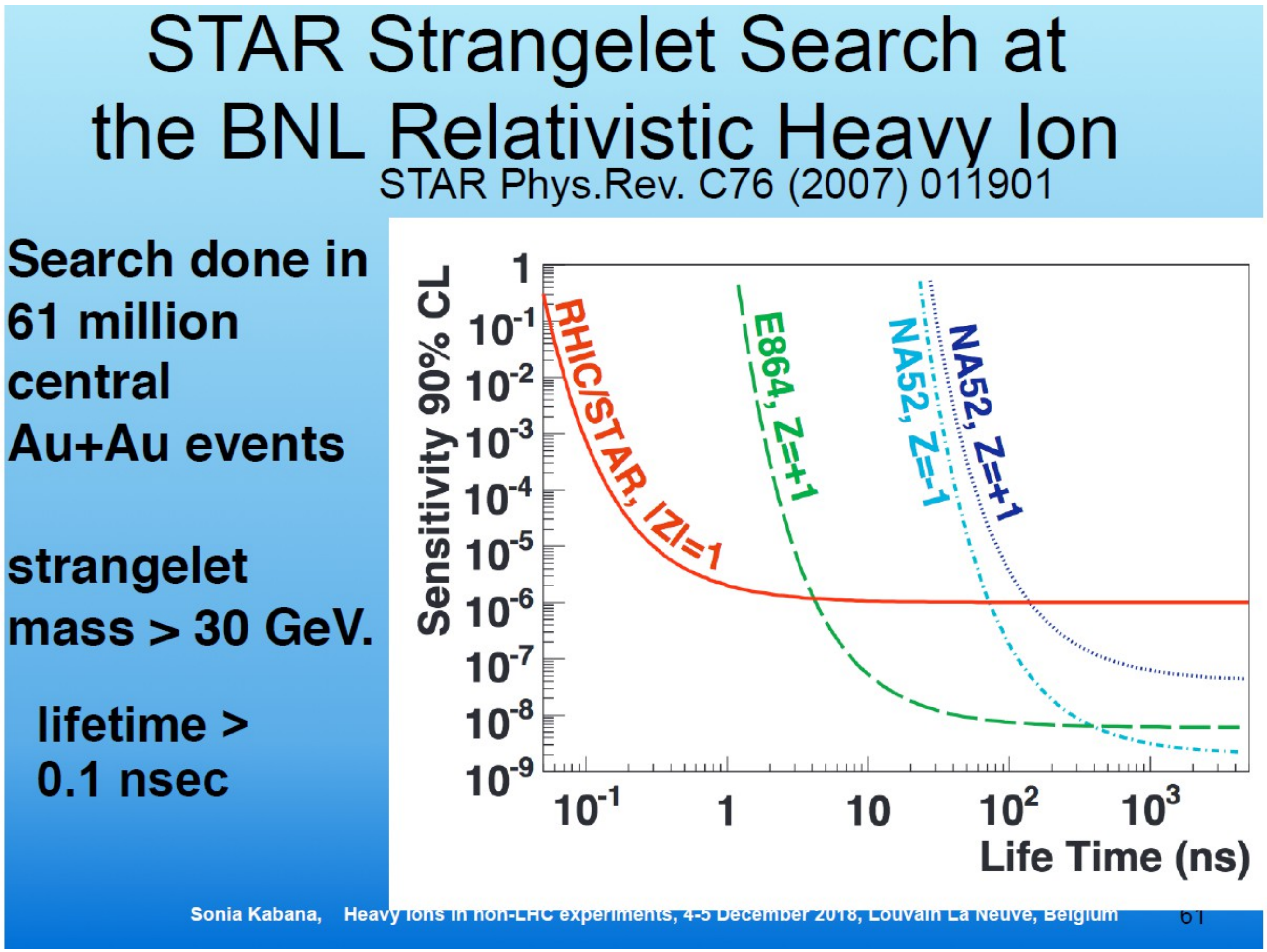
Glennys Farrar



Discussion:

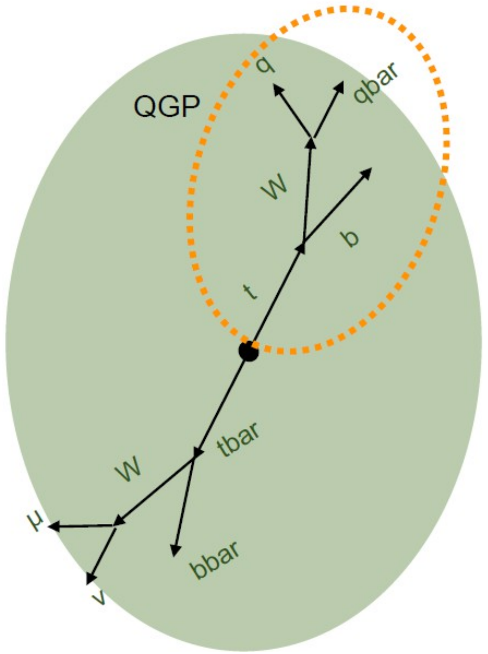
- You can set limits, but how can you claim a discovery, i.e., how do you exclude that an anomaly is yet another poorly known instrumental effect?

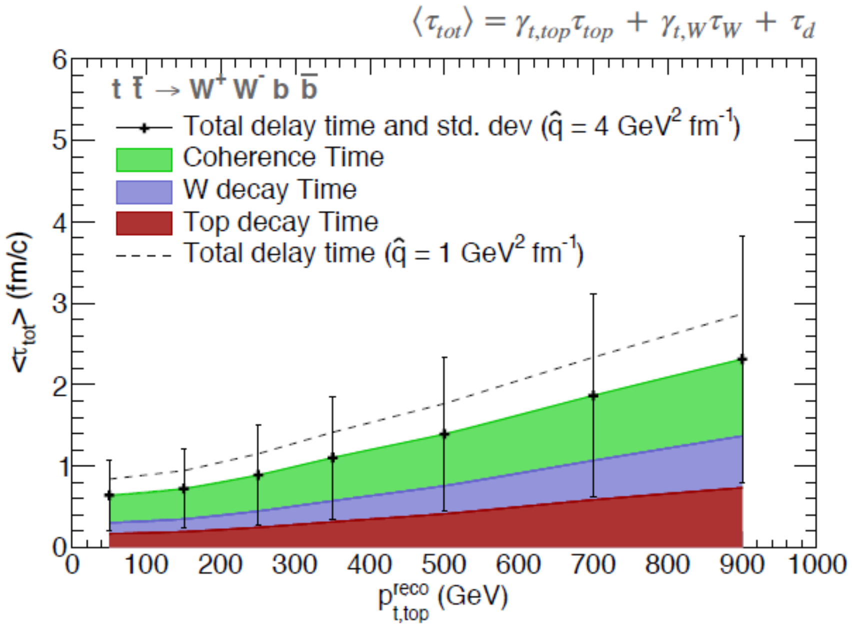
Strangelets



Sonia Kabana

What can we do with a yoctosecond chronometer?





Guilherme Milhano

although all of this was strictly physics of QGP

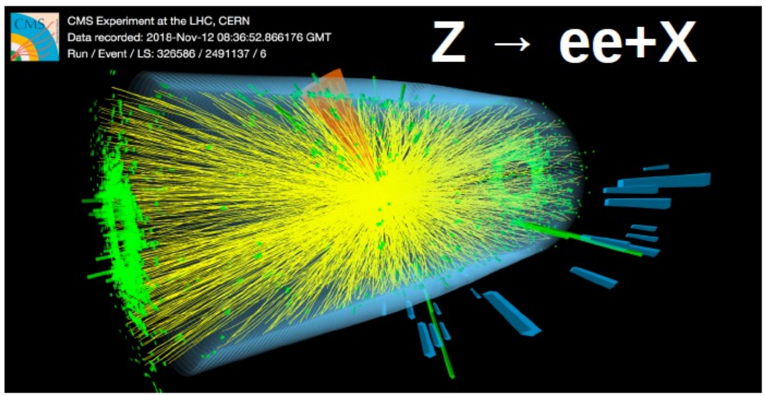
the yoctosecond chronometer could [should] be used

to explore physics of both short and long lived new

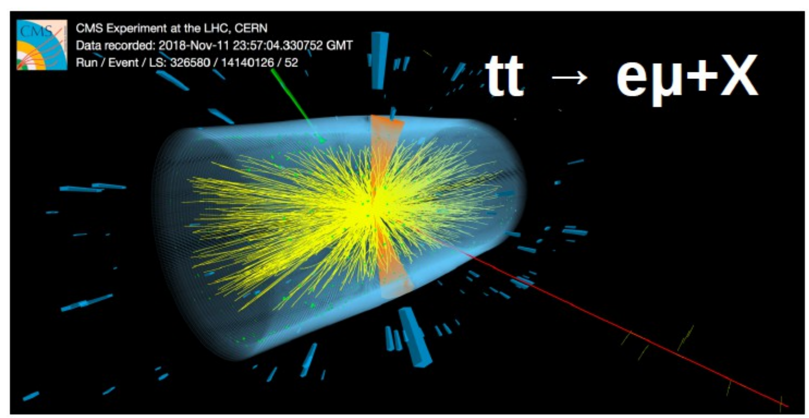
states that decay into jets

PbPb 2018

First events with "hard probes" ツ



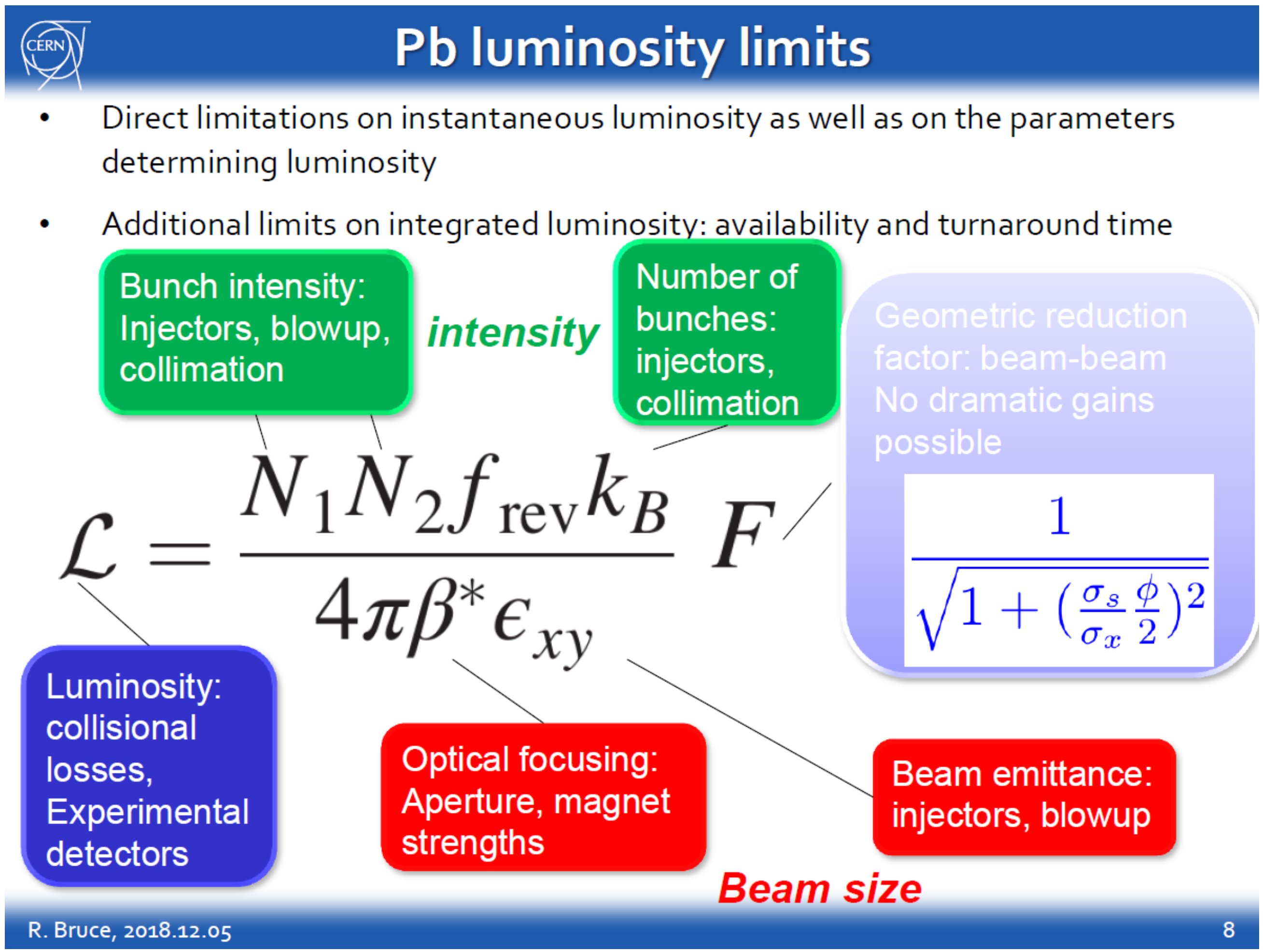
CMS-PHO-EVENTS-2018-010-19



CMS-PHO-EVENTS-2018-010-21

Georgios Krintiras

How far can LHC go?

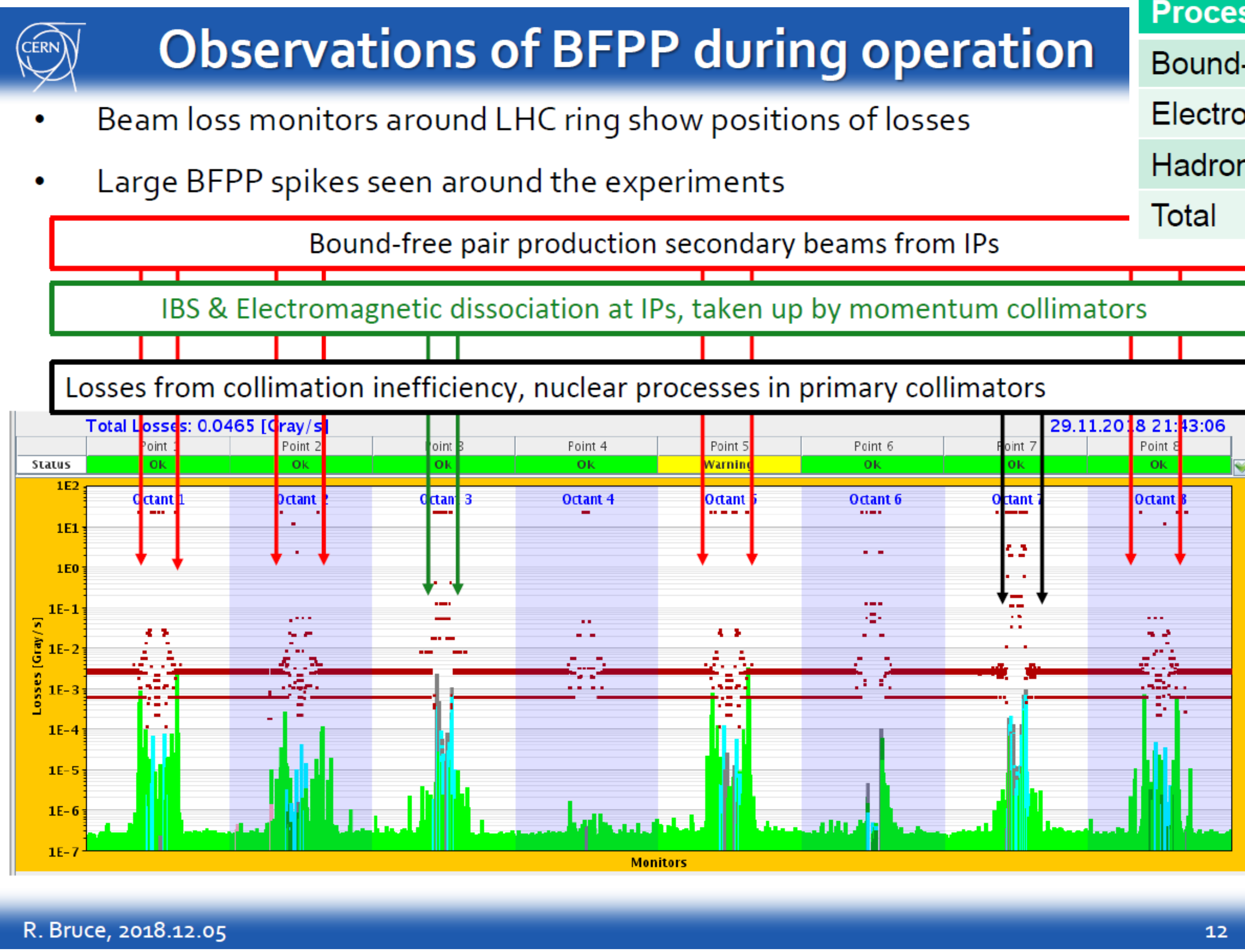


Roderik Bruce

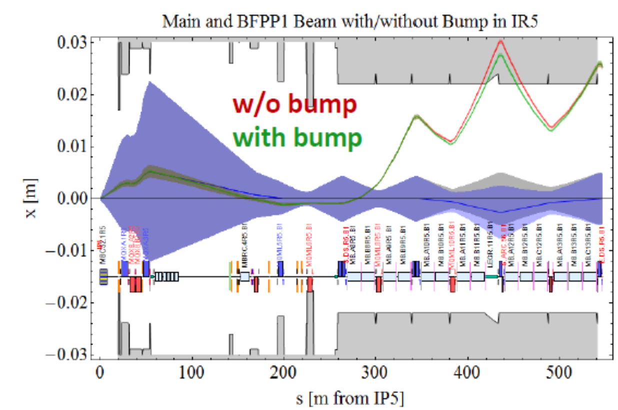
Limiting effects

Cross sections for Pb-Pb collisions at 2.76 TeV / nucleon

Process	Cross section (b)
Bound-free pair production	281
Electromagnetic dissociation	226
Hadronic nuclear inelastic	8
Total	515



Roderik Bruce

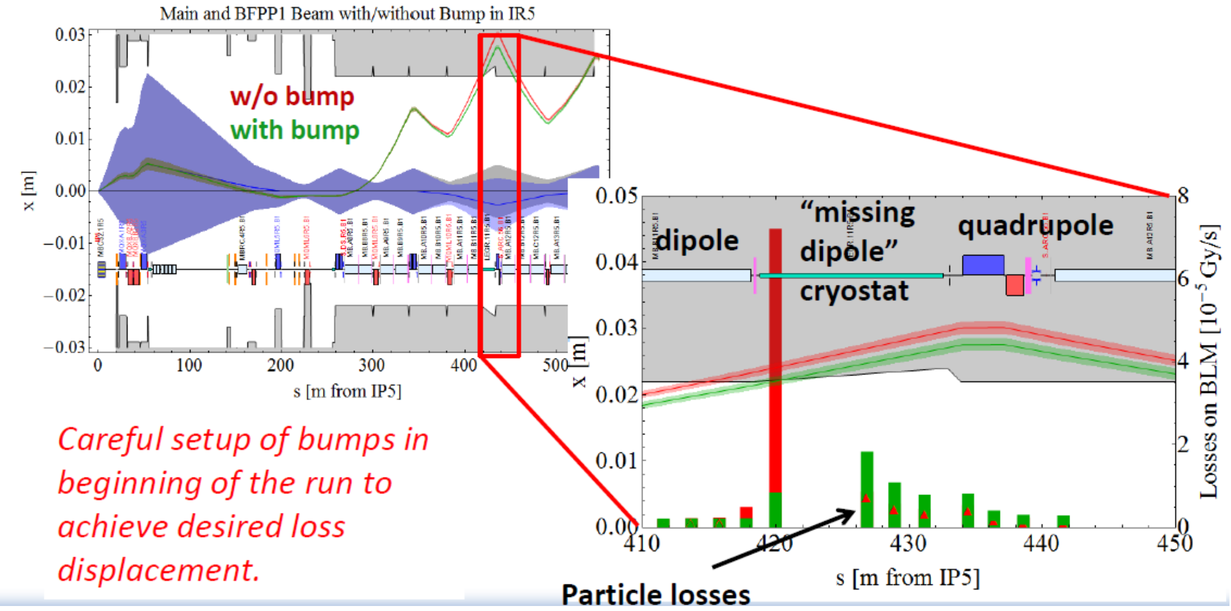


Careful setup of bumps in beginning of the run to achieve desired loss displacement.

Alleviating actions

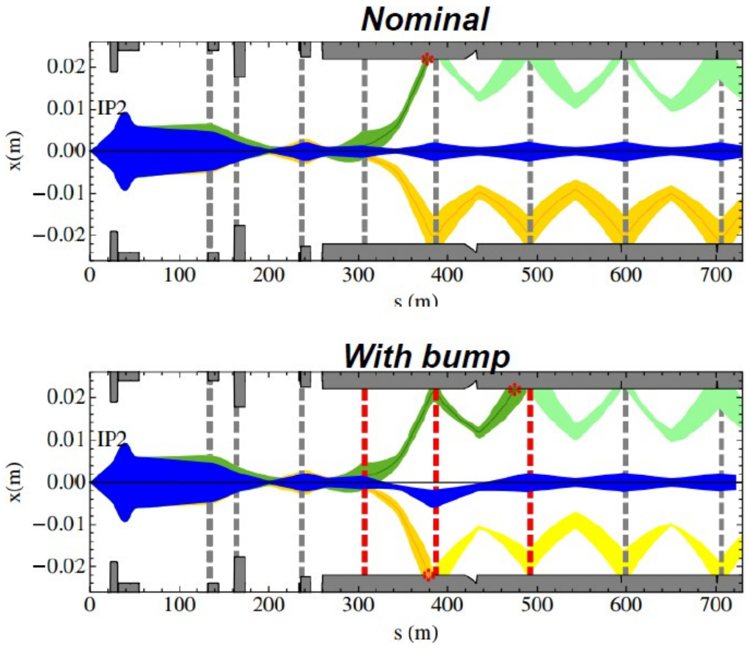
ATLAS/CMS:

- With bumps, achieved ~6E27 $cm^{-2}s^{-1}$ in ATLAS / CMS



Careful setup of bumps in beginning of the run to achieve desired loss displacement.

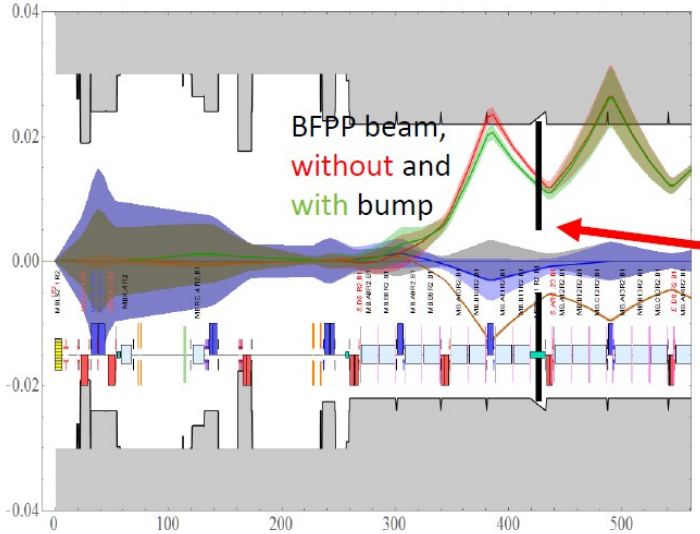
Partial solution in ALICE:

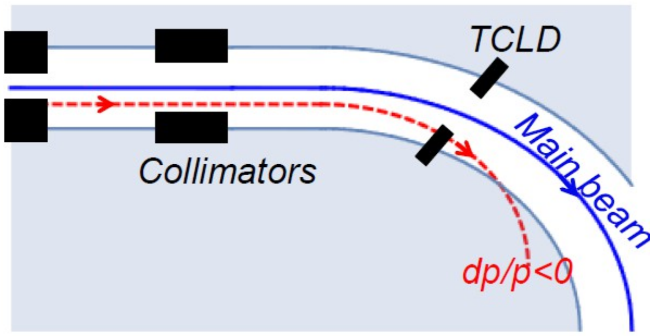


ALICE anyway leveled at 1E27 $cm^{-2}s^{-1}$

Roderik Bruce

Future alleviation: collimators



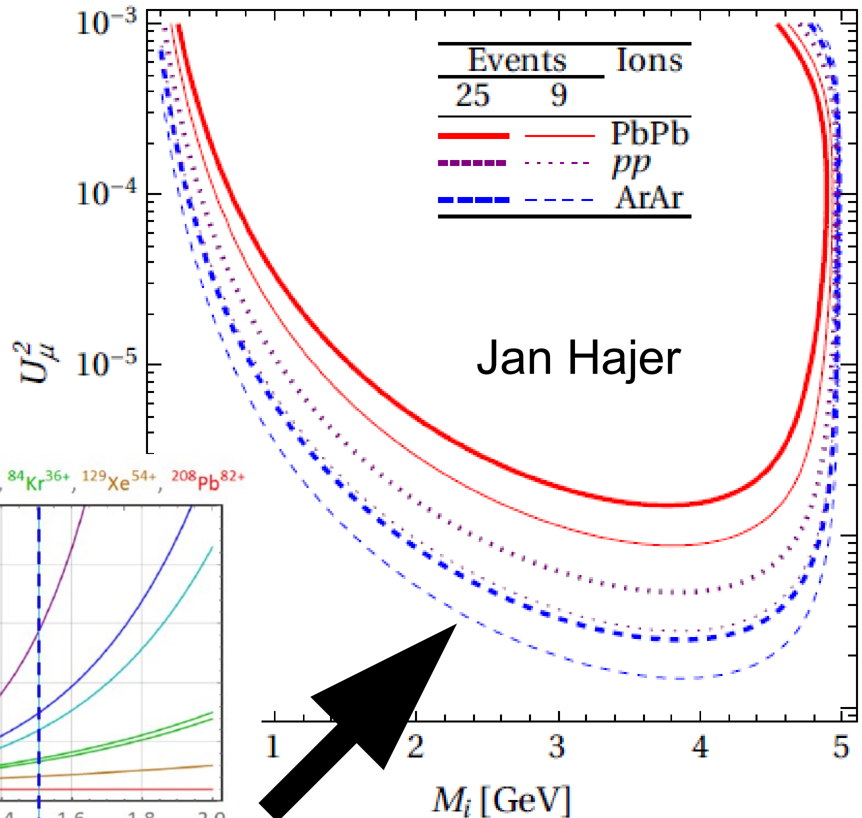


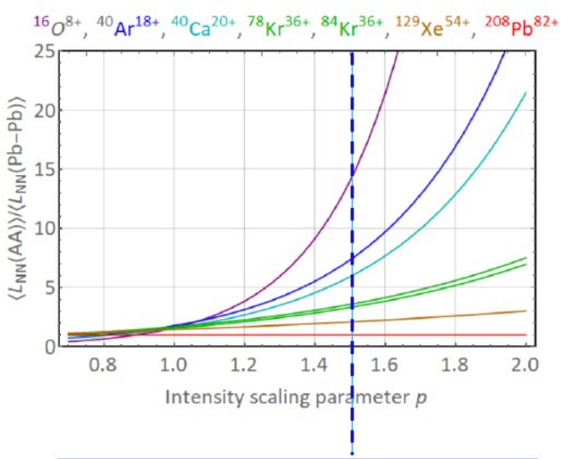
Roderik Bruce

- LHC collimation much less efficient with nuclear beams than with protons
  - Very high probability of nuclear breakup in primary collimator
  - Fragments very often miss downstream collimation stages
  - Different charge-to-mass ratio => fragments bent wrongly and lost in the first few dipoles

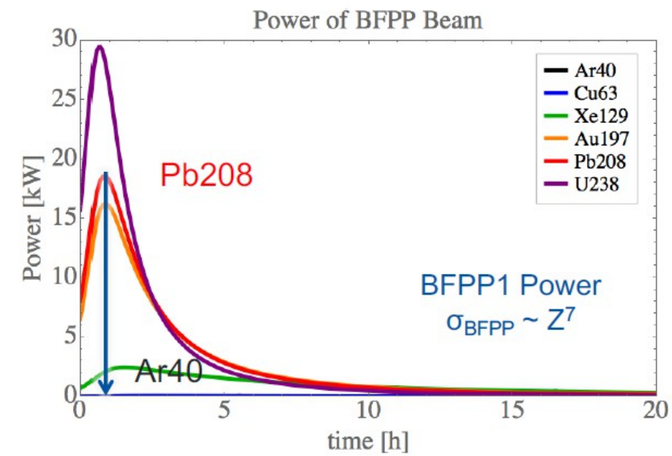
- Measured leakage to cold magnets factor ~100 worse of Pb ions than protons

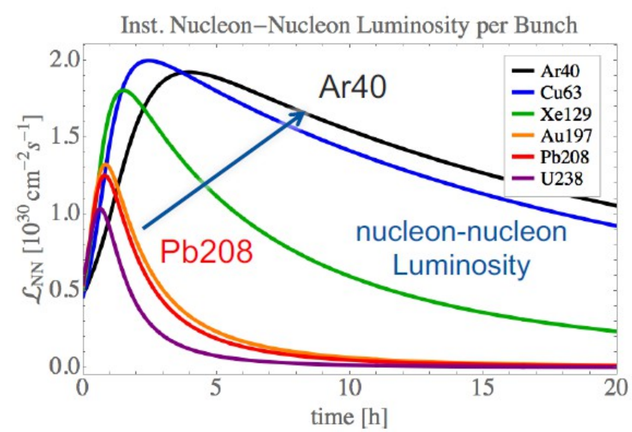
Lighter ions





Nucleon-nucleon luminosity in 1-month run: **gains** ranging up to a **factor ~13 for lightest considered ion (O) at p=1.5**

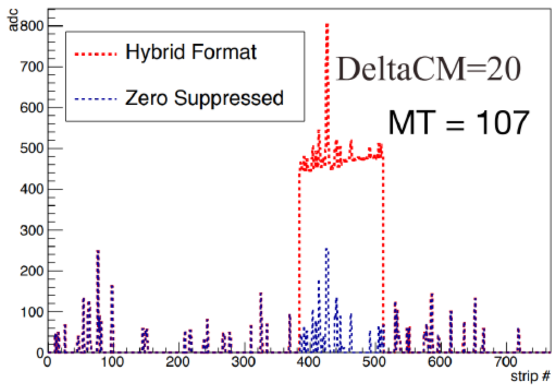




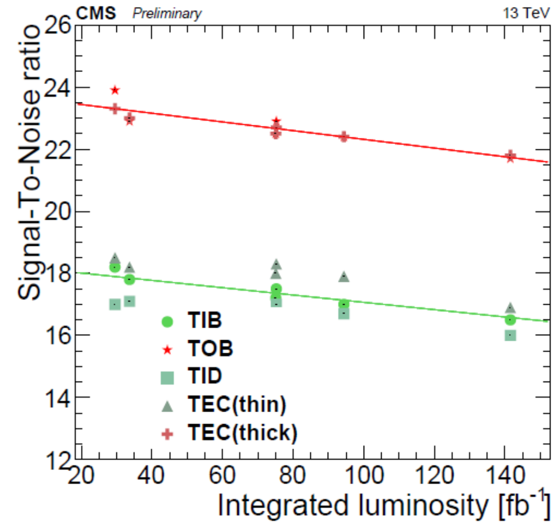
Michaela Schaumann

Detectors suffering: CMS examples

- zero-suppression in the detector frontend electronics (as in proton-proton) would reduce efficiency
- 2015 solution: no zero-suppression (big events limiting trigger rate)
- 2018 hybrid readout: zero-suppression only when baseline as expected



An example: ageing of the CMS strip tracker (relevant for HSCP searches)



Also

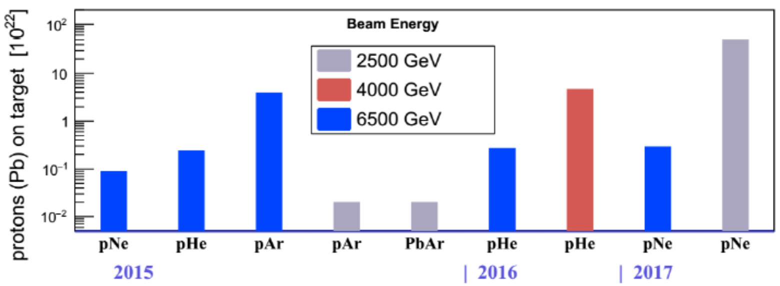
- hardware trigger / readout
- high-level trigger (online reconstruction)
- offline reconstruction (computing resources)

Pieter David

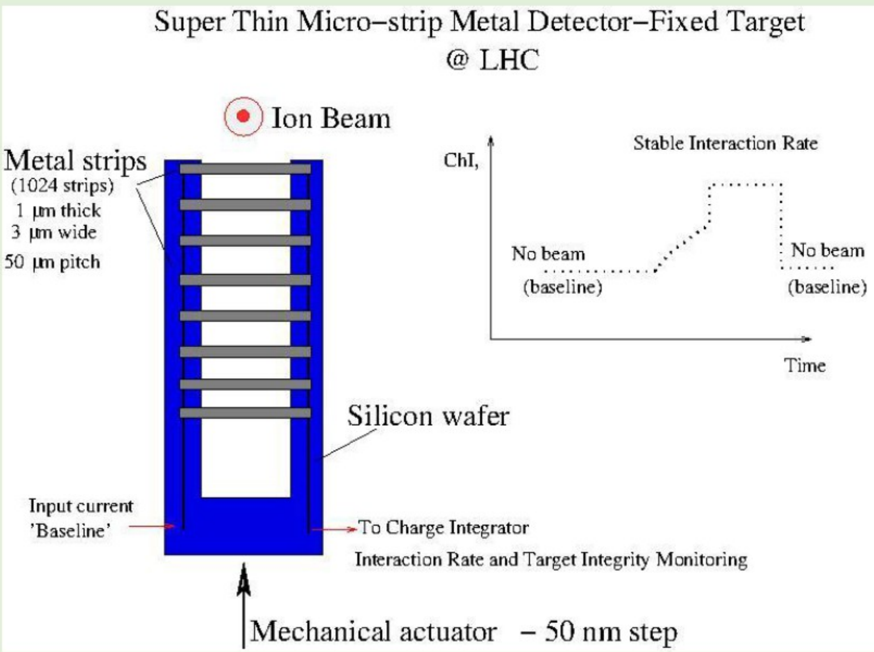
Fixed target

Today →

Tomorrow? →



Valerii Pugatch

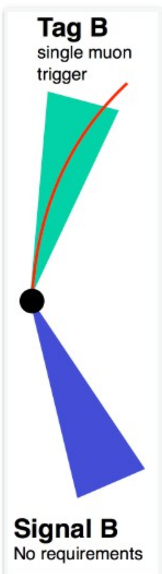


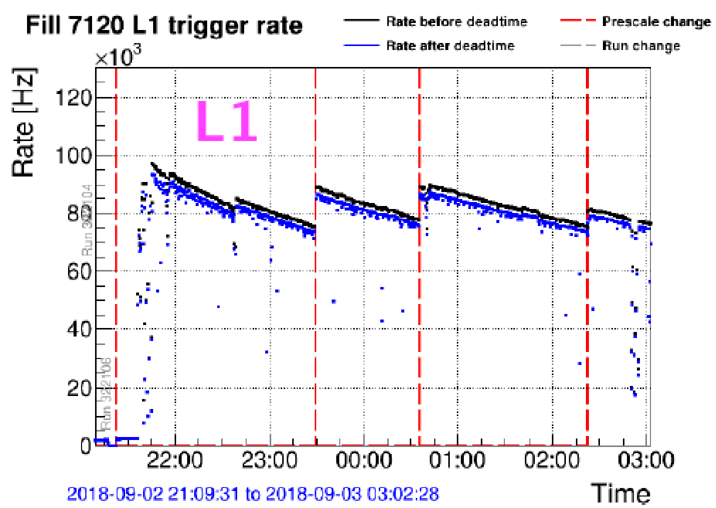
Metal Microstrip Detector –MMD-1024.

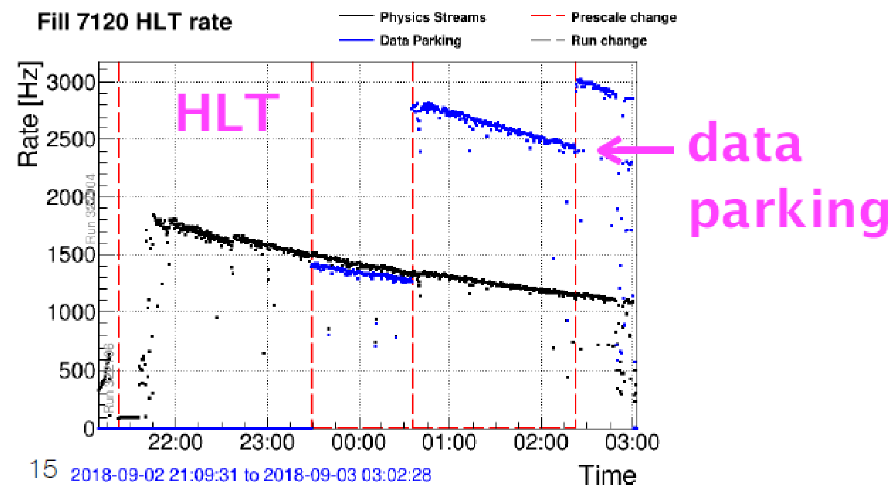
Nano-technologies evolve fast
– already nowadays- carbon nano-tubes,
fullerene structures, graphenes, ...
May become a nano-wire target components.

Parking, i.e. "better late than never"

The current use case in CMS is of relevance for B → new physics, but the concept is general:







Swagata Mukherjee,
Jessica Prisciandaro

Discussion:

- How to factor parking in HL-LHC projections?
- And what about parking also in HI context?

Scouting, i.e. "do more with less"

Trigger Bandwidth = Event Rate × Event Size

~1 kHz × ~1 MB

If we want to **increase** rate (i.e. decrease threshold)

We need to **decrease** event size

Advantage

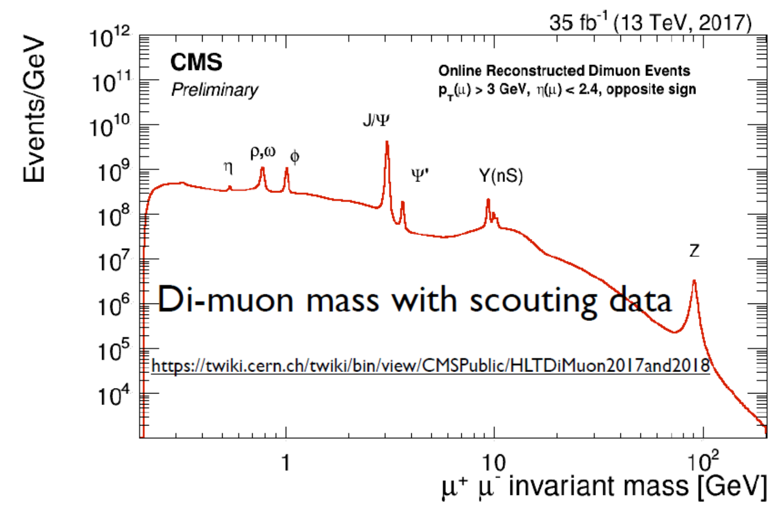
(I)Save low pT objects (II)Probe low mass regions

Dedicated di-muon scouting trigger designed for **prompt** and **displaced** di-muon search.

Loose HLT requirement:

At least 2 muons with p_T>3 (1) GeV in 2017 (2018). **No mass cut**.

Di-muon vertex can be displaced, upto ~10 cm, w.r.t primary vertex.

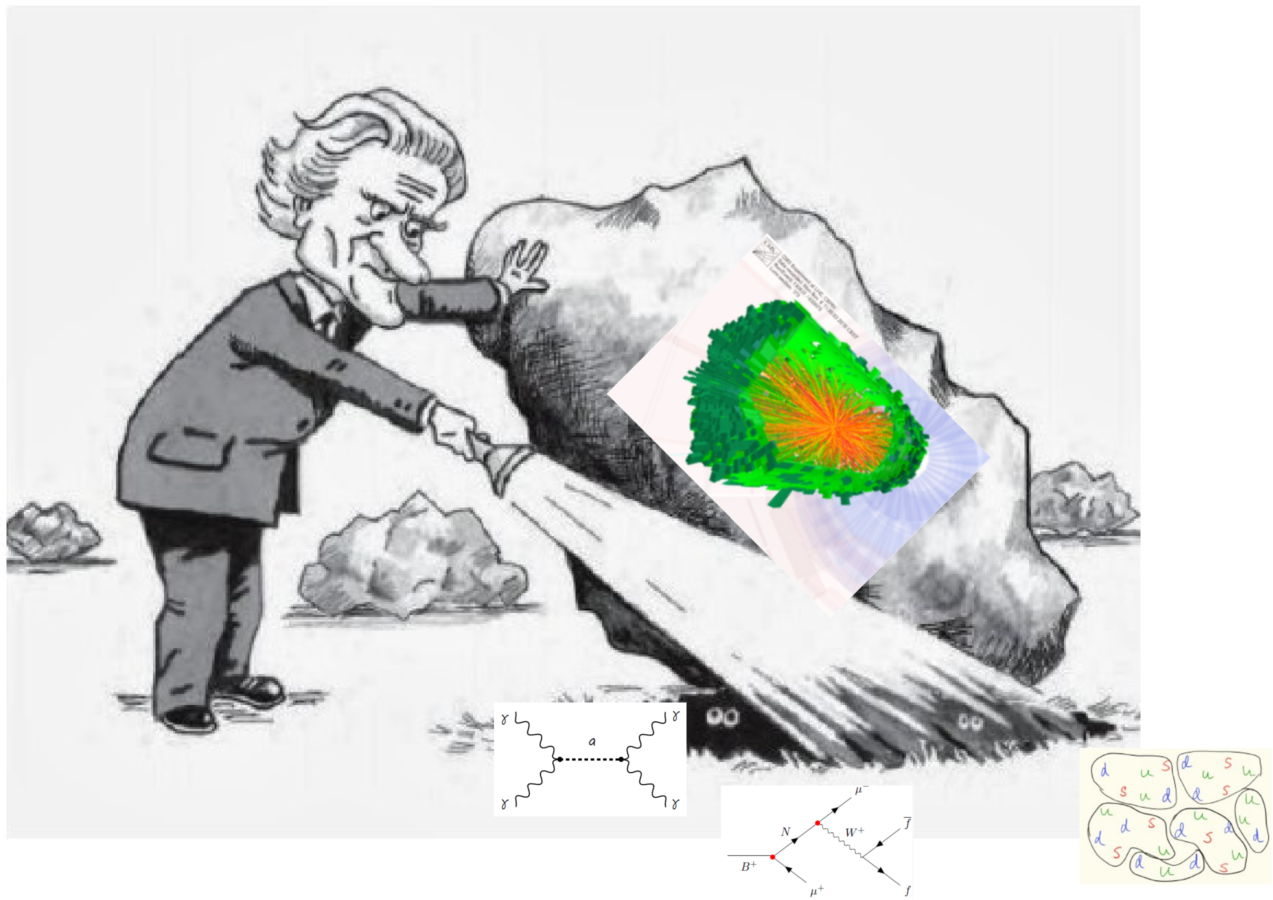


Swagata Mukherjee

Homework!

- Document on the perspectives to find "New Physics" in HI collisions to the EPPS (see guidelines)
  - Possible topics: ALPs, monopoles, LLPs, exotic QCD states (including sexaquarks), exotic plasma effects (e.g. chiral magnetic) or the general potential of HI as $\gamma\gamma$ collider
- Join this effort by writing up a very brief paragraph here: https://www.overleaf.com/6996454583xrjpgpgpsznw
  - physics case
  - references and a few numbers
  - how the heavy ion program beyond 2029 could be optimised for this proposal (e.g. choice of isotopes etc.)

Concluding the conclusions



Thanks!

I learned a lot in these two days