SOFT PHYSICS WITH PHOTON CONVERSIONS AND CHARGED PARTICLES

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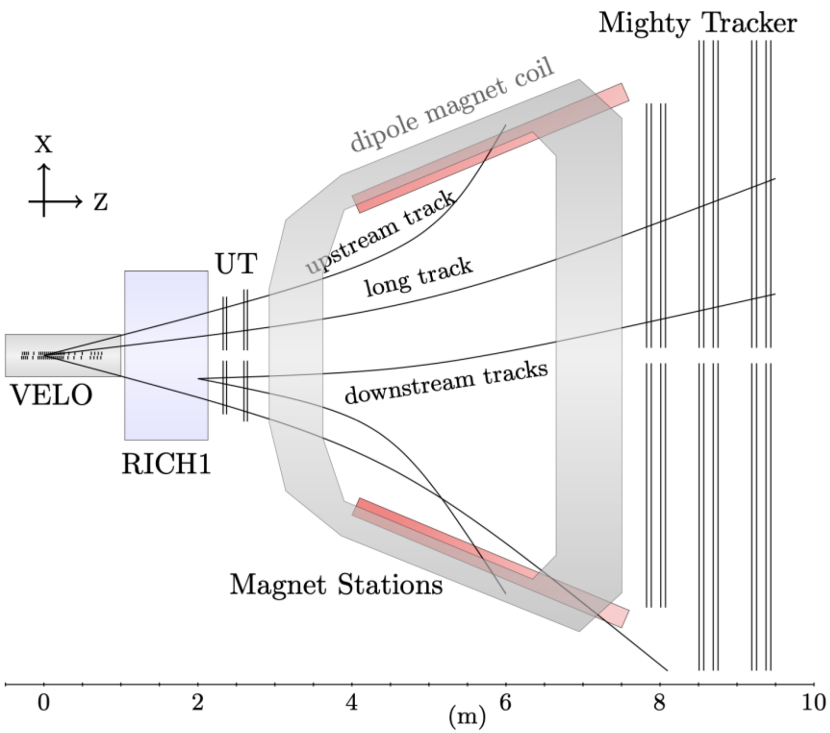
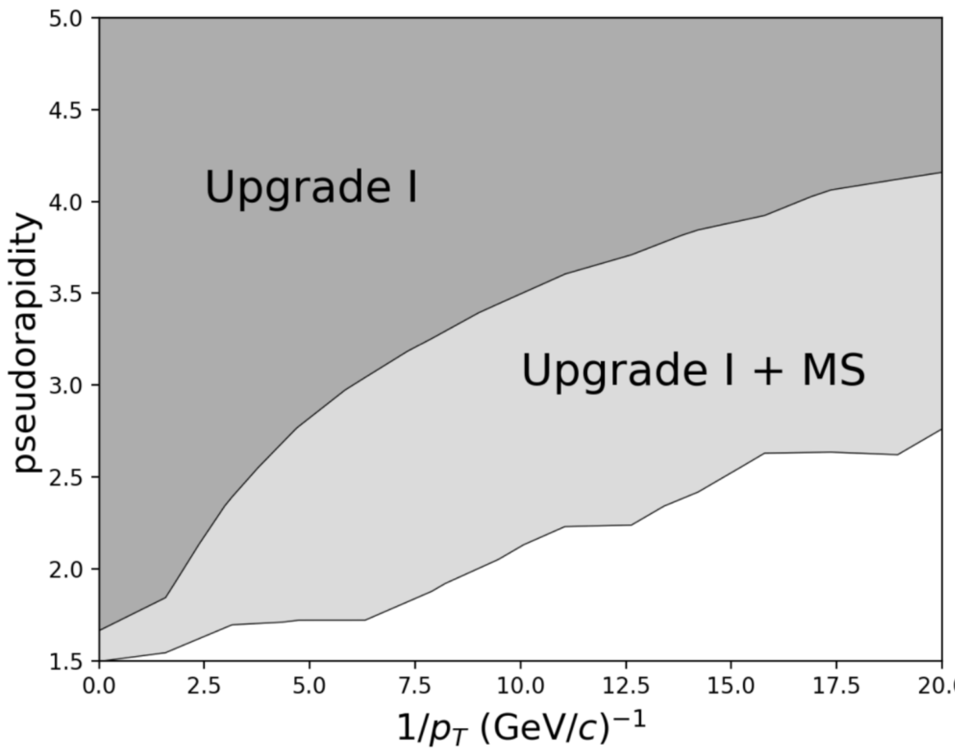
Magnet Station Workshop

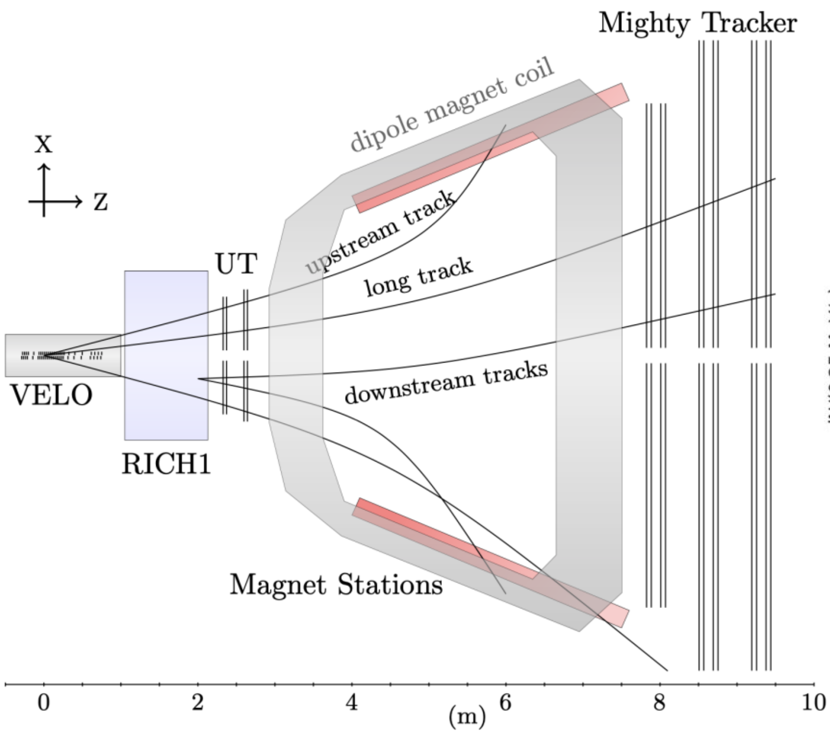
LHCb U2 Tracking

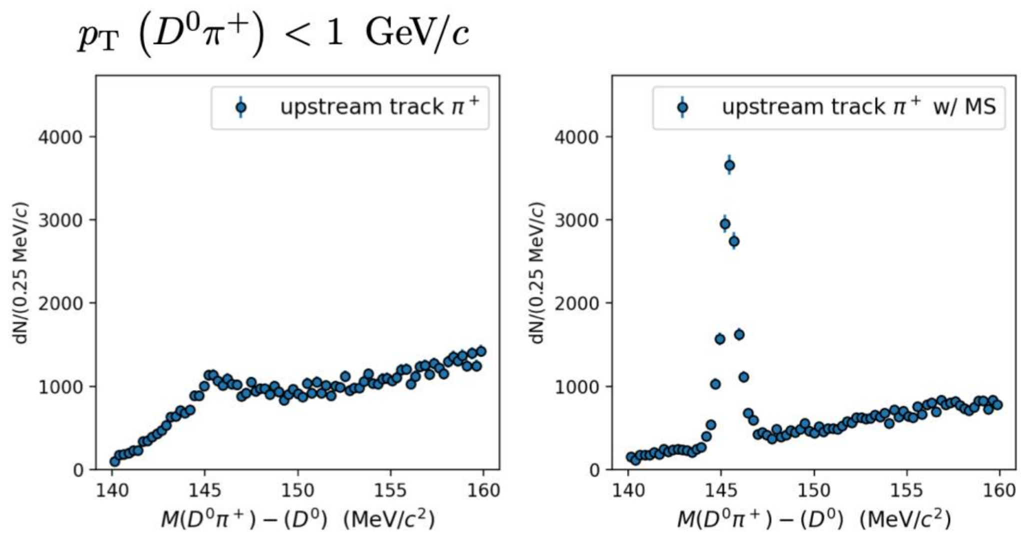




- Magnet Station installation planed to be fully installed in LS3
- Timing information in U2
- What is the physics we might be missing at very low momentum ?

LHCb Tracking

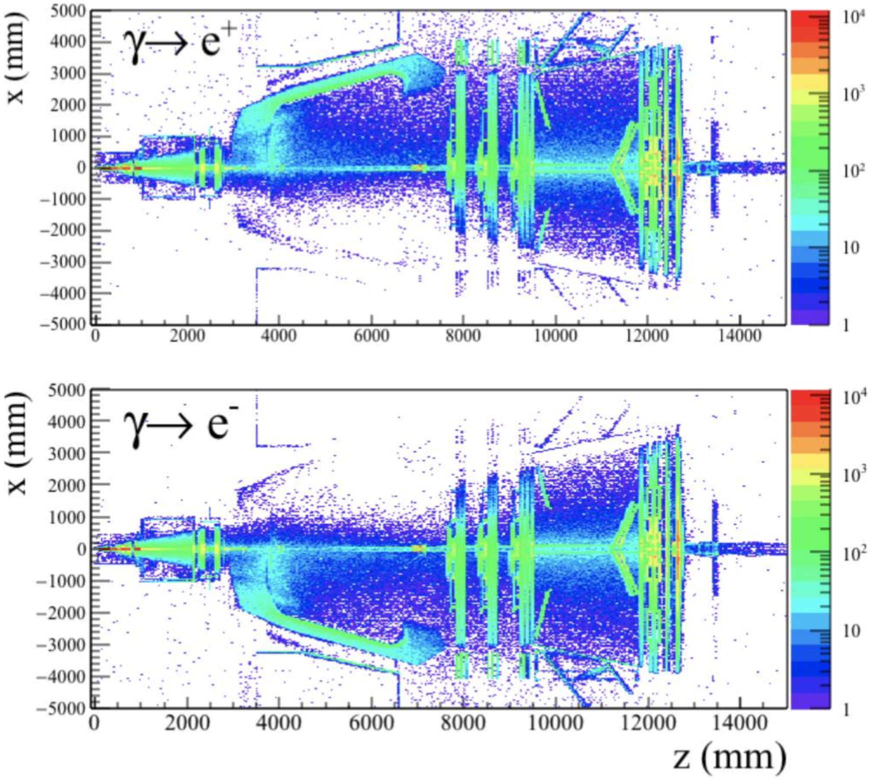




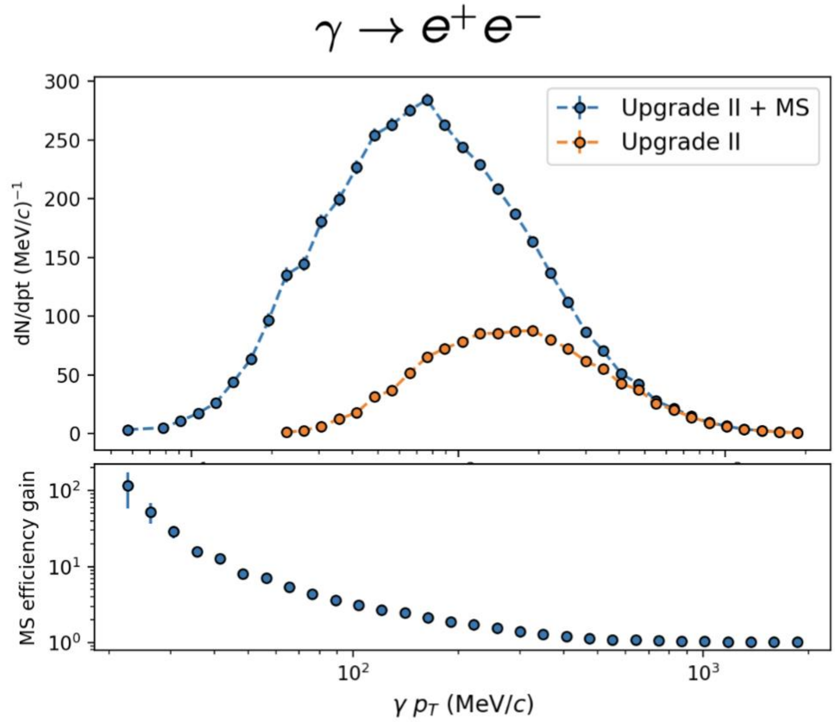
- What is the physics we might be missing at very low momentum ?
- Upstream tracks are available, but momentum resolution will improve with the Magnet Station

Photon Conversion Gain w/ Magnet Station

End point in simulation

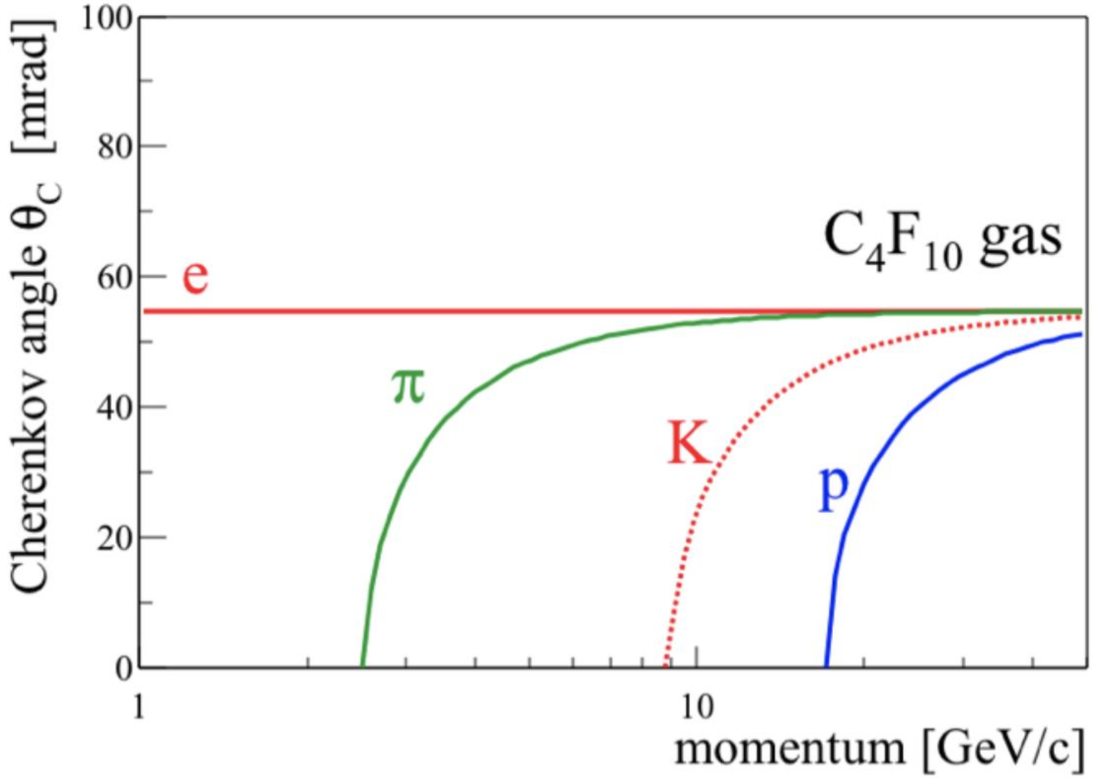


PYTHIA8 MB in LHCb U1 MC



- tracking efficiency gains >4
- enabled photon detection in the sub 100 MeV/c region

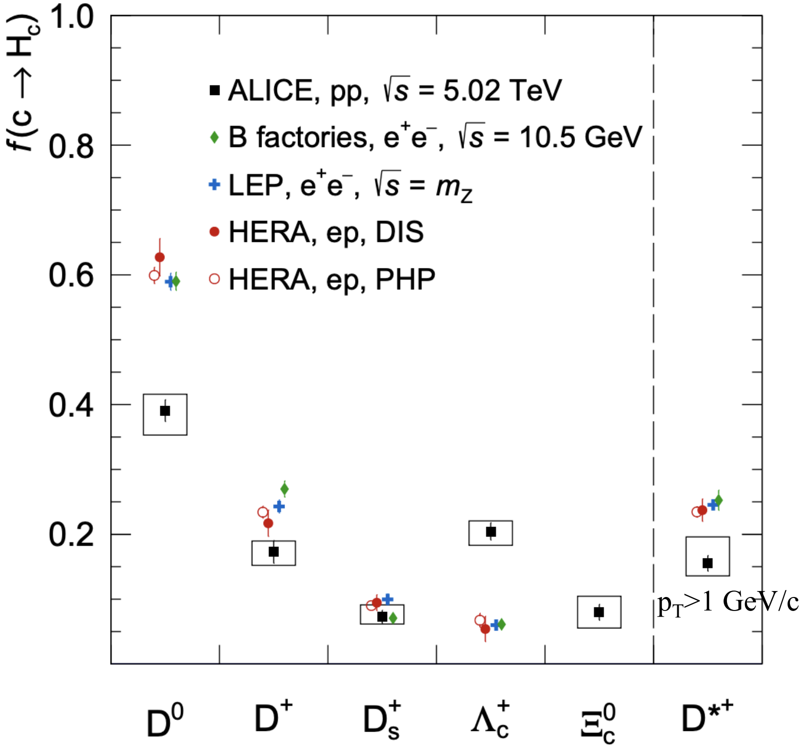
Low-p_T electron identification



- according to the n index of C_4F_{10}, electrons rings are distinct up to $p < 10$ GeV/c in RICH1
- a well defined VELO+UT+MS track will enable electron ID in this region
- additional PID could come from TOF in a LGAD plane in UT

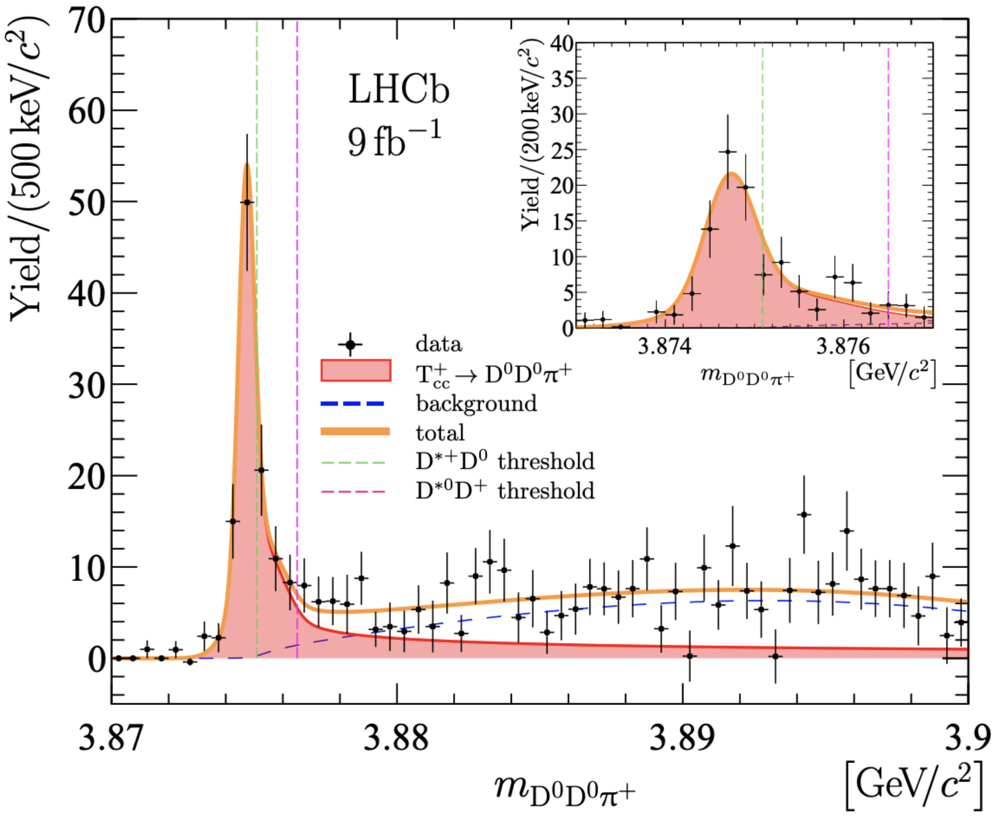
D^*

arXiv:2105.06335v2



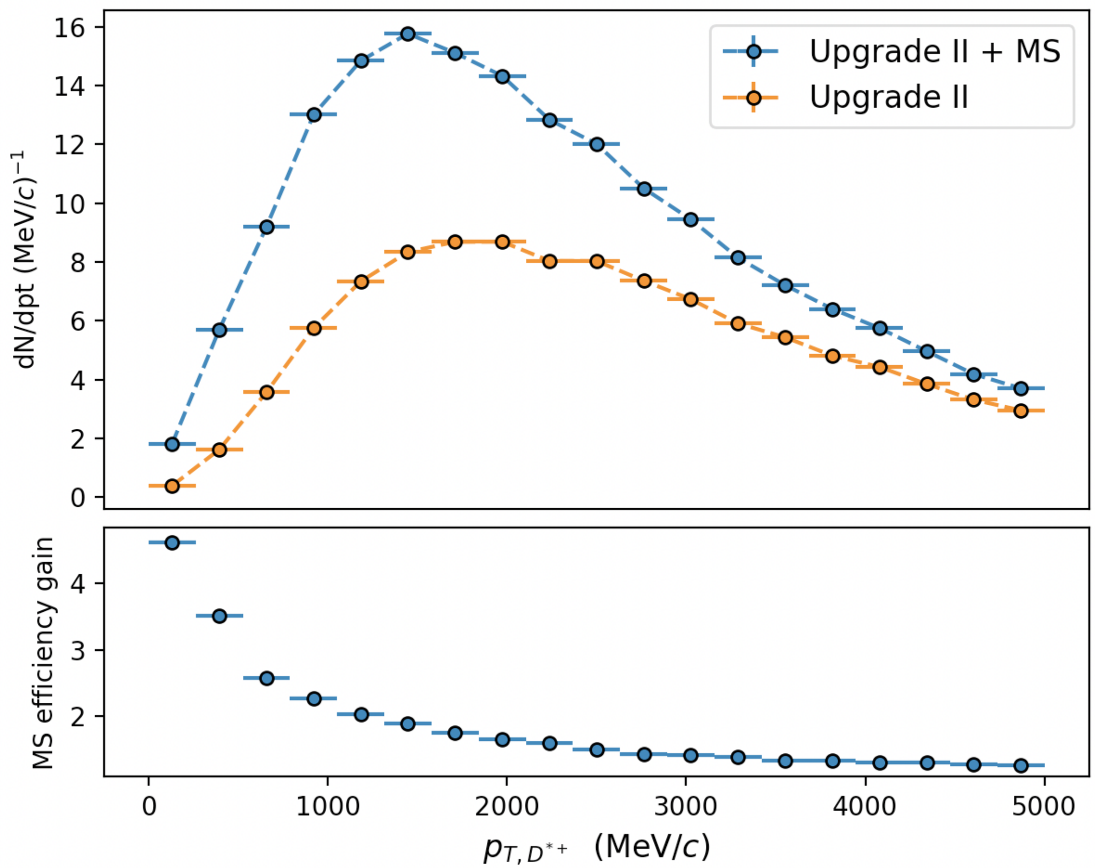
- The D^{*+} meson is depicted separately since its contribution is also included in the ground-state charm mesons
- Suppressed D-mesons and enhanced baryons relative to ep collisions
- What LHCb can do ?
  - Cover D^{*+} at p_T<1 GeV/c
  - Measure fragmentation function z distributions
  - How this affects CP-violation ?
  - How z distributions change in HI ?

D*



- D* is the decay product of many exotic particles
- If exotic particles are produced by coalescence in HI they may preferentially have small p_T

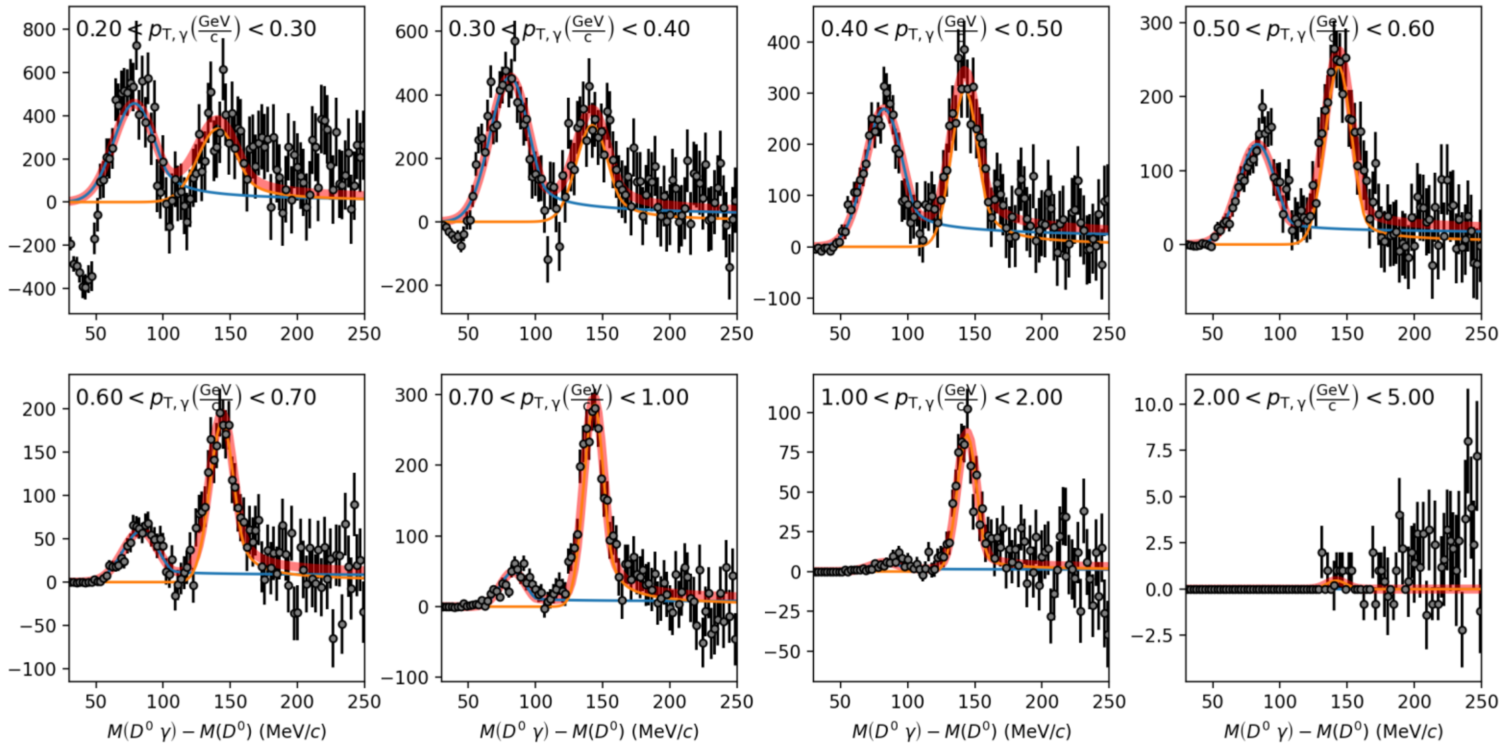
D^{*+}



- large detector efficiency boost for D^{*+} when including upstream tracks

D^{*0}

Real 2016 pPb data after combinatorial background subtraction

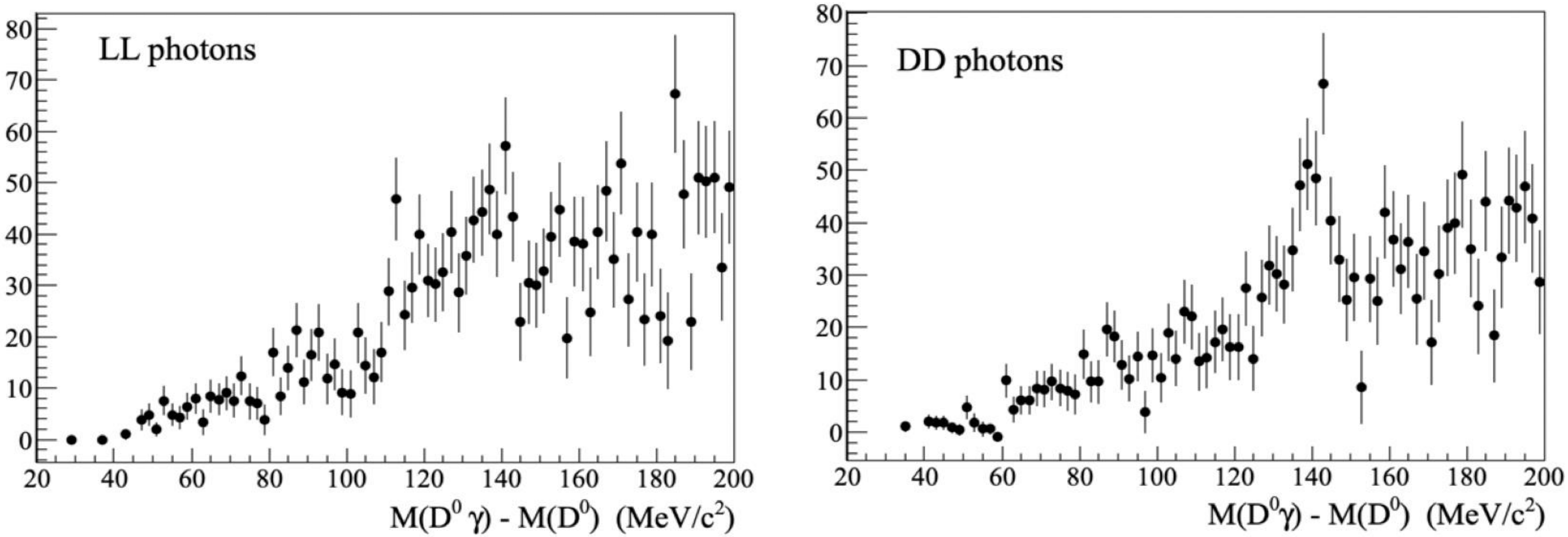


- $D^{*0} \rightarrow D^0(\pi^0 \rightarrow \gamma\gamma_{miss})$ and $D^{*0} \rightarrow D^0\gamma$ peaks after overwhelming combinatorial background subtraction

- Non-converted photon p_T down to 200 MeV !!!

D^{*0}

Real 2016 pPb data converted photons

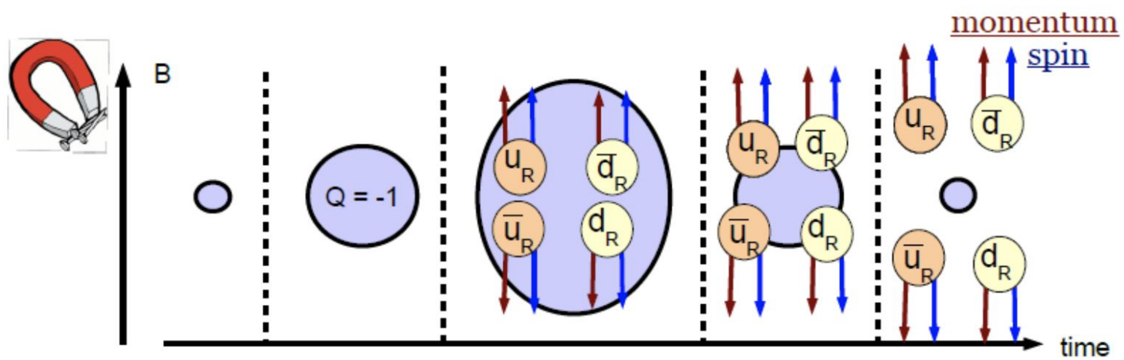


- $D^{*0} \rightarrow D^0(\pi^0 \rightarrow \gamma\gamma_{miss})$ and $D^{*0} \rightarrow D^0\gamma$ peaks after overwhelming combinatorial background subtraction
- Converted photons may help once upstream tracks can be incorporated

Chiral magnetic symmetry

Los Alamos NATIONAL LABORATORY EST. 1943

Topological Charge + Magnetic field =
Chirality + Polarization =



Q < -1: Positively charged particles move parallel to magnetic field, negatively charged antiparallel

... = Electromagnetic Current

P- and CP-odd effect --> Chiral Magnetic Effect: Kharzeev, McLerran & HJW ('08)

D.Kharzeev, L.McLerran, K.Fukushima, H.Warringa,…

10^{18} – 10^{19} Gauss in the early stages of PbPb collisions

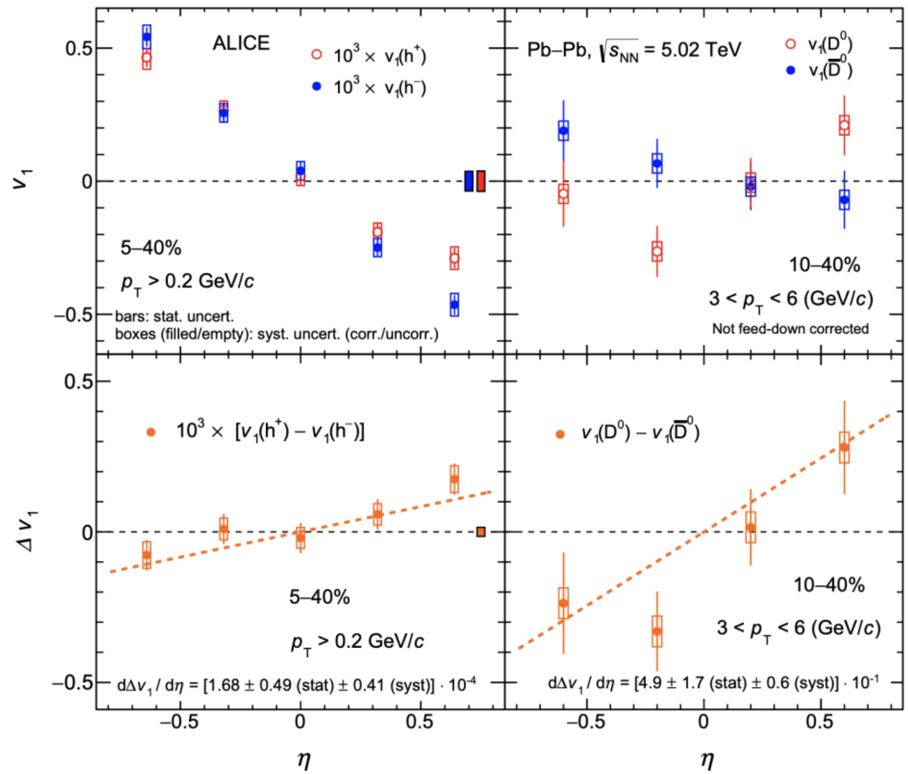
neutron star : 10^{10} – 10^{13} Gauss

magnetar : up to 10^{15} Gauss

Opportunity for monopole search …

Chiral magnetic symmetry

PhysRevLett.125.022301

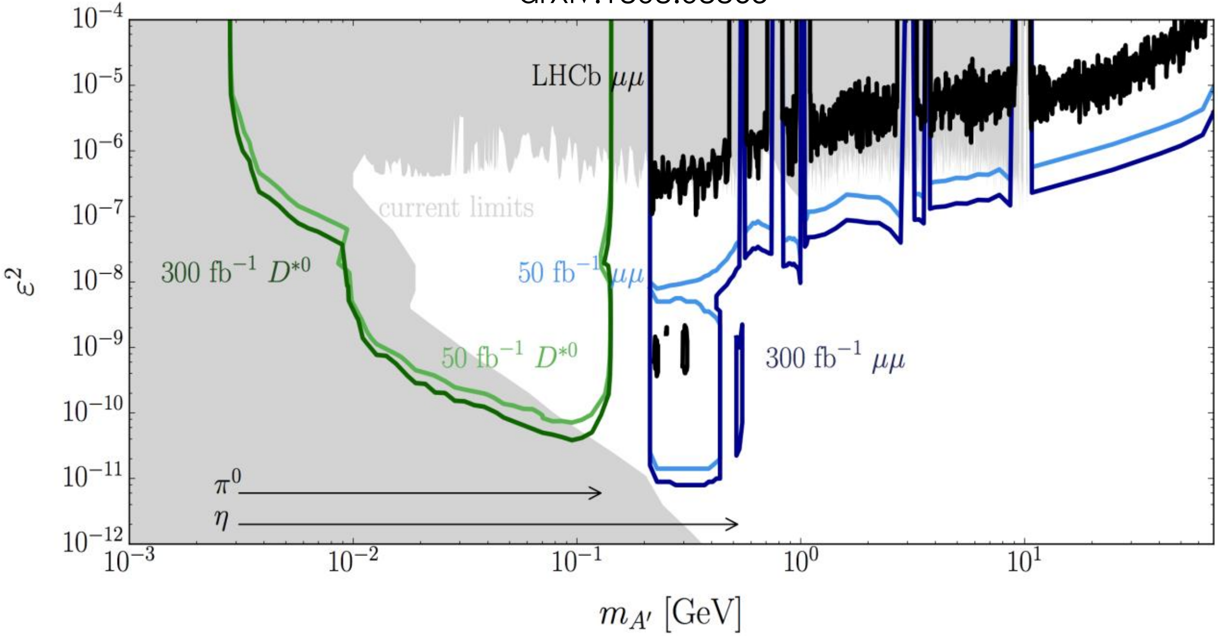


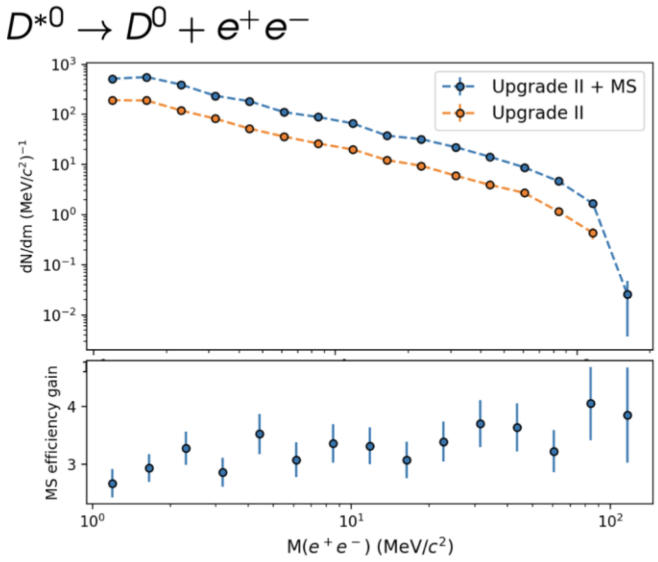
- Signature is the charge asymmetry in the v_1 measurement
- D^0 shows the largest v_1 asymmetry but larger error bars

- Opportunities for LHCb:
  - Asymmetry tends to grow towards large rapidity
  - D^0 oscillation minimizes charge effects in the magnet field
  - D^{*+} has much shorter lifetime. v_1 of its slow pion decay may carry the initial MF effect
  - Comparison with D^{*0} v_1 may confirm (or not) MF effect

Dark Photon Search

arXiv:1808.08865

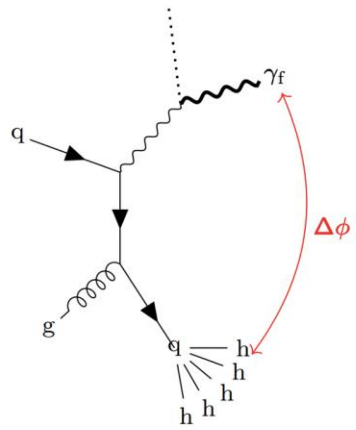


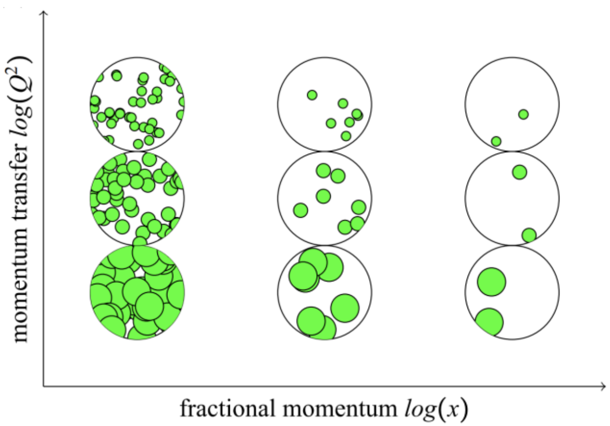


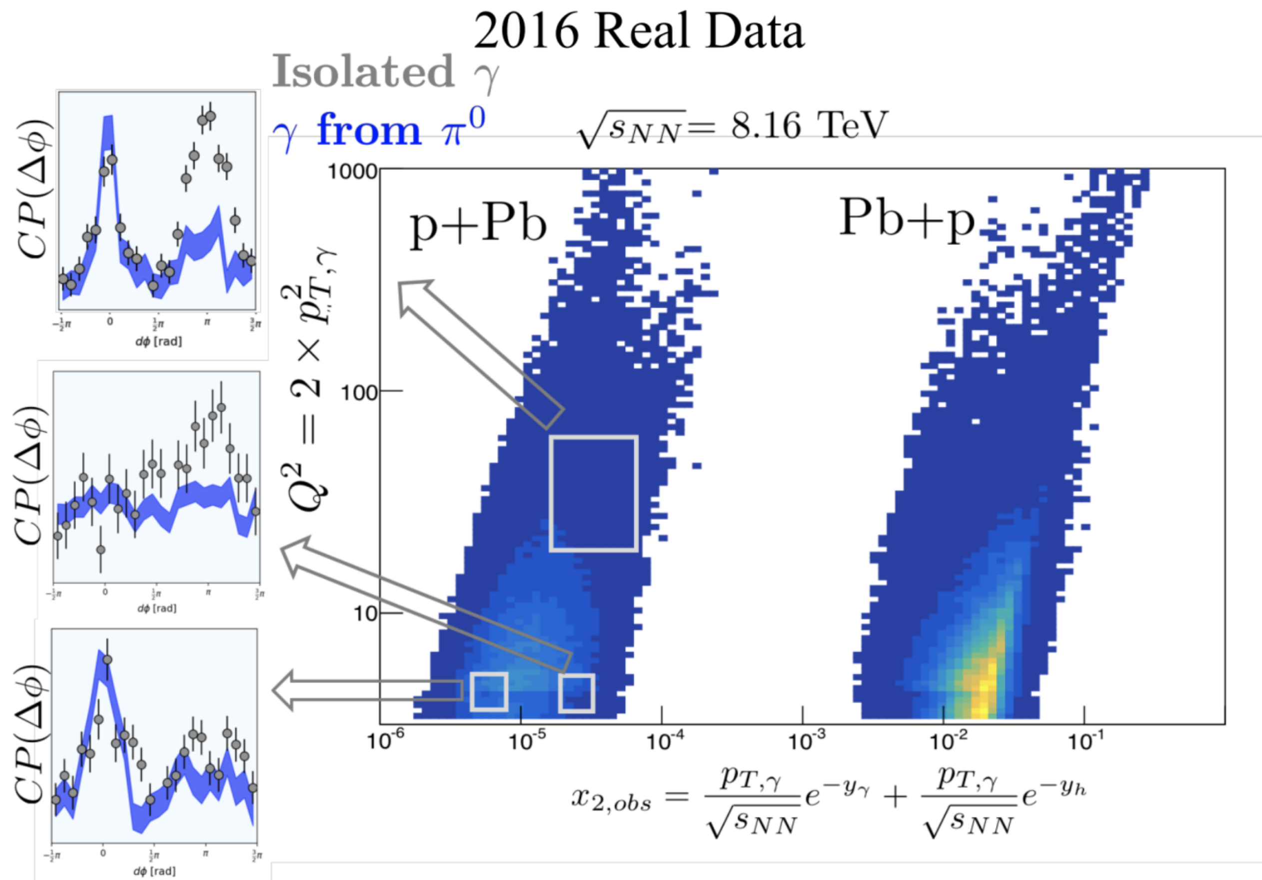
$$D^{*0} \to D^0(A' \to e^+e^-)$$

Dielectron coverage down to O(10 MeV) can cover the gap in dark photon search.
May also try with $\pi^0 \to \gamma(A' \to e^+e^-)$

Gluon Saturation Search

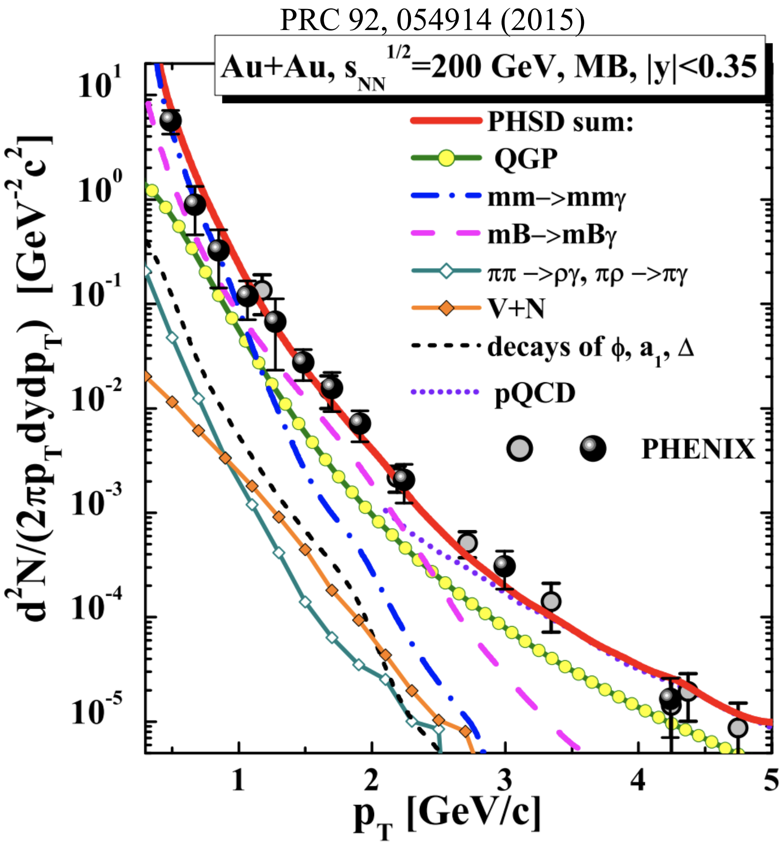


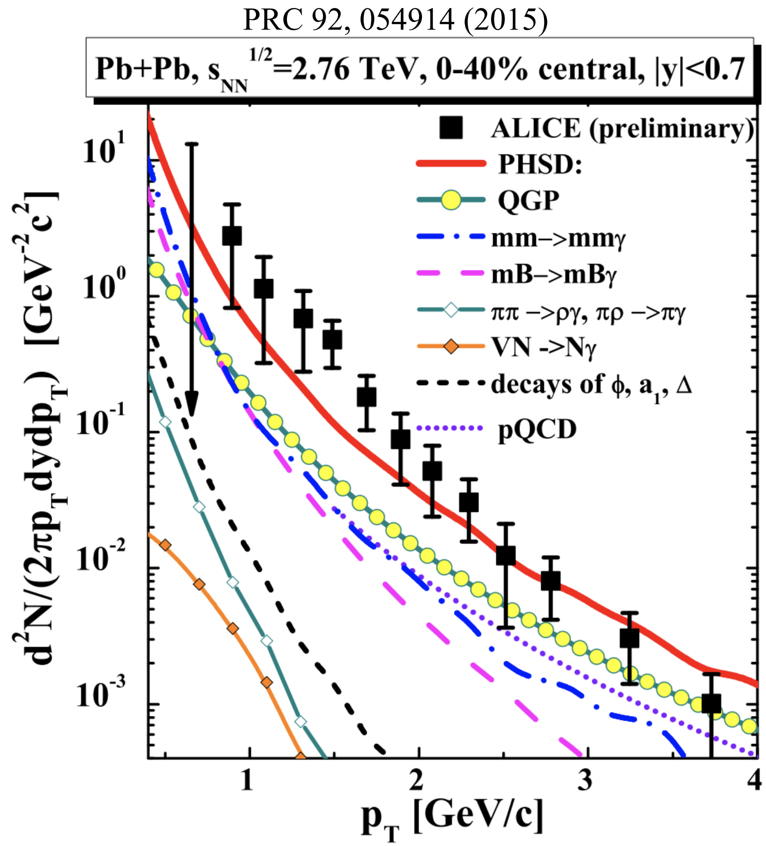




- MS can improve small Q^2 detection efficiency by improving
  - small p_T hadron detection efficiency
  - small p_T photons using conversions

Constraining bremsstrahlung

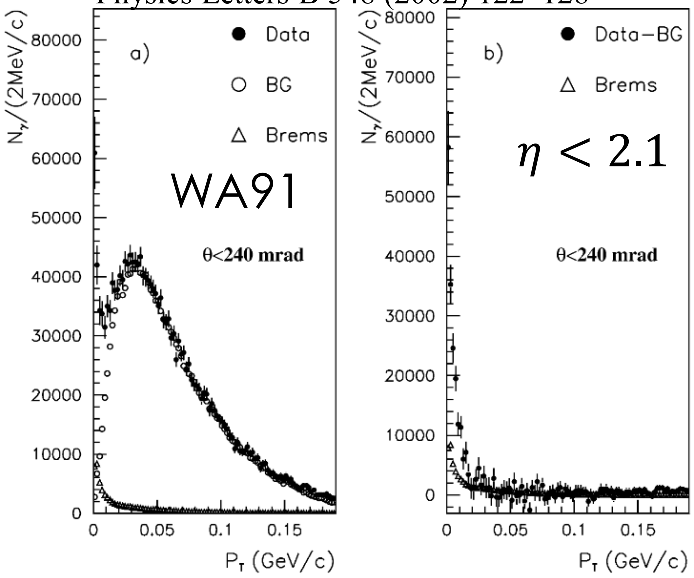




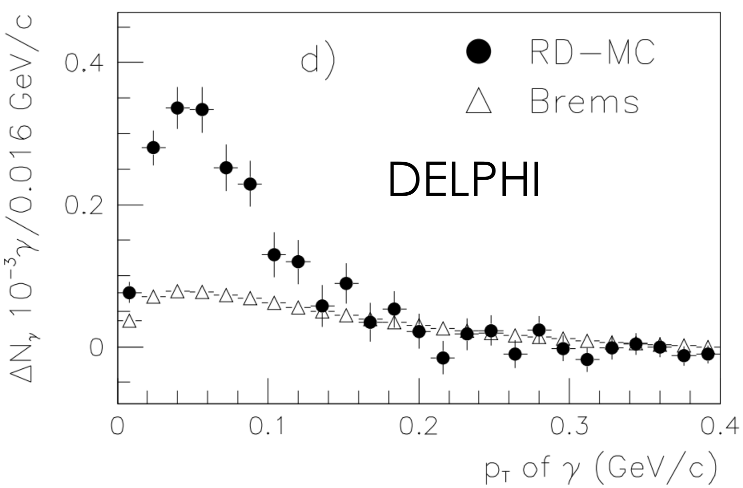
- hadron bremsstrahlung accounts for about 50% of the "thermal" photon yields
- lack of recent soft charged particle data to improve bremsstrahlung background to QGP temperature estimations

Soft Photon excess

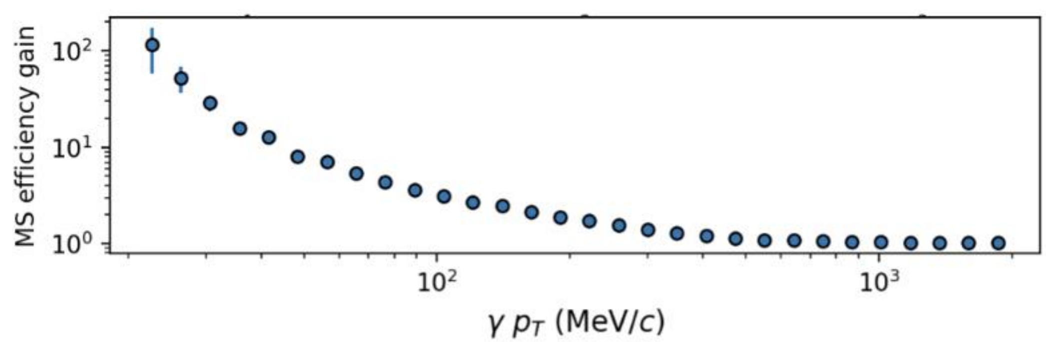
Physics Letters B 548 (2002) 122–128



Eur. Phys. J. C 47, 273–294 (2006



- Soft photon excess observed by many experiments
- Opportunities for LHCb
  - soft charged particle measurements can help the estimations of Brems contribution
  - Needs to reach photons at p_T~10 MeV/c using conversions to be sensitive to the excess



Low theorem is broken ?

PHYSICAL REVIEW VOLUME 110, NUMBER 4 MAY 15, 1958

Bremsstrahlung of Very Low-Energy Quanta in Elementary Particle Collisions

F. E. Low
Department of Physics and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts
(January 29, 1958)

It is shown that the first two terms in the series expansion of the differential bremsstrahlung cross section (in powers of the energy loss) may be calculated exactly in terms of the corresponding elastic amplitude and the electromagnetic constants of the participating particles.

Possible causes of the excess

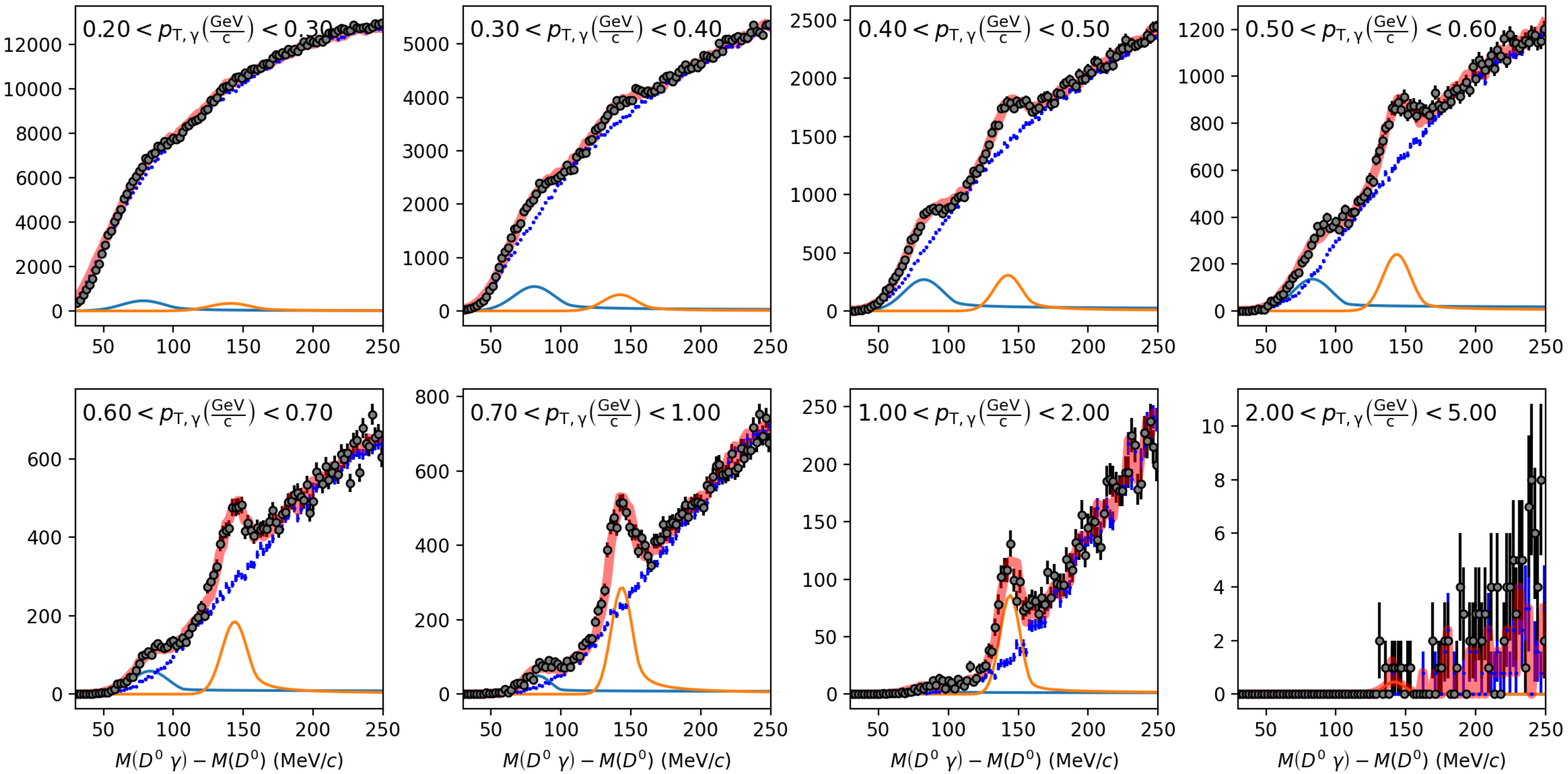
- poor bremsstrahlung estimations because of the lack of soft charged particle measurements
- Non-perturbative QED which would add terms involving magnet charge terms [A.Strominger ,arxiv:1703.05448]
- Axions
- Many more models in the market, see Cheuk-Yin Wong [arxiv:1404.0040], for instance
- Part of the main ALICE program for Run4,5. [arXiv:1902.01211]

Conclusions

- Forward coverage and future use of upstream tracks with the Magnet Station will enable LHCb to pursue soft physics for QCD and BSM studies

- Growing physics opportunities with soft hadrons and photons in LHCb
  - D* physics
    - Charm fragmentation/coalescence studies
    - Exotic search
    - Chiral magnetic symmetry
  - Dark photon search
  - Gluon saturation studies
  - Hadron bremstrahlung for QGP temperature estimations using photons
  - Study of the anomalous soft photon excess

EXTRAS



Simulated $D^{*0} \rightarrow D^0(\pi^0 \rightarrow \gamma\gamma_{miss})$

Simulated $D^{*0} \rightarrow D^0\gamma$

Mixed event