ALICE

THERMAL RADIATION AND DILEPTONS CHAPTER STATUS

Outline:

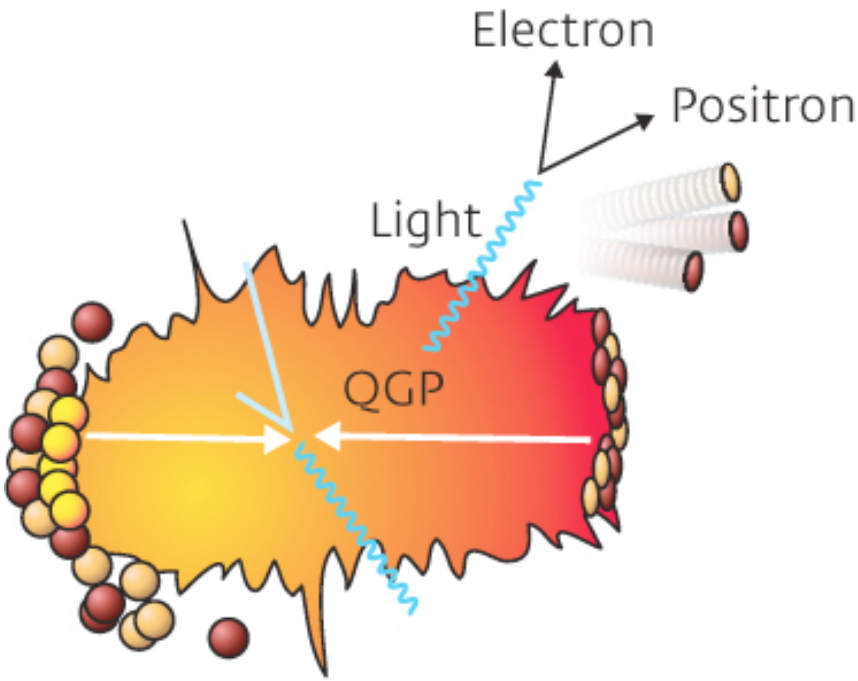
- Reminder: Electromagnetic probes of the QGP
- Disclaimer
- Status
- Figures / place holders

MICHAEL WEBER (SMI)
ON BEHALF OF THE «PHOTON AND DILEPTON» SUBGROUP
20.06.2018

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

FTE NATIONALSTIFTUNG FORSCHUNG | TECHNOLOGIE | ENTWICKLUNG

ELECTROMAGNETIC PROBES OF THE QGP



Photons: measure γ (Calo, PCM)
Dileptons: measure e^+e^- or $\mu^+\mu^-$ pairs

- Couple to **EM current**
- **very low interaction** with QCD medium (no strong interaction)

- **Sensitive to**
  Photons:
  - Thermal radiation

  Dileptons:
  - Thermal radiation
  - Vector meson spectral shape
  - Beyond SM particles with $J^{PC}=1^{--}$ (e.g. dark photons)

Dilepton emission rate in thermal equilibrium:

$$\frac{\mathrm{d}N_{ll}}{\mathrm{d}^4x\mathrm{d}^4q} = -\frac{\alpha^2}{3\pi^3}\frac{L(M^2)}{M^2}\,\mathrm{Im}\,\Pi^{\mu}_{\mathrm{em},\mu}(M,q;\mu_B,T) \times f^B(q_0;T)\ ,$$

DISCLAIMER

- No update on expected performance in this report
  - See next slide
- All figures are place holders:
  - Will either be kept (from ALICE upgrade documents)
  - Or updated with new simulations (if available in time)
- Chapter for yellow report in preparation
  - https://gitlab.cern.ch/miweber/HLLHC-WG5-photons-dileptons
  - Structure, titles, etc. might still change though

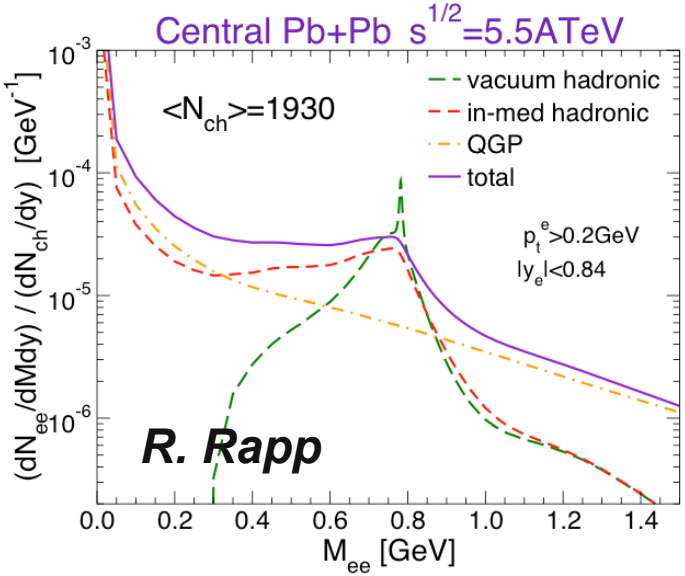
YELLOW REPORT STATUS

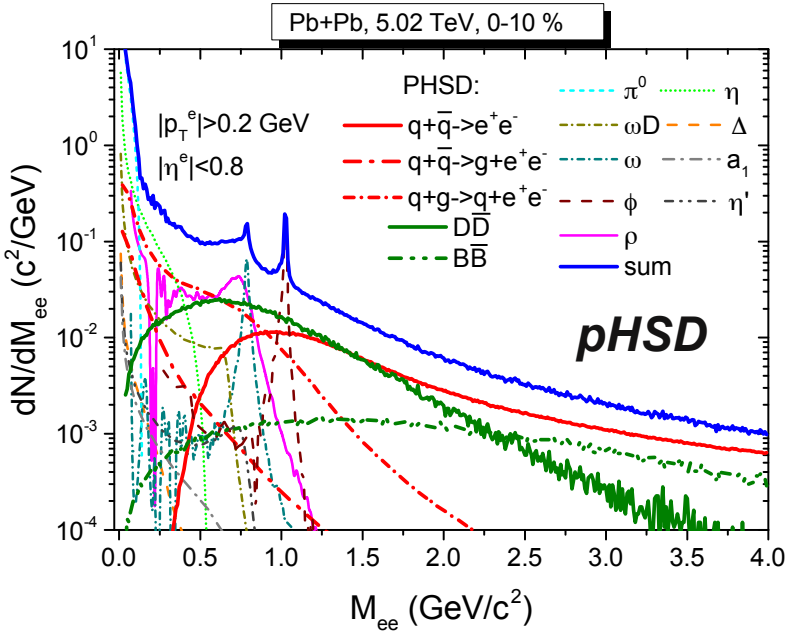
	Photons	Dielectrons	Dimuons
Spectra	No projections yet	ALICE LoI Fast simulation	ALICE LoI Improved heavy flavour systematics/ lower p_T threshold
Temperature	No projections yet	ALICE LoI Fast simulation	See above
Flow	No projections yet	ALICE LoI Fast simulation	?
Other	Comparison to virtual photon method	DCA method; Dark photons, Peripheral collisions	Peripheral collisions

Available
In preparation
Not for yellow report?

GIT: *https://gitlab.cern.ch/miweber/HLLHC-WG5-photons-dileptons*
Mailing list: *hllhc-wg5-photons-dileptons@cern.ch*

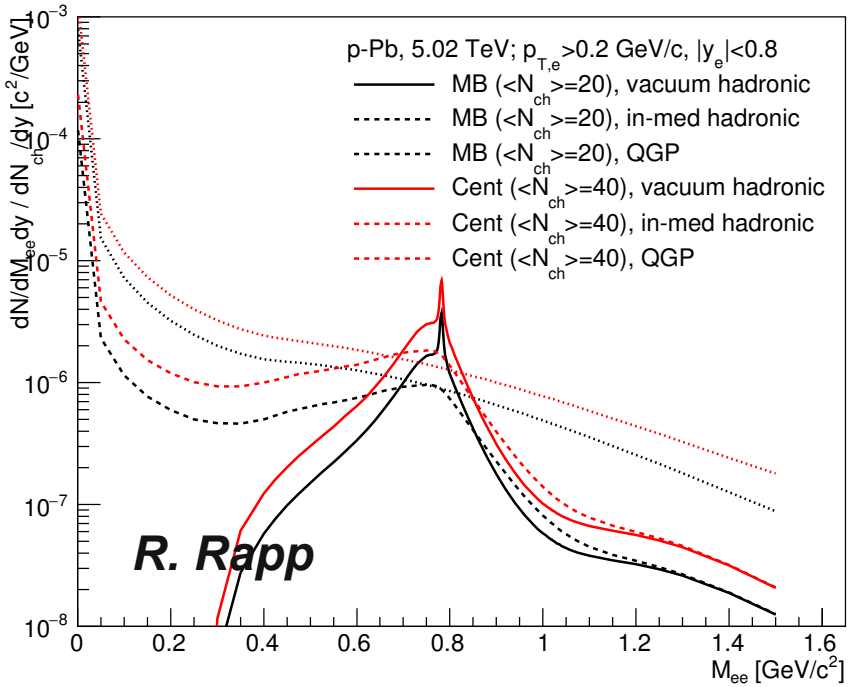
INTRODUCTION/THEORY

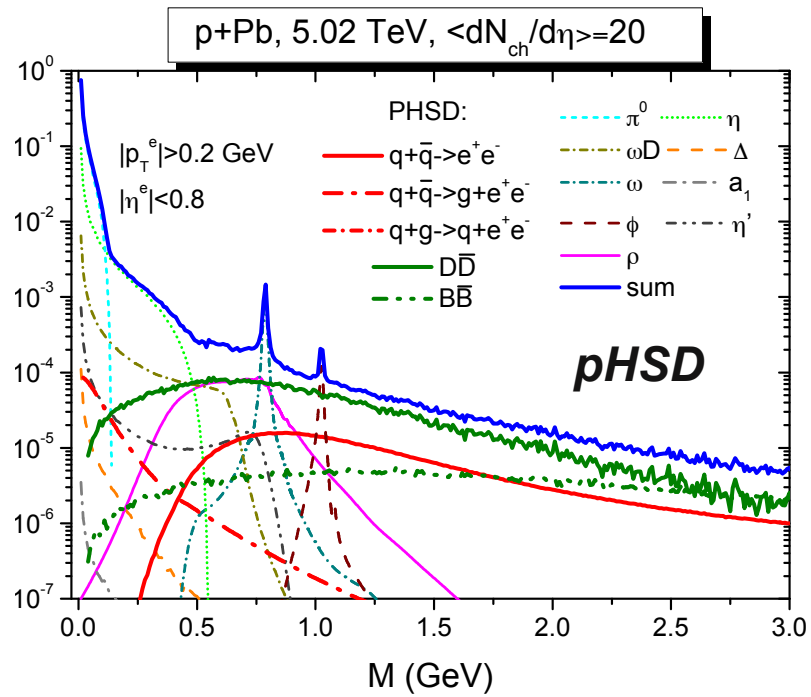




- Fireball model: Ralf Rapp
- Transport model: pHSD
- Flow (together with bulk observables): constraints on fundamental properties of the medium (e.g. transport coefficients) as well as its "initial conditions" or "pre-equilibrium" dynamics
- Lattice QCD, electromagnetic conductivity, directly comparable at LHC energies, discuss new developments in the next years
- **New input:** Functional Renormalization Group, see e.g. QM 2018

SMALL SYSTEMS/LIGHT IONS





- Estimates for thermal radiation with dileptons in “small systems” chapter
  - **ToDo:** use a scaled signal strength from models in p-Pb collisions and extract sensitivity
- **Open question:** systematic uncertainty form theory, especially are those models applicable at all?
- **Additional:** expectation for light ions (e.g. Ar-Ar)?

Also other calculations available:
e.g. Jean-Francois Paquet et al., Physical Review C 95 014906 (2017)

PHOTONS

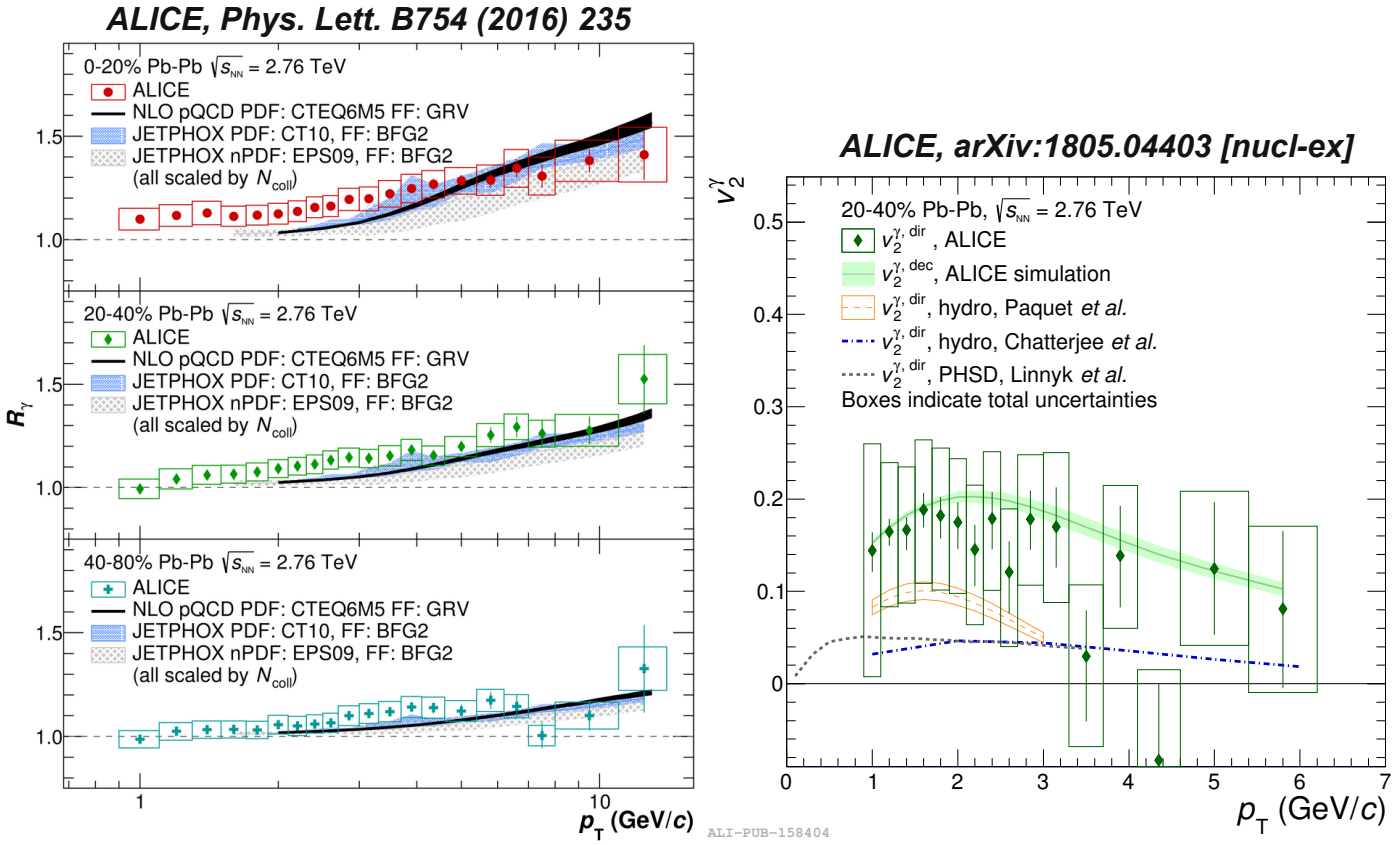


Fig. 3: Placeholder: Measurements of photon spectra (R_γ) and flow

- Soft exponential component of photon p_T spectrum: **T~300 MeV**
- Direct photon elliptic flow: **v_2 > 0**
- **ToDo:** Future measurement (Run3/4): **reduce stat./syst. uncertainty (material budget)**

DILEPTONS - SPECTRA

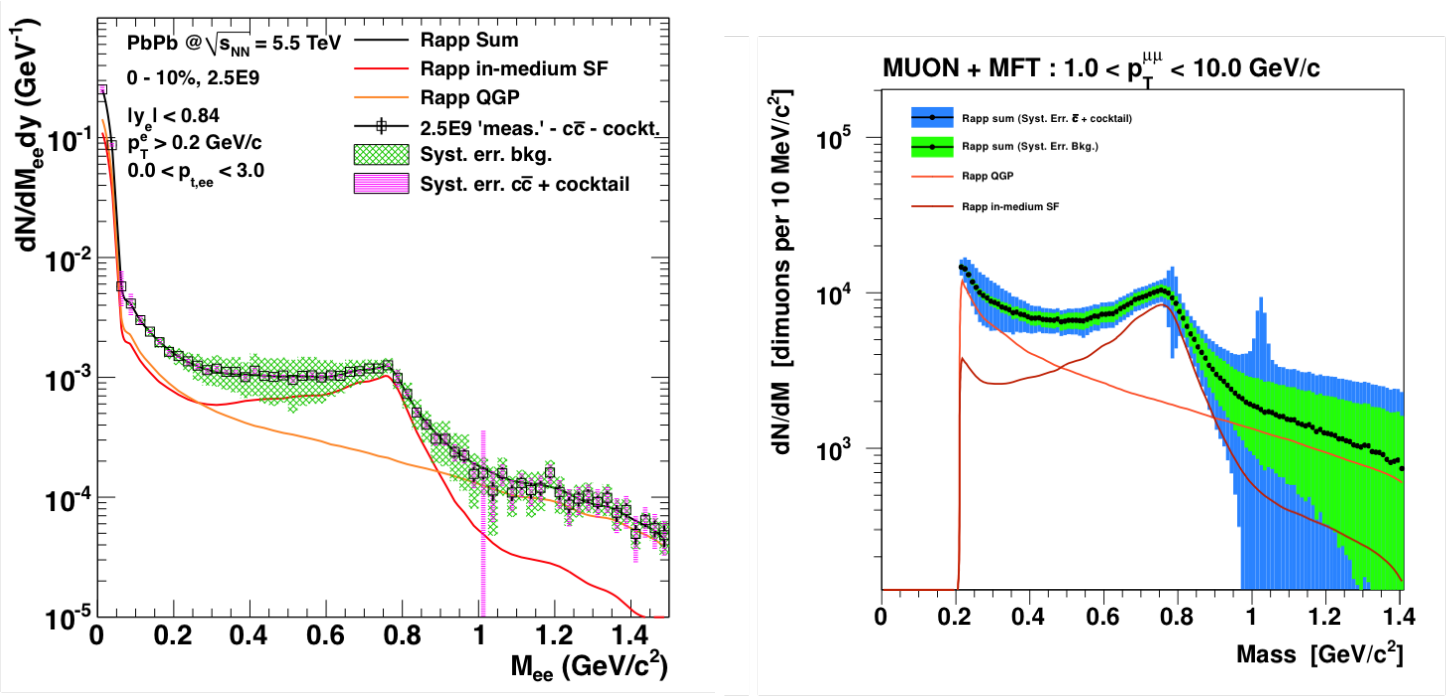


Fig. 4: Placeholder: Expected performance for invariant mass spectra for dielectrons and dimuons

- Low mass spectral function with **~20% uncertainty**
- **ToDo:** Results from fast/full simulation with more realistic geometry and photon conversion in preparation
- Thermal radiation for dimuons (M > 1GeV/c^2) difficult due to large heavy-flavour (HF) systematic uncertainty

DILEPTONS – TEMPERATURE AND FLOW

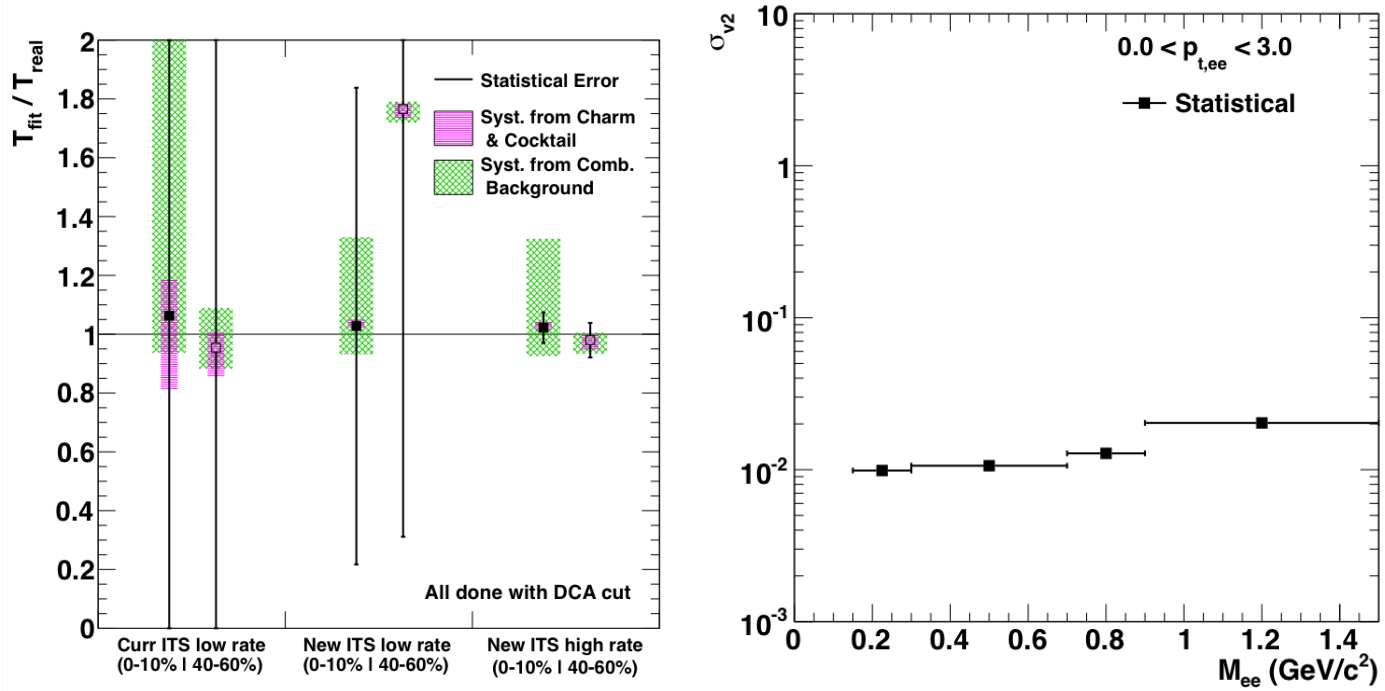


Fig. 5: Placeholder: Expected performance for dielectron temperature and flow

- Temperature and flow with **~10%** uncertainty
- **ToDo:** Results from fast/full simulation with more realistic geometry and photon conversion in preparation
- **Additional:** determine HF yield via multidimensional fit (as for pp publications) -> reduce syst. uncertainty, estimate requirement in statistics

PLANNED UPDATES

- **Photons:**
  - Improvement in stat. and syst. uncertainties (main source: material budget uncertainty)

- **Dielectrons – fast/full simulation:**
  - Updated geometry of Inner Tracking System with full reconstruction of central Pb-Pb collision events
    - Conversion electrons → Signal-to-Background ratio
    - Combinatorial background → Signal-to-Background ratio
    - Pointing resolution → HF rejection/subtraction
    - DCA Template fits → HF rejection/subtraction
  - Updated systematic uncertainties
    - Signal extraction/combinatorial background
    - HF rejection/subtraction

PERIPHERAL COLLISIONS

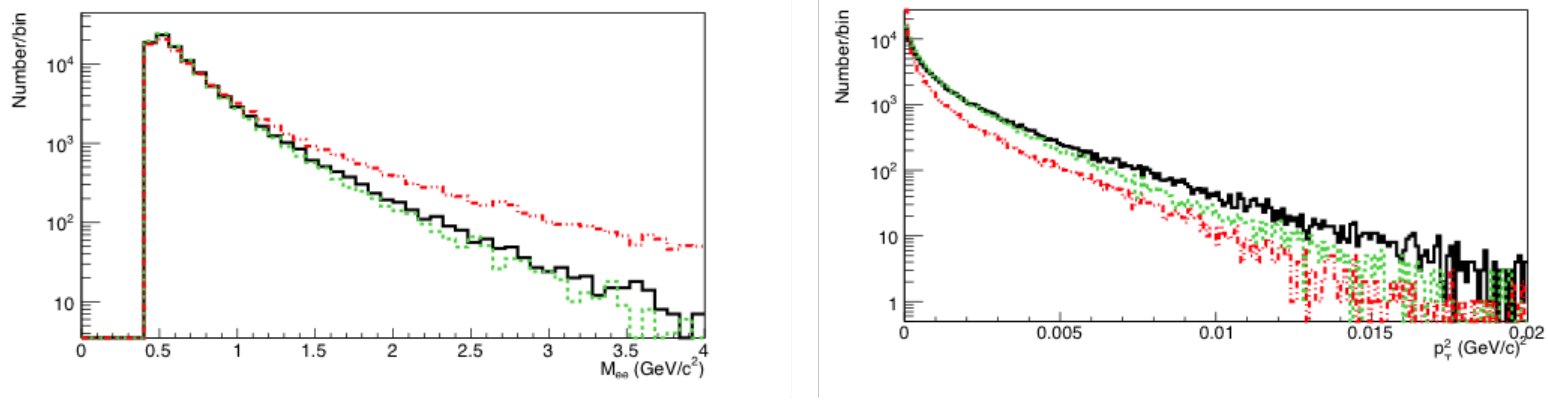


Fig. 7: Placeholder: Expected performance for invariant mass measurement in peripheral collisions

- Excess of dilepton pairs with p_T < 100 MeV/c in peripheral heavy ion collisions
  - STAR sees J/ψ + a mass continuum
  - ALICE sees only J/ψ
- Rate and kinematics are consistent with expectations from coherent photoproduction and $\gamma\gamma \rightarrow l^+l^-$ (***S. Klein, Phys. Rev. C97, 054903 (2018)***)
- **New:** ATLAS results (QM2018) on two-photon production of dimuons, evidence for an in-medium effect?
- **ToDo:** Expectations for LHC (ALICE acceptance) in Run3/4 in preparation

DARK PHOTONS

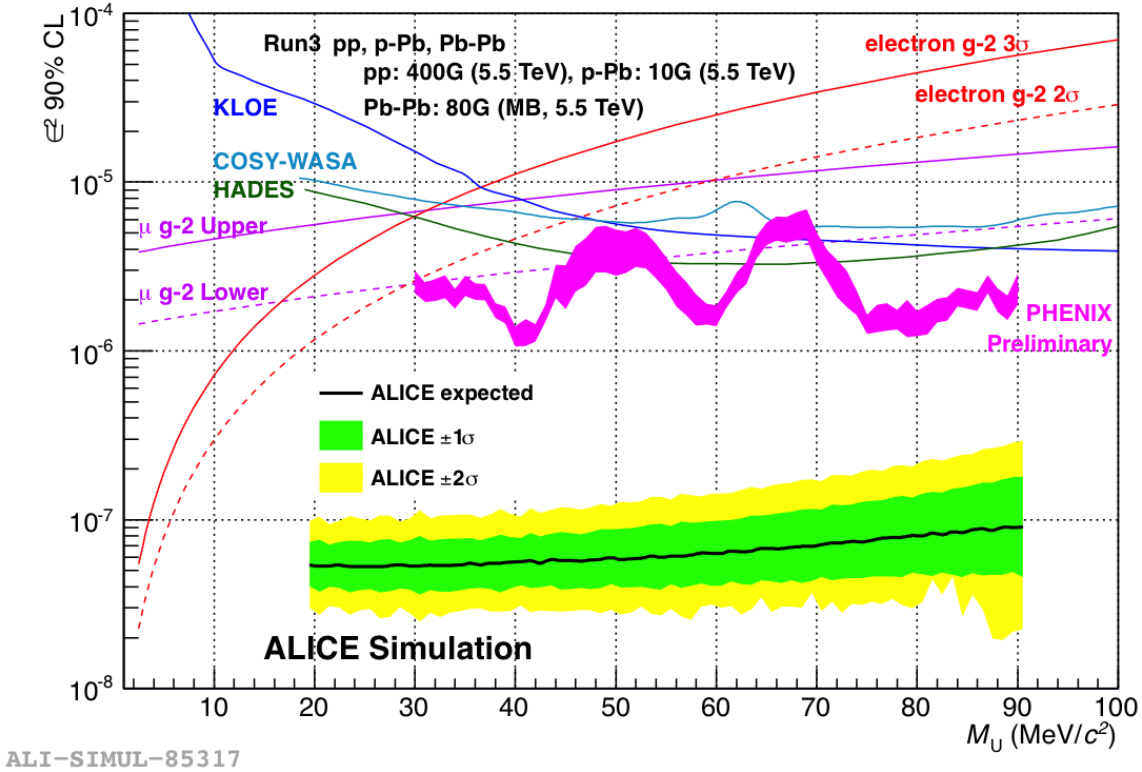


Fig. 6: Placeholder: Expected performance for dark photon limits

- Preliminary Run1 results from ALICE
- **ToDo:** Missing updated projections for Run 3/4
- **Open question:** Overlap with "Dark WG"? Divide expectations in Pb-Pb/p-Pb and pp collisions?

LUMINOSITY REQUIREMENTS

Used so far in current estimates:

- Pb-Pb:
  - Dielectrons: 3 nb^{-1} with B=0.2T (instead of B=0.5T)
  - Dimuons: 10 nb^{-1}
- p-Pb:
  - Dielectrons (very simple estimate): 50 nb^{-1}
- pp:
  - No estimate (yet)
  - Could compare to Run 2 results (as for simple estimate p-Pb):
    - $L_{MB} = 7.87 \pm 0.40\ nb^{-1}$
    - $L_{HM} = 2.79 \pm 0.15\ pb^{-1}$

LUMINOSITY REQUIREMENTS

Used so far in current estimates:

First results for B=0.2 T presented at QM2018

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INSTEAD OF A SUMMARY

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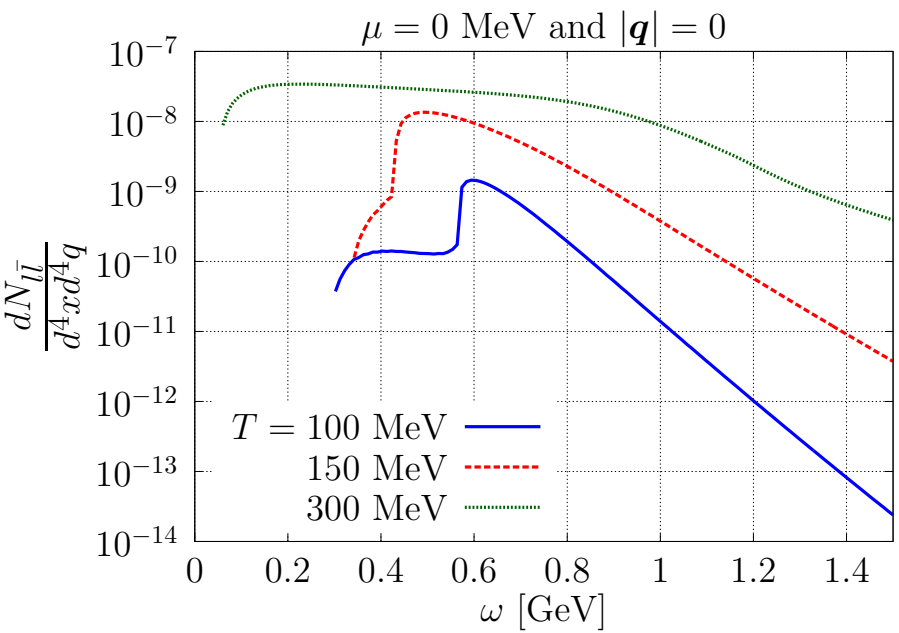
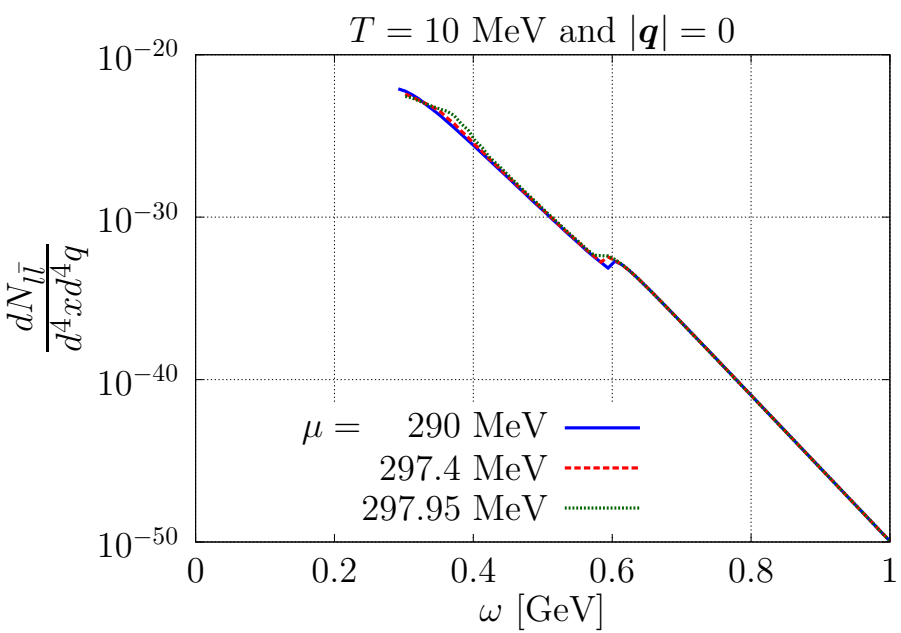
BACKUP

Dilepton rates - preliminary





- clear changes are visible with increasing temperature
- no distinct signatures for the critical endpoint yet $\rightarrow$ improve truncation

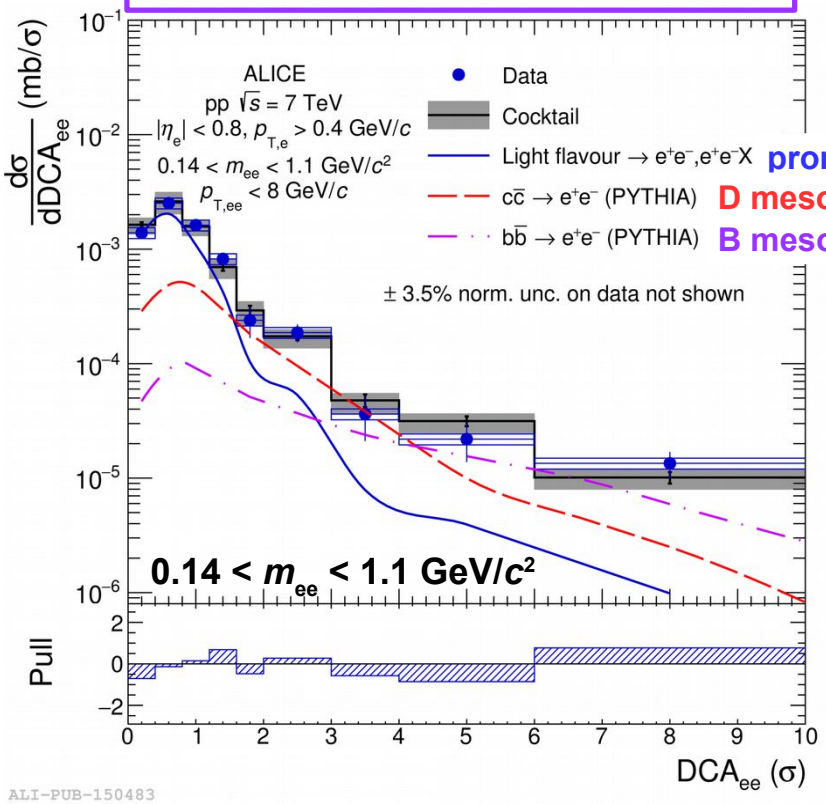
R. Tripolt, QM 2018

DCA_{ee} analysis in pp collisions at $\sqrt{s}$ = 7 TeV

S.Scheid
ELW-25

ALICE

arXiv:1805.04391 [hep-ex]
submitted to JHEP



prompt

D mesons: $c\tau \approx 150$ μm

B mesons: $c\tau \approx 470$ μm

Observable: $$\mathrm{DCA_{ee}} = \sqrt{\frac{(\mathrm{DCA}_1/\sigma_1)^2 + (\mathrm{DCA}_2/\sigma_2)^2}{2}}$$

DCA = Distance-Of-Closest-Approach to primary vertex of $e^{\pm}$
σ = DCA resolution for $e^{\pm}$

→ Can separate prompt and non-prompt sources with DCA_{ee} (Useful in Pb-Pb to study the origin of possible enhancement)

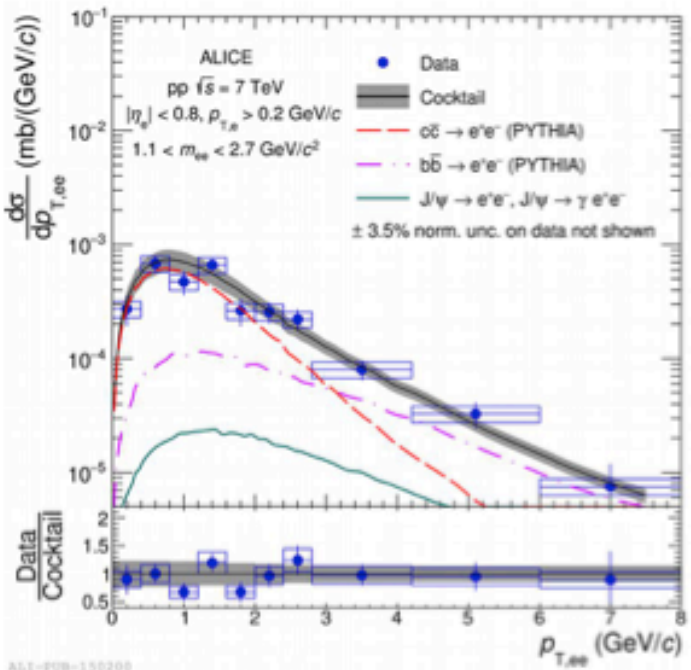
DCA_{ee} resolution better in Run-3 → higher separation power

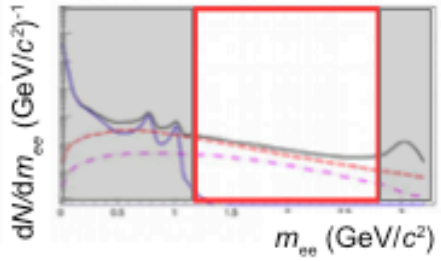
R. Bailhache, QM 2018

$p_{T,ee}$ and DCA_{ee} analyses in pp collisions at $\sqrt{s}$ = 7 TeV

arXiv:1805.04391 [hep-ex]
submitted to JHEP

$p_{T,ee}$ spectrum



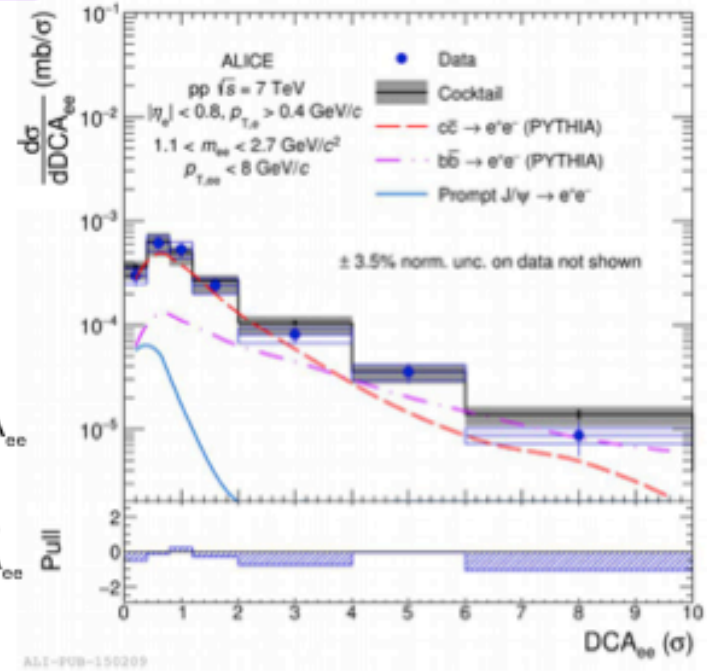


Intermediate-mass region

Charm dominates at low $p_{T,ee}$ ($p_{T,ee}$ < 3 GeV/c) and small DCA_{ee}

Beauty dominates at large $p_{T,ee}$ ($p_{T,ee}$ > 4 GeV/c) and large DCA_{ee}

DCA_{ee} spectrum



→ Let the normalization of the $c\bar{c}$ and $b\bar{b}$ contributions free in the cocktail
→ Fit $m_{ee}/p_{T,ee}$ and DCA_{ee} spectra independently to extract the $\sigma_{c\bar{c}}$ and $\sigma_{b\bar{b}}$ cross sections

S.Scheid
ELW-25

R. Bailhache, QM 2018

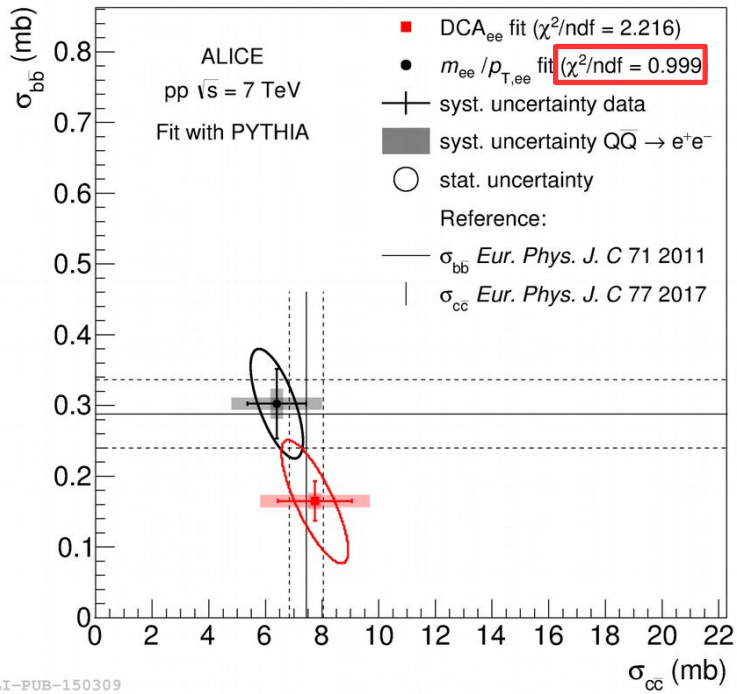
Model dependences

arXiv:1805.04391 [hep-ex]
submitted to JHEP

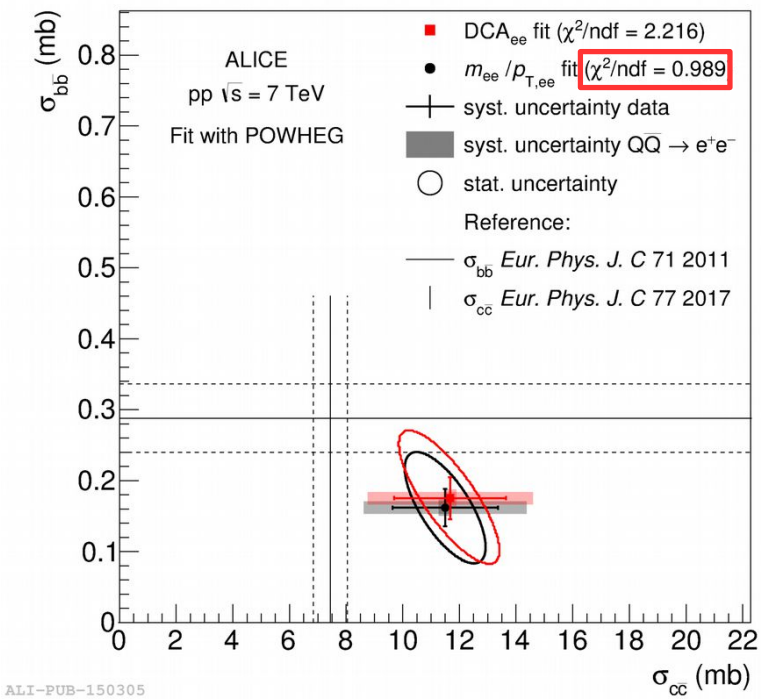
S.Scheid
ELW-25

ALICE

PYTHIA 6 Perugia 2011 tune (LO with parton shower)

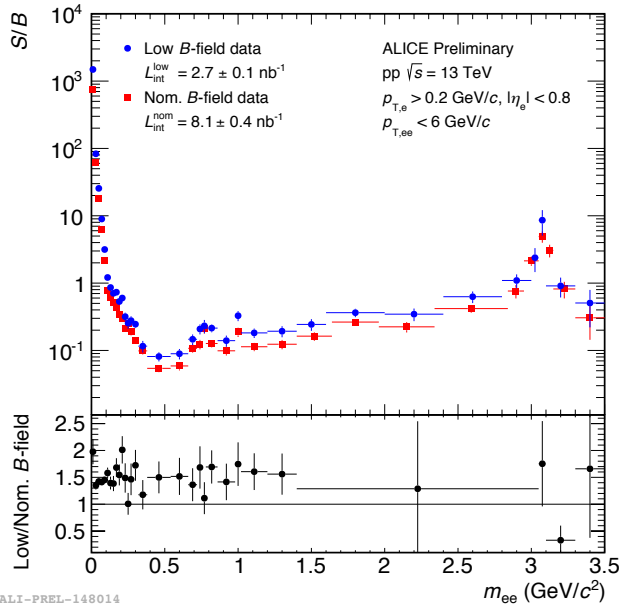


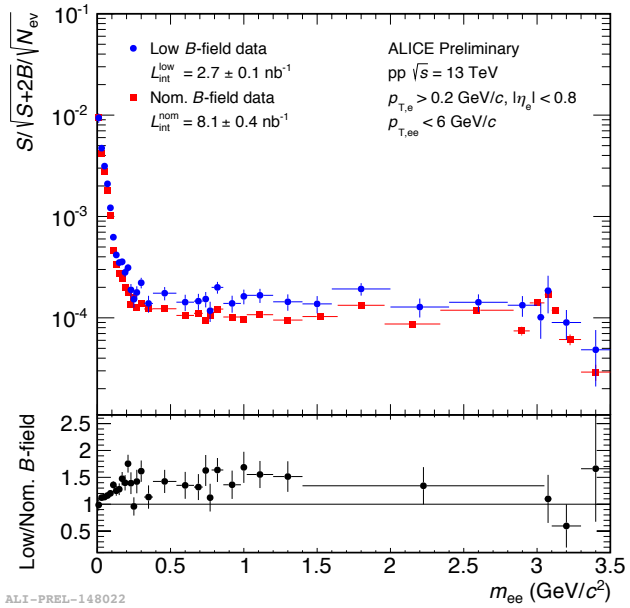
POWHEG (NLO) + PYTHIA 6 parton shower

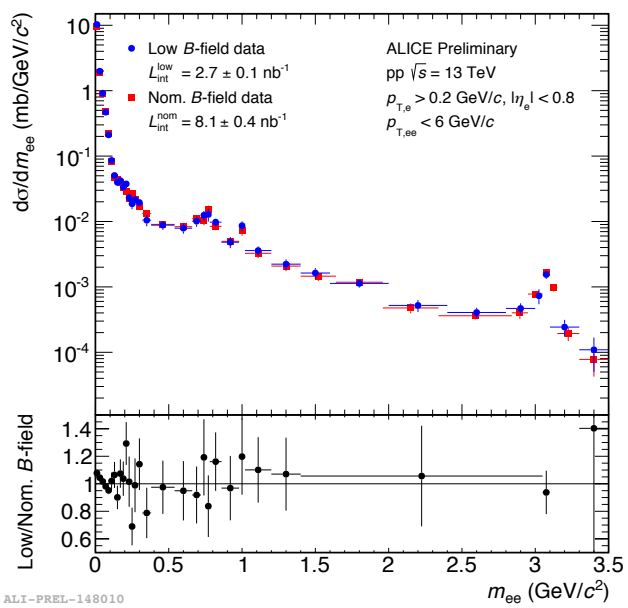


Significant model dependence of the extracted $\sigma_{c\bar{c}}$ and $\sigma_{b\bar{b}}$
Sensitivity to the different implementation of heavy-quark production mechanisms

LOW B FIELD RESULTS



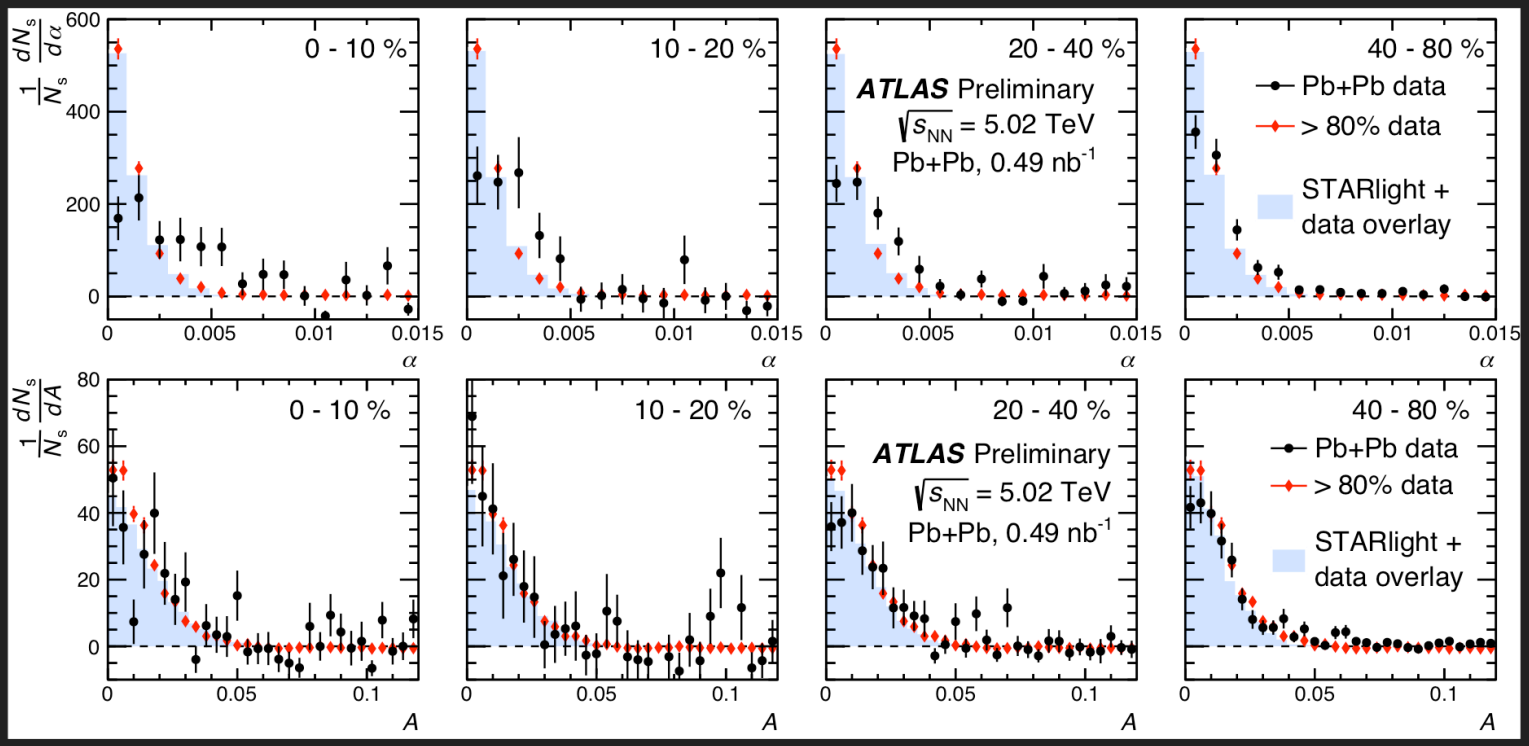




- B=0.2T compared to B=0.5T (pp collisions, 13 TeV)
- Higher signal-to-background ratio and significance
- Consistent dielectron cross section

J. Jung, QM 2018

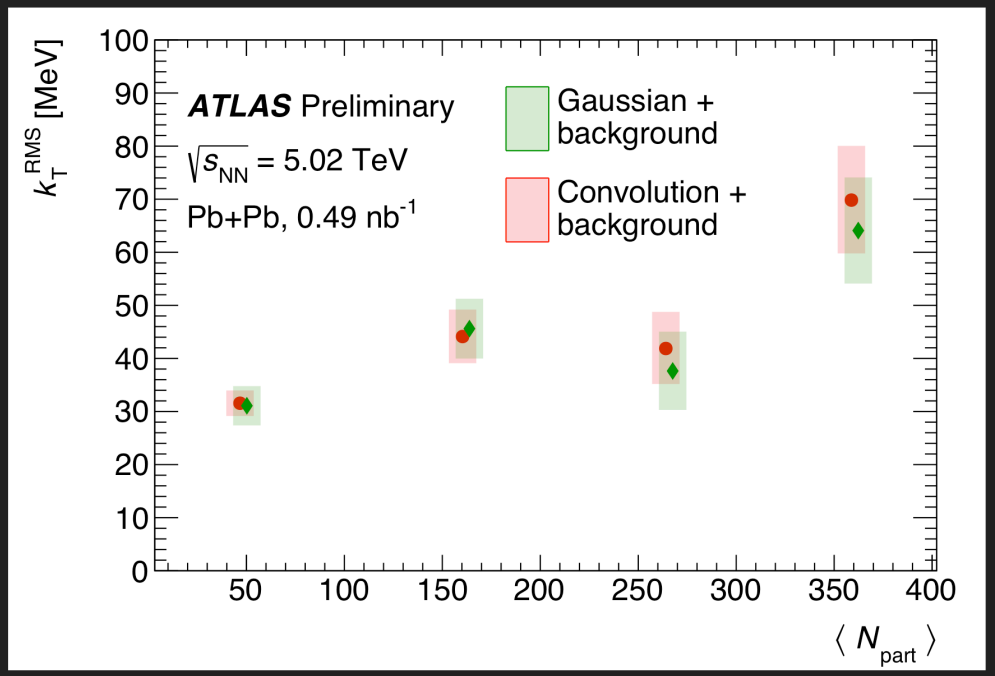
CORRECTED SIGNAL DISTRIBUTIONS

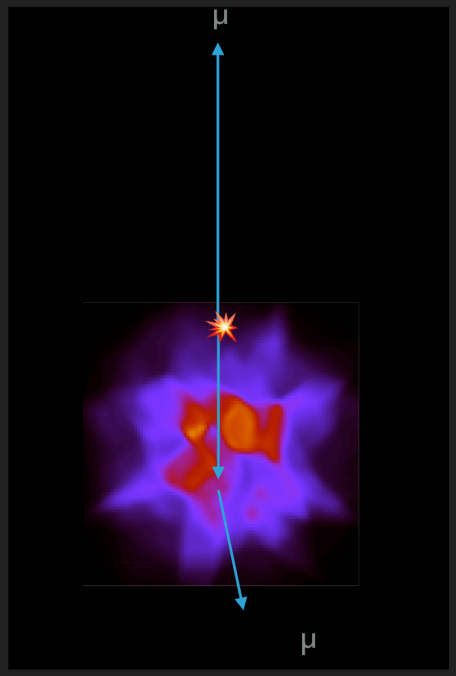


- Simulated STARLIGHT events show no centrality-dep. broadening
- HF-determined backgrounds saturate tails
  - *No obvious contribution from Drell-Yan, ϒ, or dissociative processes*

P. Steinberg, QM 2018

FITS TO EXTRACT RMS K_T

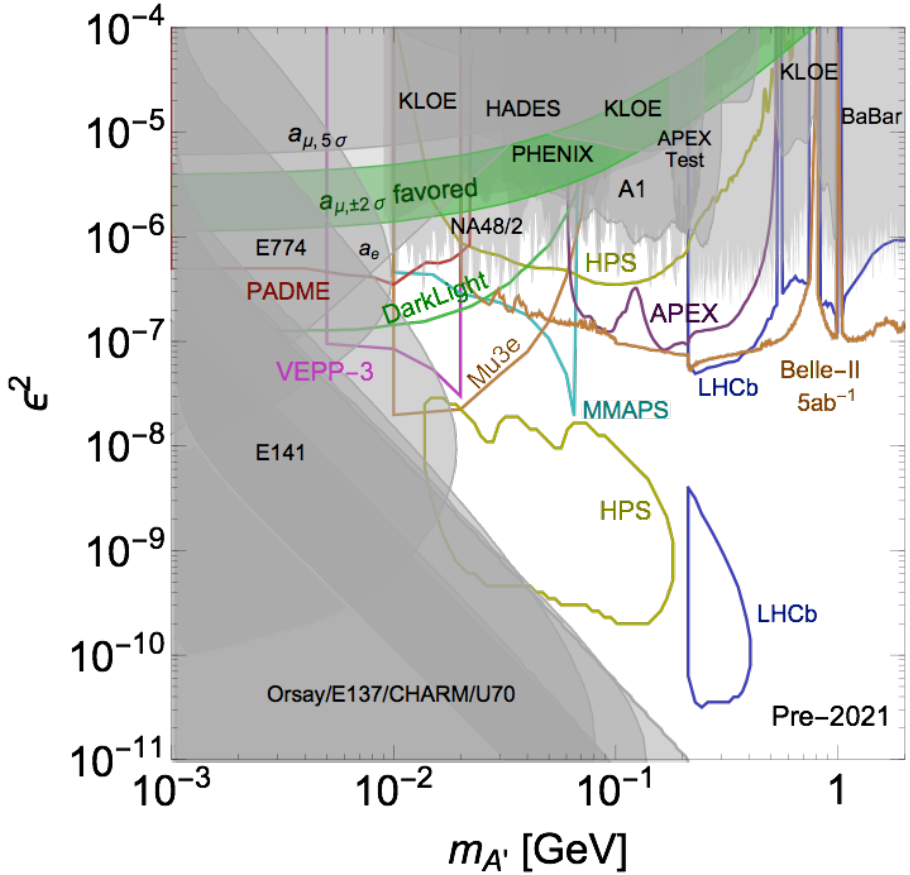


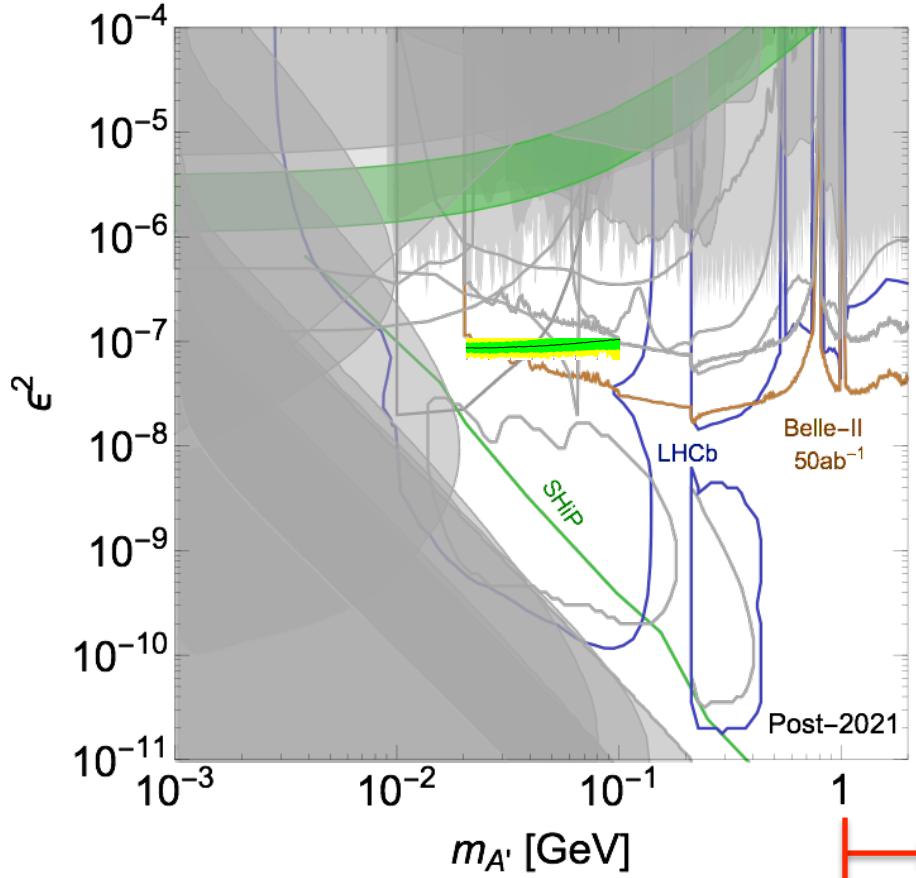


- Additional per-muon RMS k_T beyond that found for >80% centrality (UPC)
- Small in absolute terms, but grows systematically with centrality
- In most central events $\langle k_T \rangle$ ~ 70 MeV
- Specific "tomographic" interpretation hinges on whether there are additional mechanisms for influencing muons in the context of a heavy ion collision.

P. Steinberg, QM 2018

DARK PHOTONS: WORLD DATA + ALICE



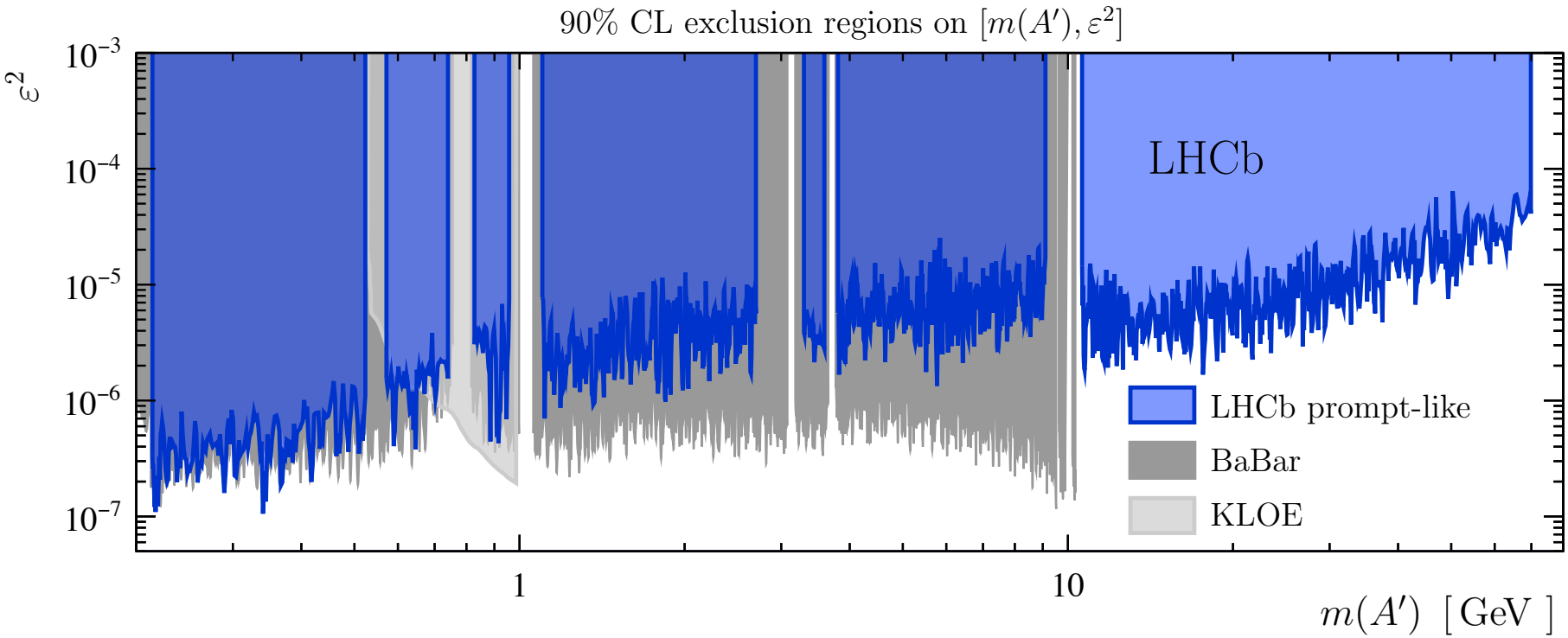


GeV scale?

***J. Davis, C. Boehm**, arXiv:1306.3653*

Dark Sector Community Report 2016
arXiv:1608.08632

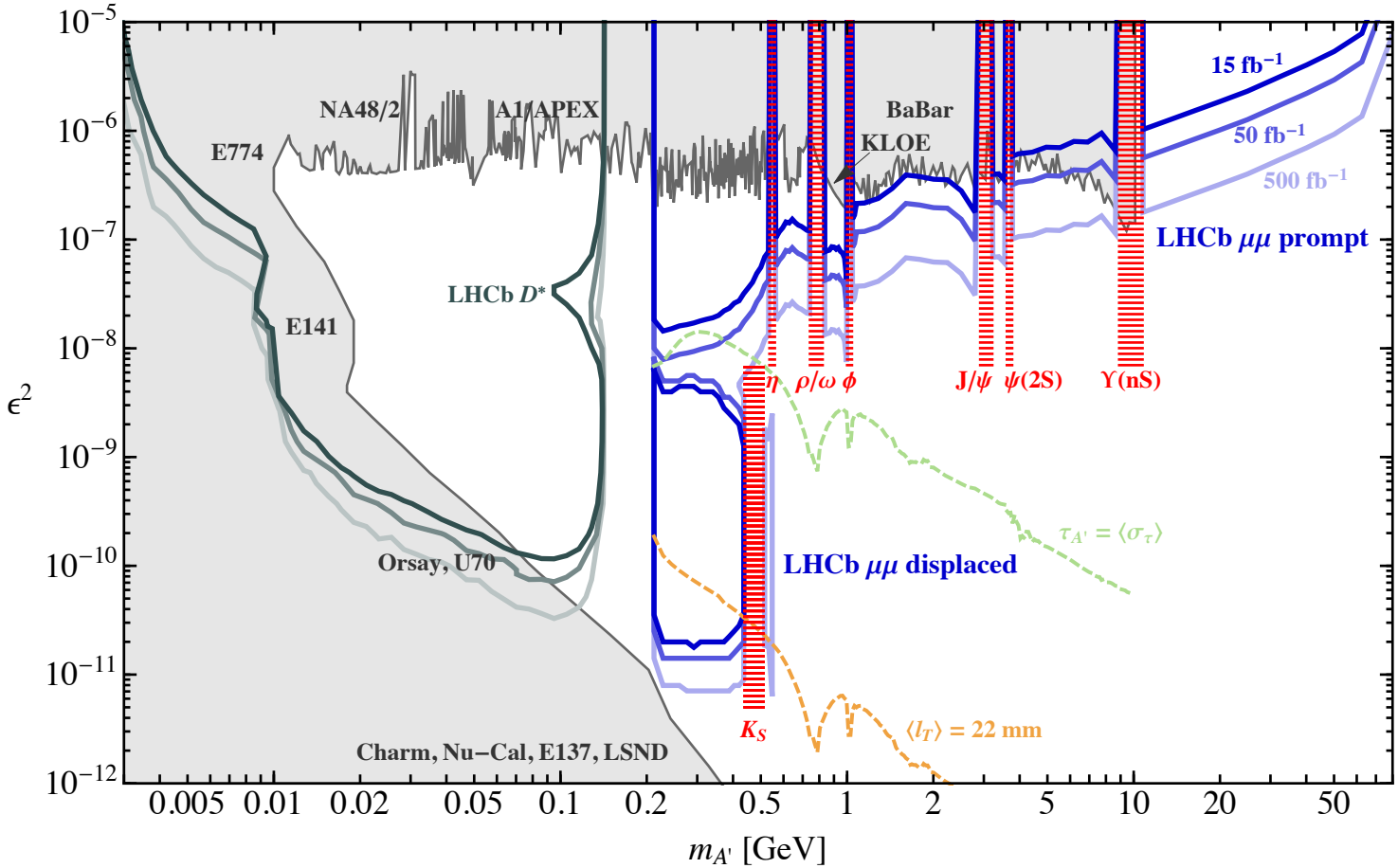
OTHER LHC EXPERIMENTS, e.g. LHCb



- Possibility to measure below 100 MeV?

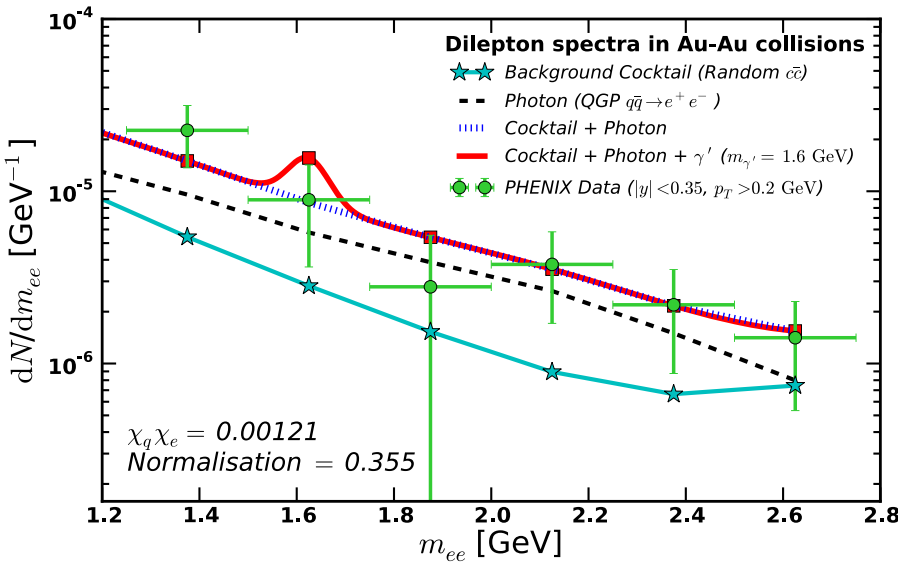
LHCb, arXiv:1710.02867 [hep-ex]

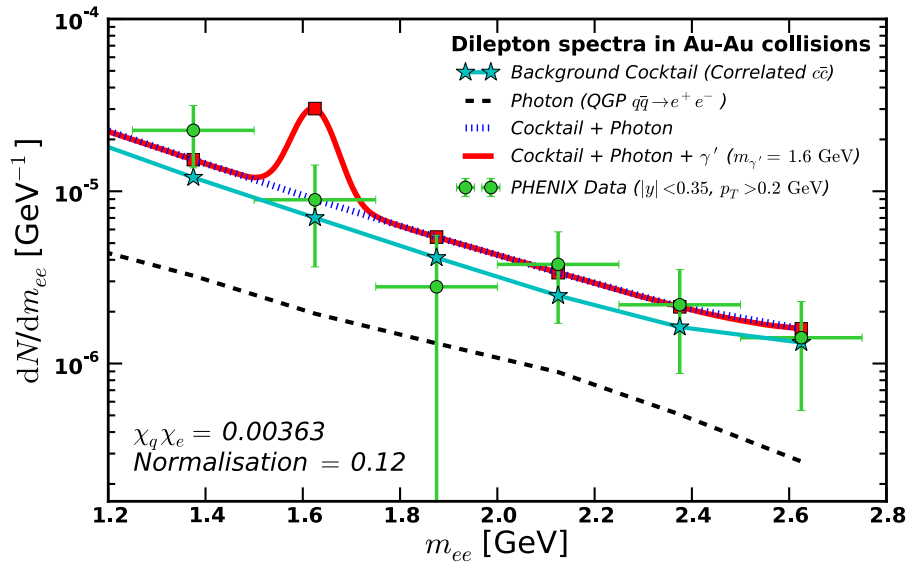
DARK PHOTONS – LHC B

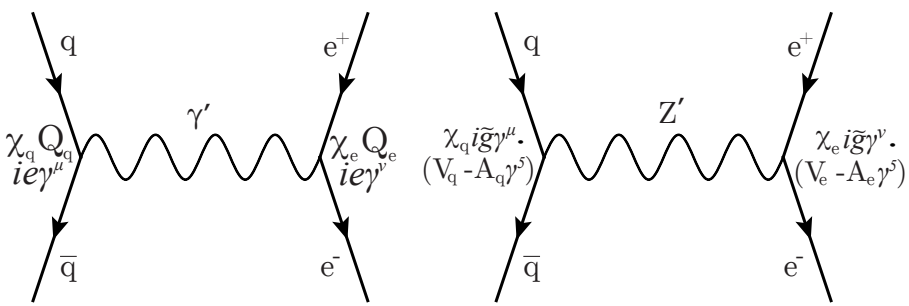


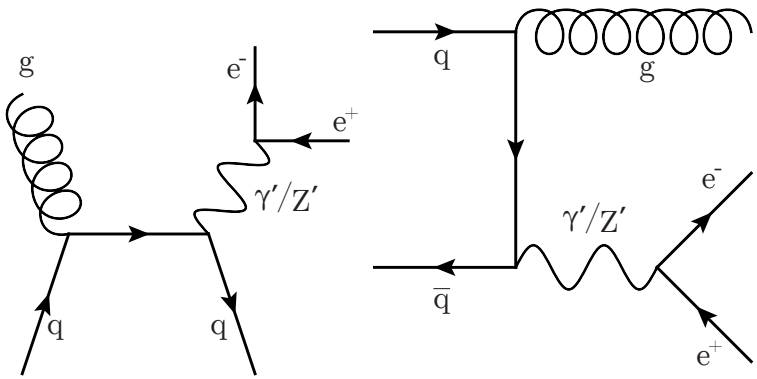
***LHCb**, Phys. Rev. Lett. 116, 251803 (2016)*

GEV-SCALE NEW GAUGE BOSONS









***J. Davis, C. Boehm**, arXiv:1306.3653*