A Large Ion Collider Experiment

Dark Photon Searches at ALICE

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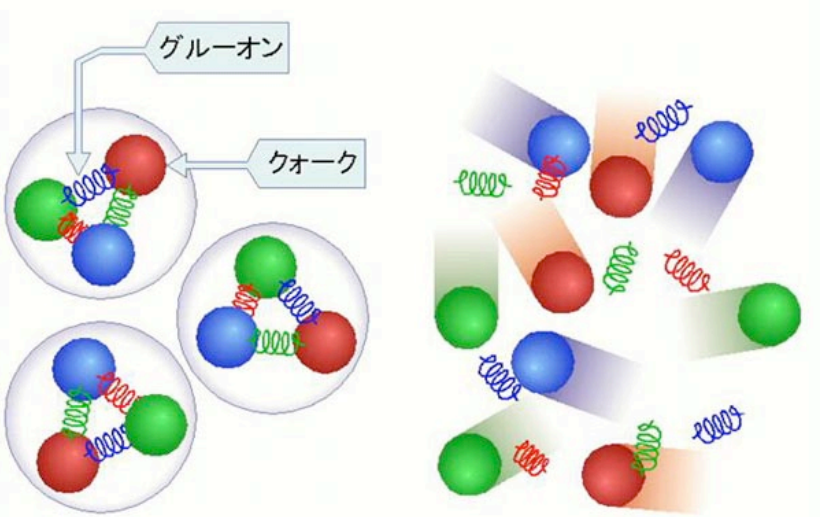
Outline

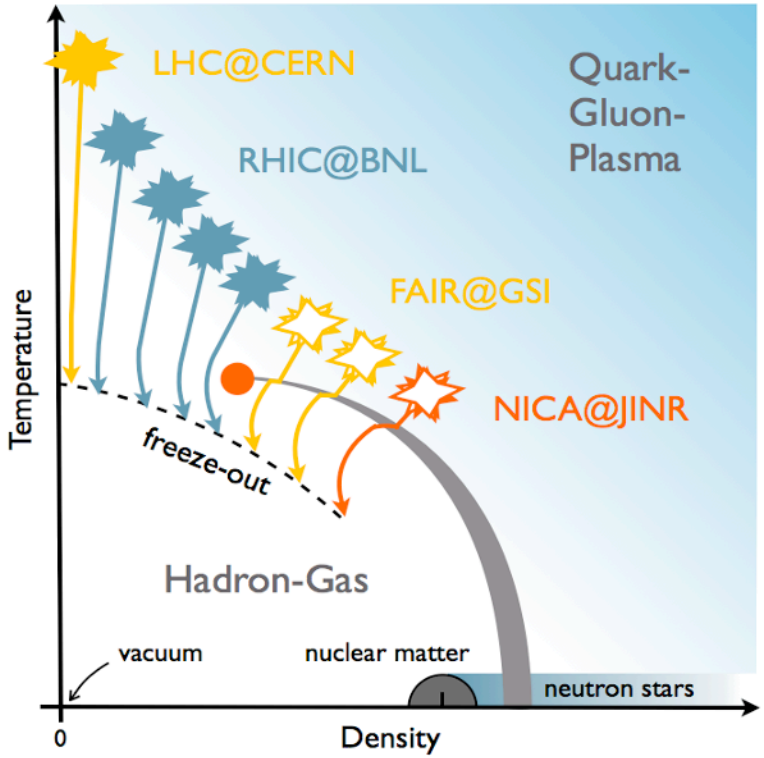
- ALICE Experiment
- ALICE Detectors
- Di-electron measurement in ALICE
- Dark Photon Searches in Run1
- ALICE Upgrade in LS2
- Perspectives in Run3
- Summary and Outlook

ALICE Experiment

- Dedicated to Heavy-Ion Collisions at the LHC
  - Characterization of the “Quark-Gluon-Plasma”
    - De-confined state composed of quarks and gluons
    - Realized at high temperature (T~170MeV)
    - Early Universe

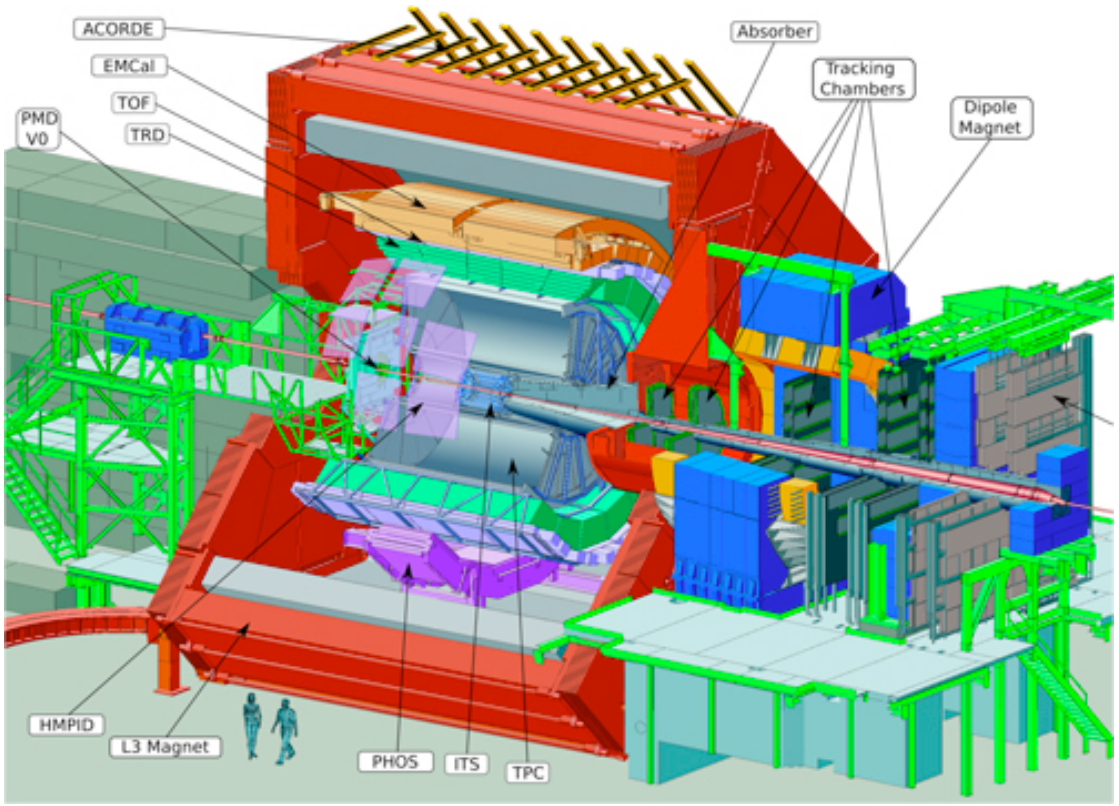
    (10μs after Big Bang)

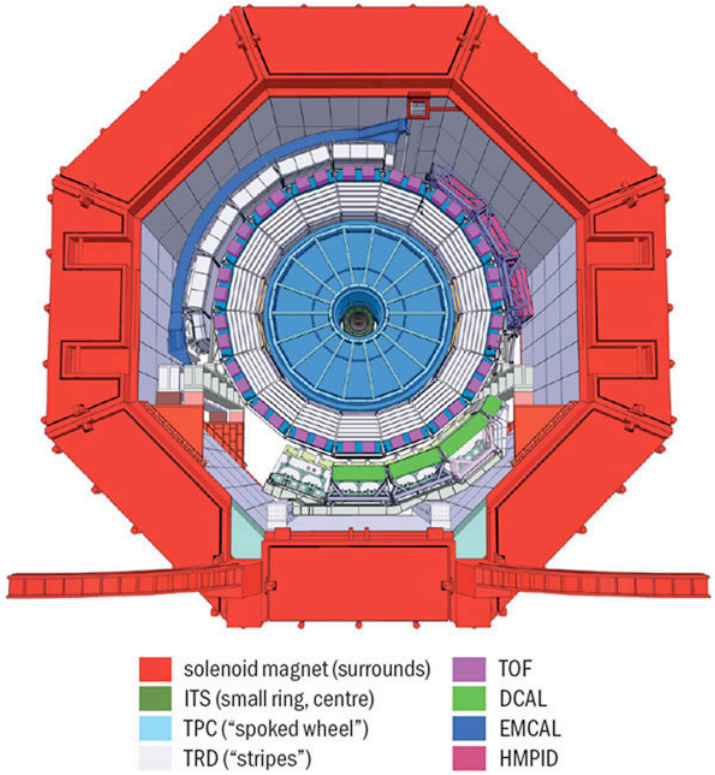




ALICE Detectors

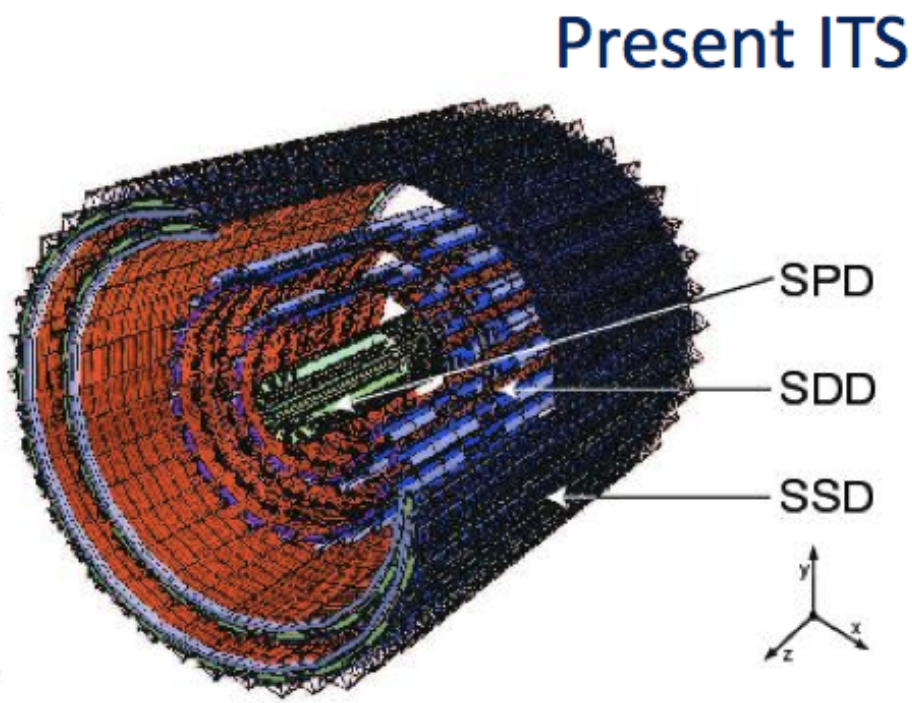
- Multi-purpose detectors to measure many observables (PID-hadrons, leptons, photons, jets)
  - Central Barrel: ITS-TPC-TRD-TOF-Calorimeters



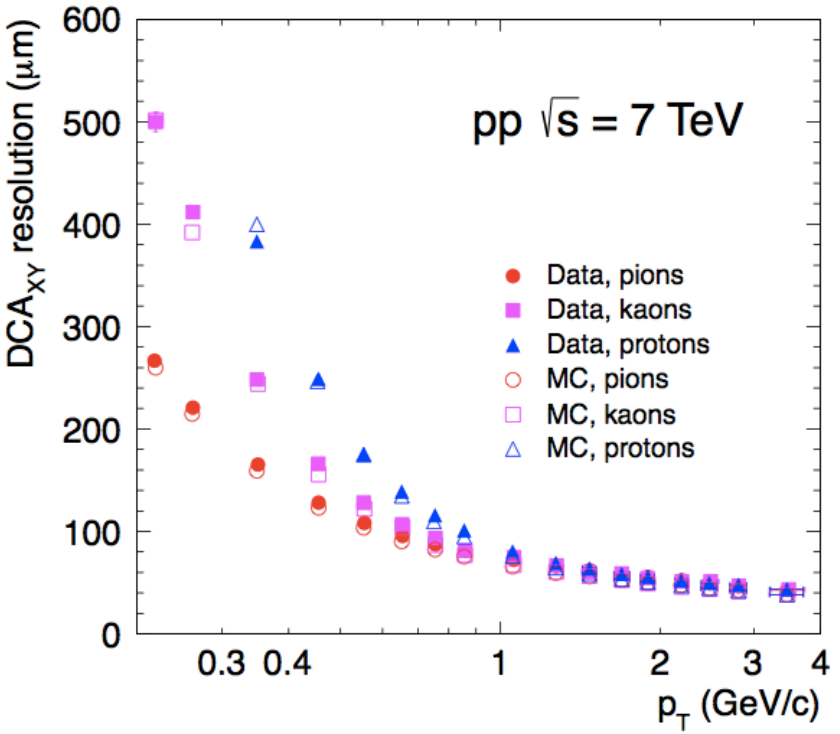


Inner Tracking System

- 6 cylindrical layers of silicon detectors
  - 2 layers each of Silicon Pixel Detector (SPD), Silicon Drift Detector (SDD) and double sided Silicon microStrip Detector (SSD)

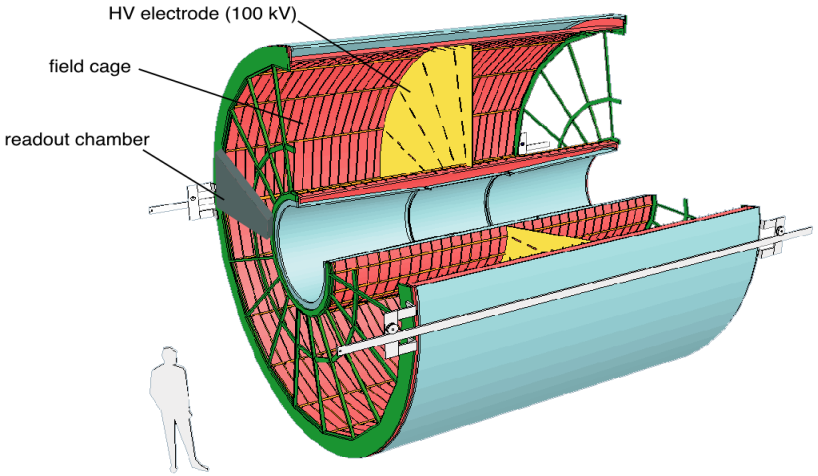


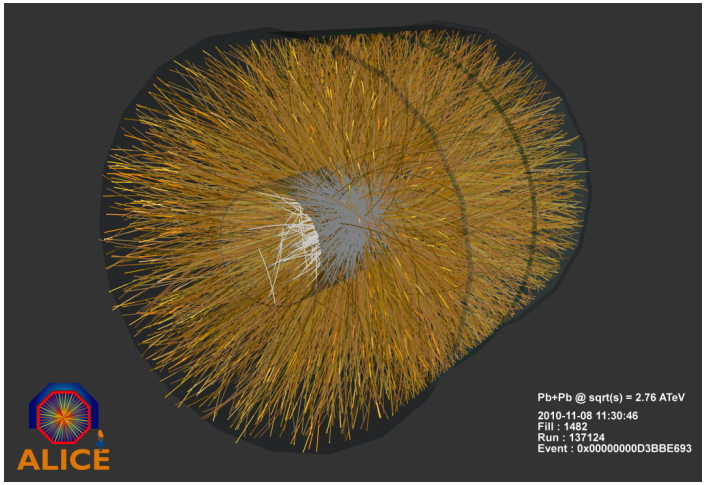
ALICE, arXiv:1402.4476



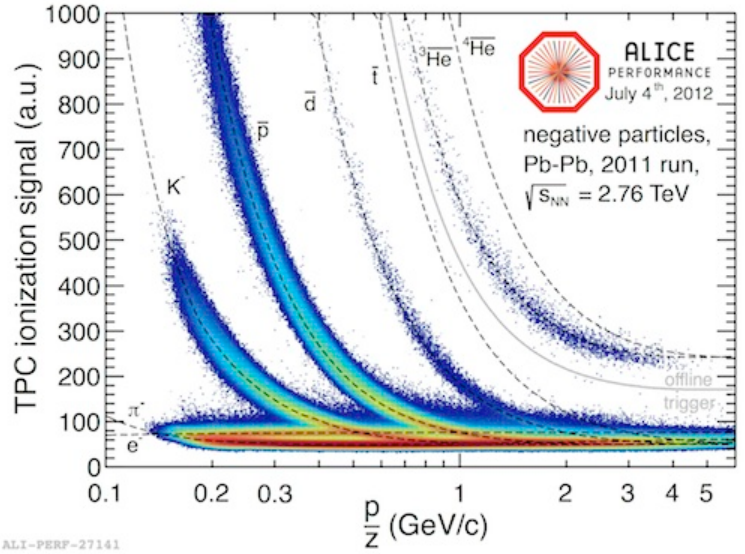
Time Projection Chamber

- The main tracking device with PID capabilities (dE/dx)





Volume: ~90m^3 (largest TPC in the world!)
Gas: Ne/CO_2/N_2 (90/10/5)
Ar/CO_2 (90/10) for Run2
Drift field : 0.4kV/cm, 94μsec drift time
Gating grid operation (100μsec + 180μsec)
→ Maximum rate = 3.5kHz
72 MWPCs with 557768 readout pads

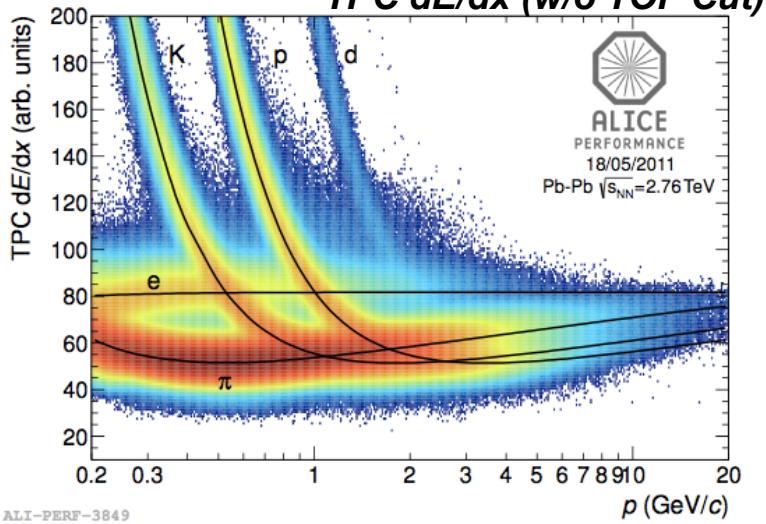


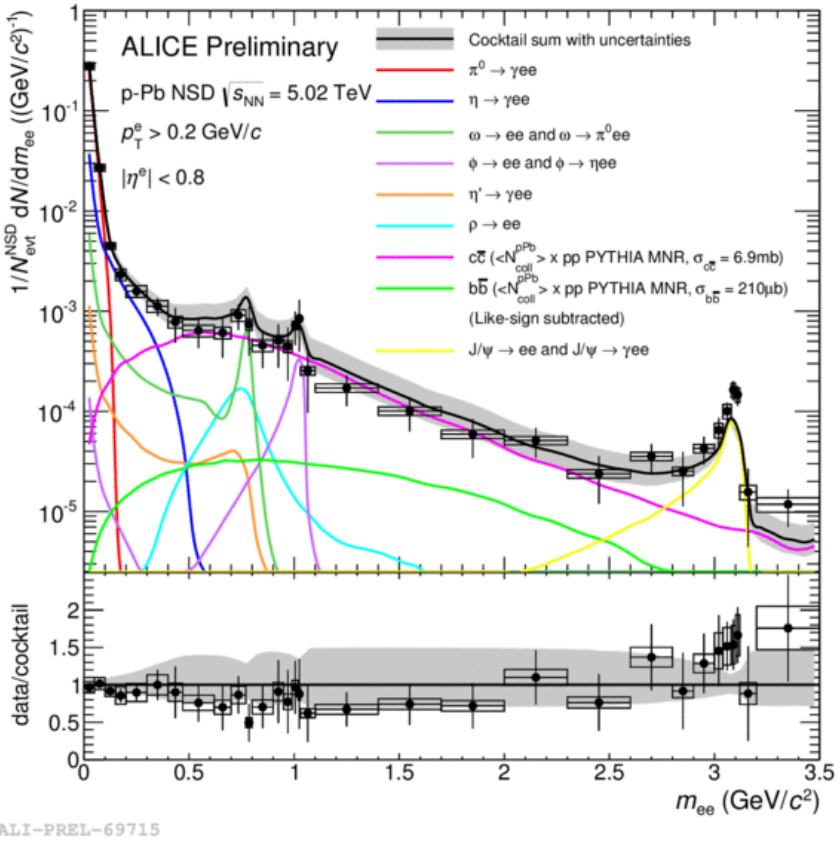
Di-electron analysis

- Electron identification by TPC/TOF/TRD
  - Hadron Contamination ~1(pp)-7(Pb-Pb)%
  - S/B at M_{ee}(0.5GeV) ~ 0.1(Pb-Pb)-1(pp)%
- Mass resolution ~ 1%
- p-p and p-Pb consistent with cocktail. Pb-Pb analysis is on-going

Data sample (events)
pp, $\sqrt{s} = 7$ TeV
▸ 3.5×10^8 (min. bias)
p–Pb, $\sqrt{s_{\rm NN}} = 5.02$ TeV
▸ 1.1×10^8 (min. bias)
Pb–Pb, $\sqrt{s_{\rm NN}} = 2.76$ TeV
▸ 16×10^6 $(0-10\%)$
▸ 11×10^6 $(20-50\%)$

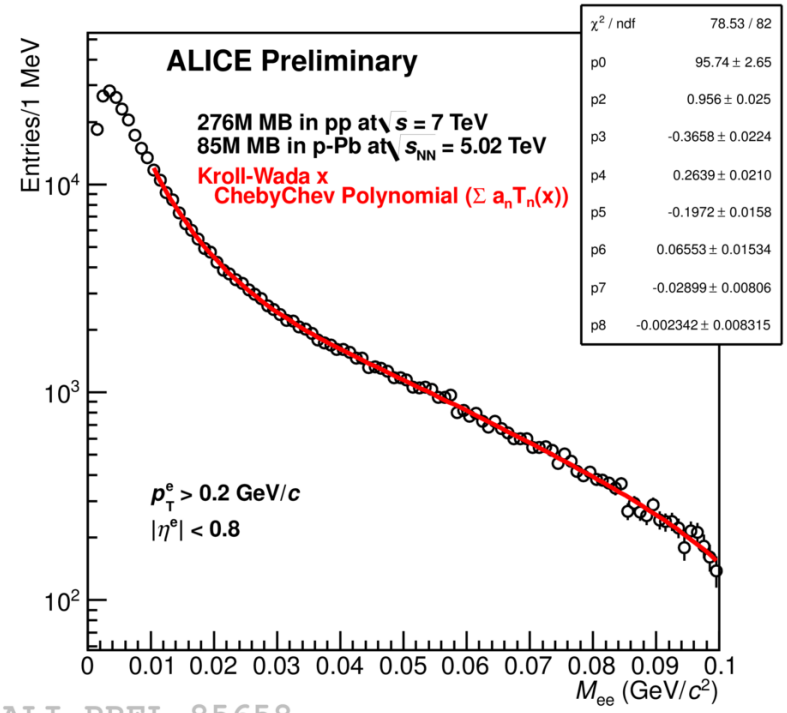
TPC dE/dx (w/o TOF Cut)

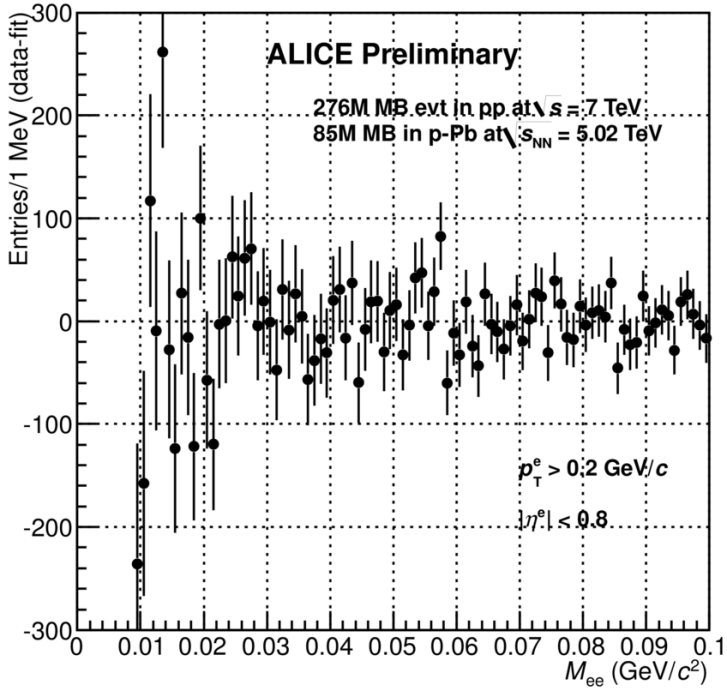




Dark Photon Searches in ALICE

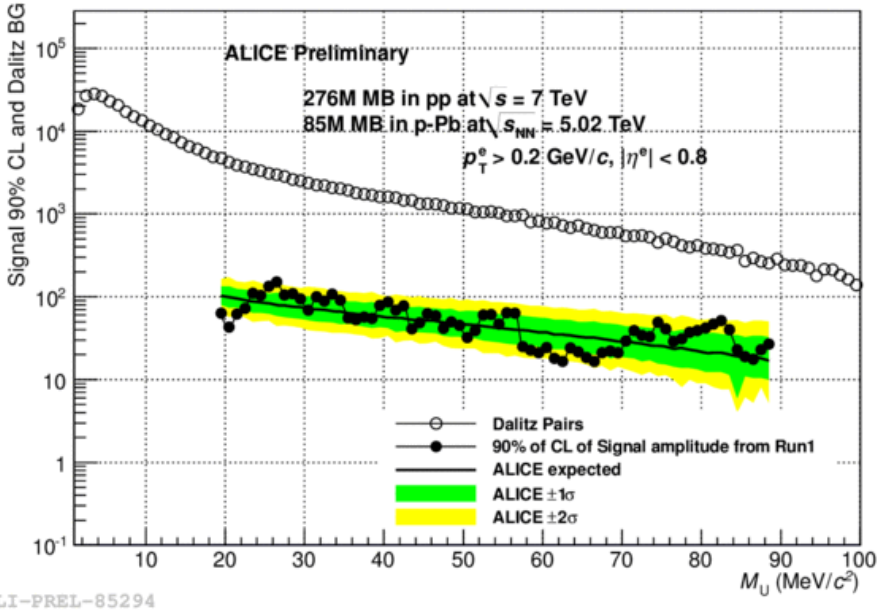
- Dark Photon Searches in low mass Dalitz pairs
- Similar analysis strategy as done in PHENIX
  - Combined p-p (276M) and p-Pb (85M) data
  - Fitting with Kroll-Wada + ChebyChev function

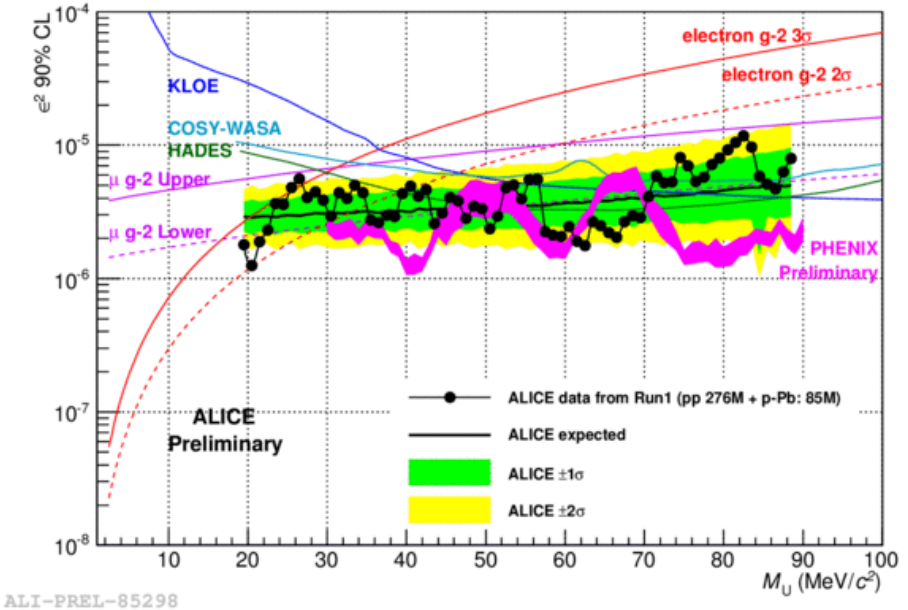




90% CL of Mixing Parameter

- CLs method to extract 90% CL, 1σ and 2σ band
  - Similar or slightly worse CL_{90} compared to PHENIX
  - No dark photon signal is observed
- x4 improvement with Run2 statistics (→ $\varepsilon^2<10^{-6}$) and ε^2 for $M_U>100$ MeV



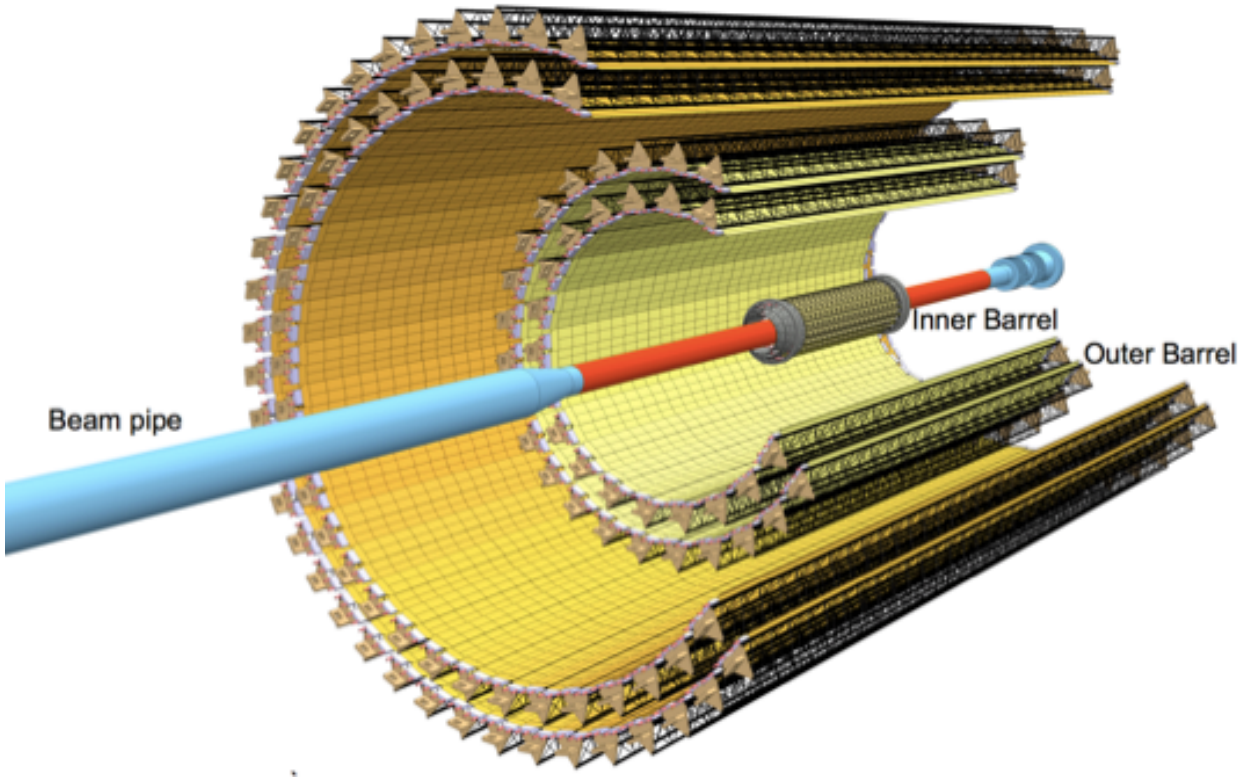


ALICE Upgrade in LS2

- Operate ALICE at high luminosity in Run3 (>2019).
  - **Target recorded luminosity:**
    - **Pb-Pb:** ≥ 10 nb^{-1} ➡ 8 × 10^{10} events
    - **pp (@5.5 TeV):** ≥ 6 pb^{-1} ➡ 1.4 × 10^{11} events
  - Exploit full potential of the ALICE in 50kHz HI collisions
- Major detector upgrades
  - Si-based Tracking System at central and forward rapidities
  - GEM TPC upgrade with continuous readout
  - Fast readout electronics
  - online-offline upgrades

New Inner Tracking System

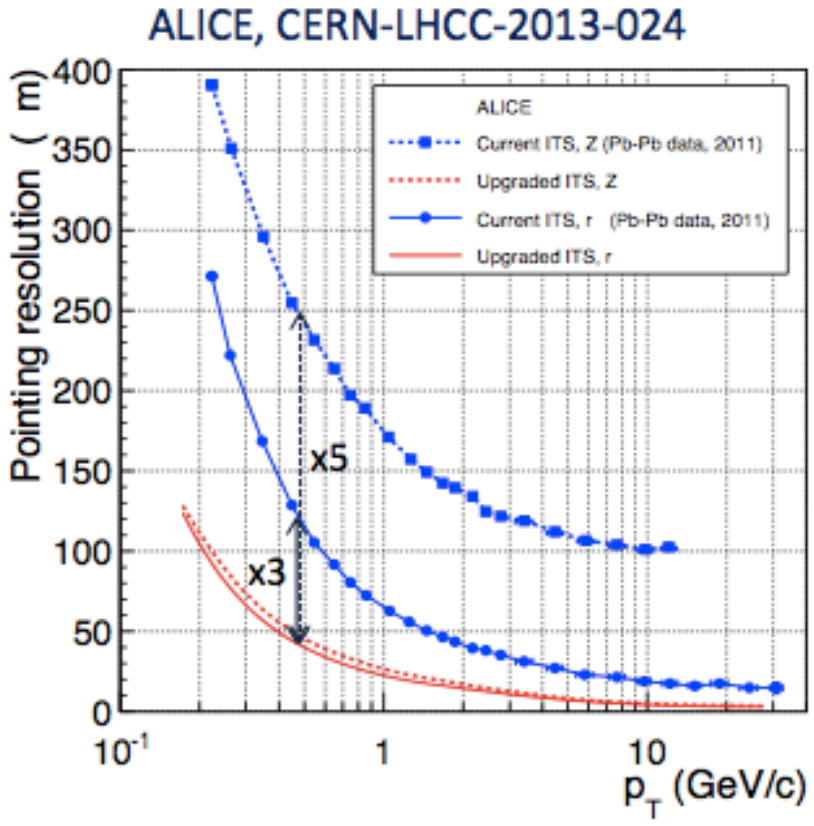
- 7-layer barrel geometry of MAPS
  - Inner barrel (3 layers) and outer barrel (4 layers)
  - Many R&D (ALPIDE and MISTRAL/ASTRAL)

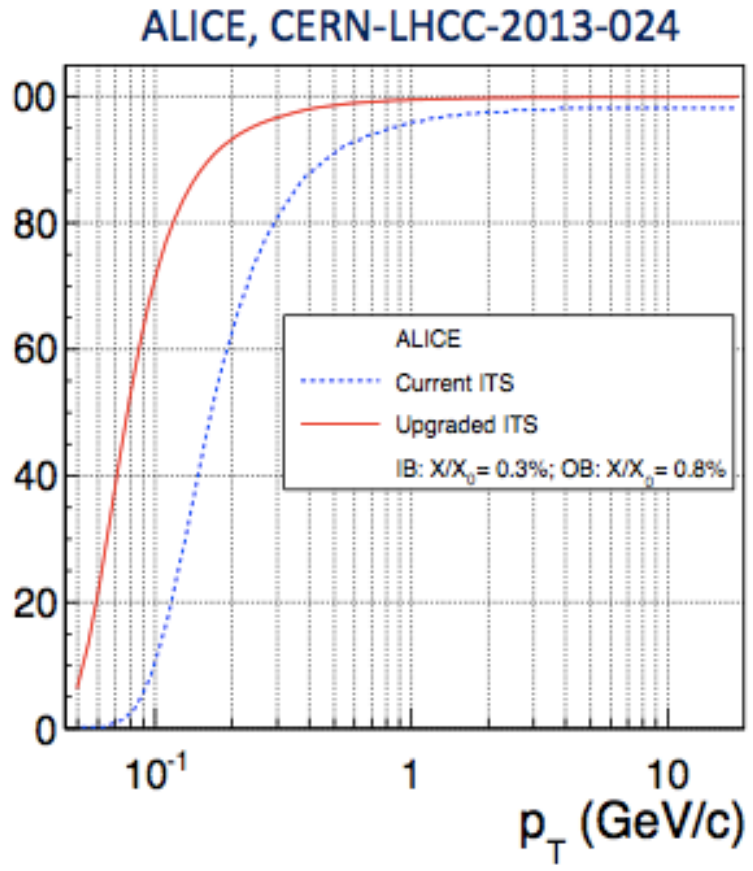


First layer close to IP (39mm → 22mm)
Reduced material budget (X/X_0 = 1.14% → 0.3% for first layer)
Smaller pixel size (50x425um^2 → O(20x20um^2))
Increase data rate (1kHz → 50kHz in Pb-Pb and 200kHz in p-p)

Detector Performances

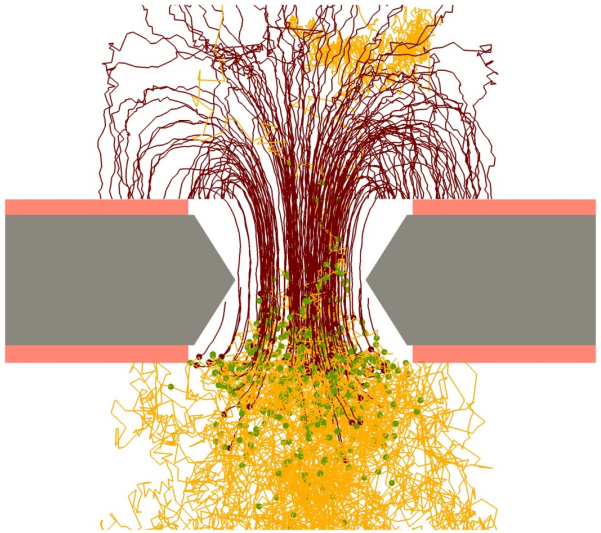
- Expected improvement on pointing resolution (left) and tracking efficiency (right)

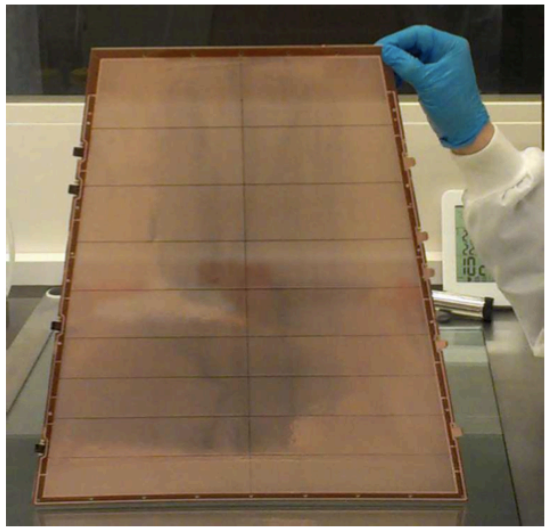


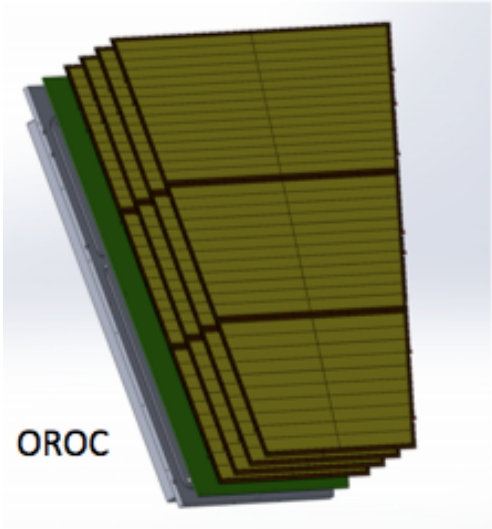


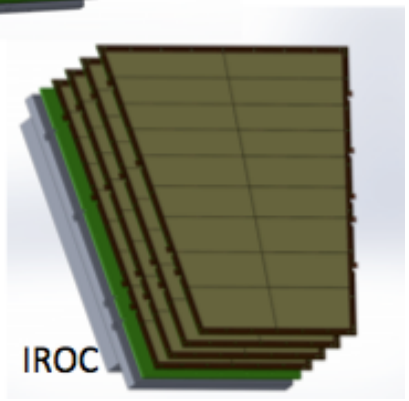
GEM TPC Upgrade

- Need high rate capability and small ion backflow to prevent space-charge distortions. Preserve current performances.
- Continuous readout with micro-pattern gaseous detectors using the advantages on:
  - Reduction of ion backflow
  - High rate capability
  - Less ExB effect





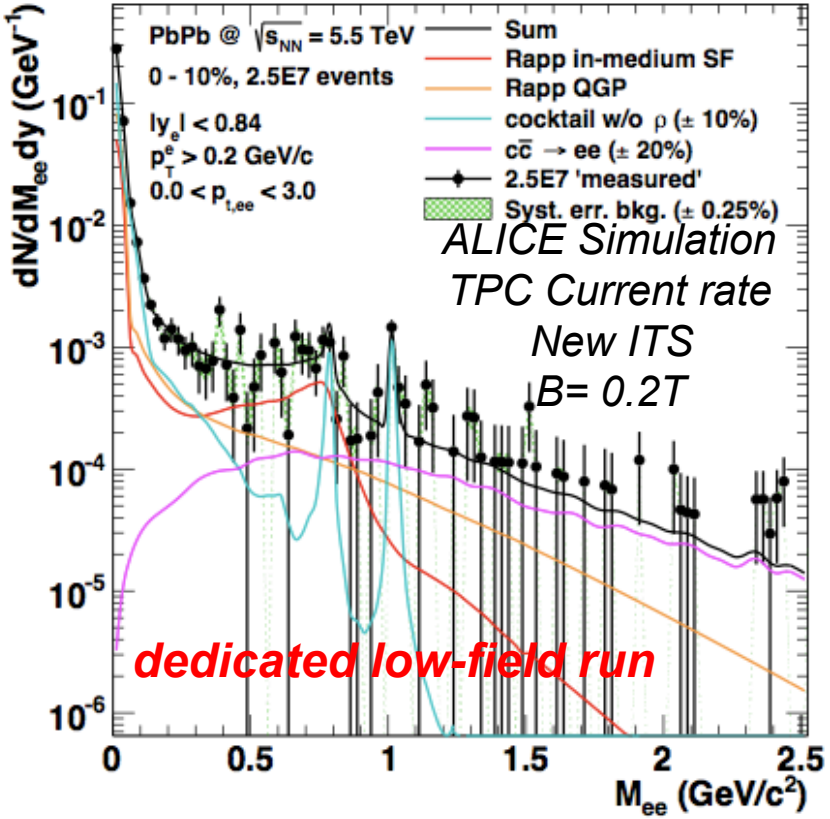


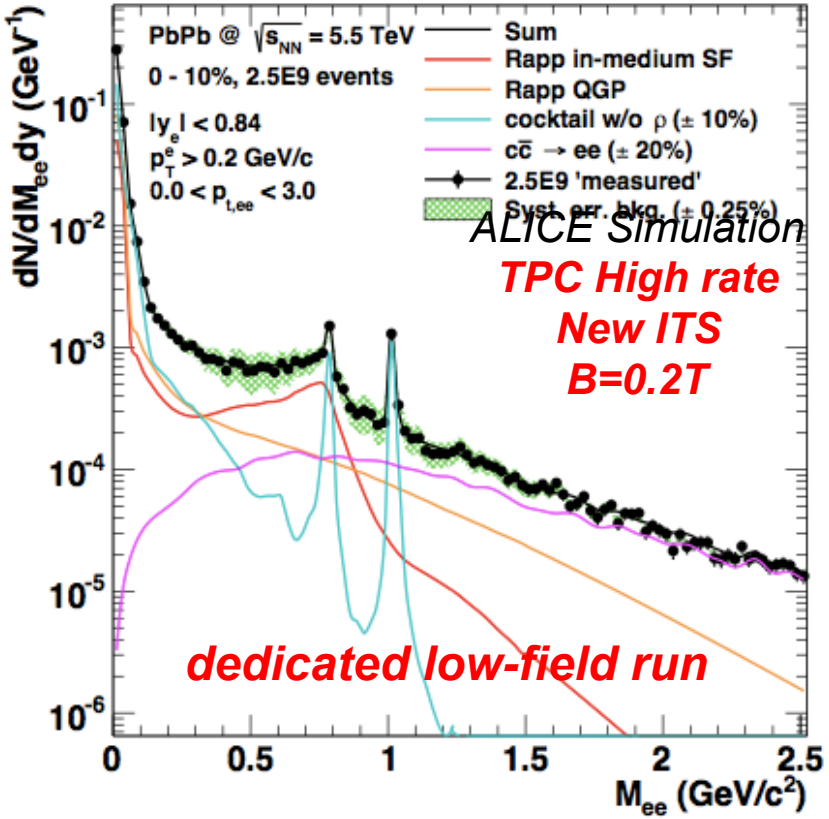


Low Mass di-electrons in Run3

- High statistics + Dalitz, conversion and charm rejection in new ITS. Reduced uncertainties from charm decay
- Significantly Improved measurement for M_{ee}>0.2 GeV

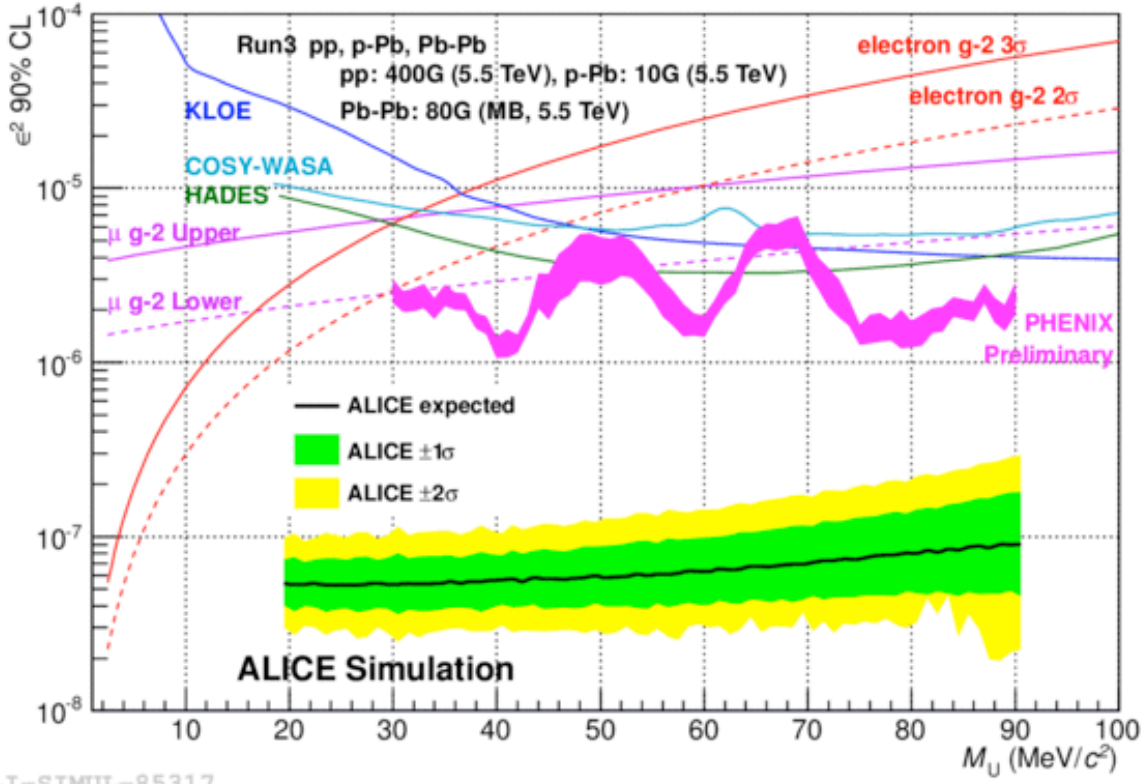
ALICE, CERN-LHCC-2013-020





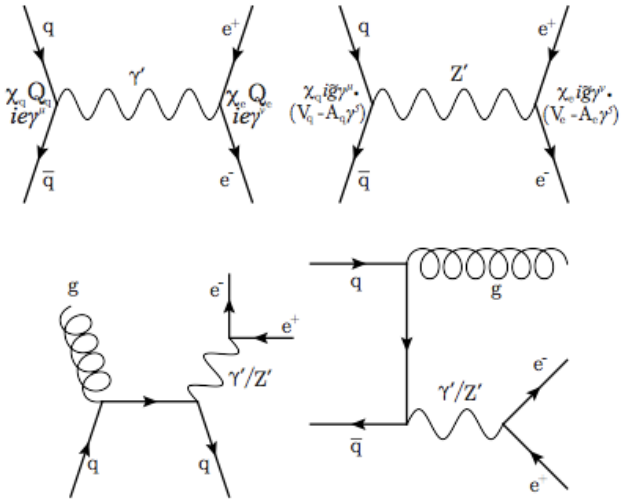
Expected Reach of 90% CL

- 1G Pairs in M_{ee}<0.1 GeV from 5.5 TeV p-p, p-Pb and Pb-Pb at Run3 and Run4 (cf. 0.6M in Run1)
  - p-p running at 14 TeV under consideration
- $\varepsilon^2<10^{-7}$ will be reachable.
- Feasibility of long-lived DP searches with new ITS will be evaluated.

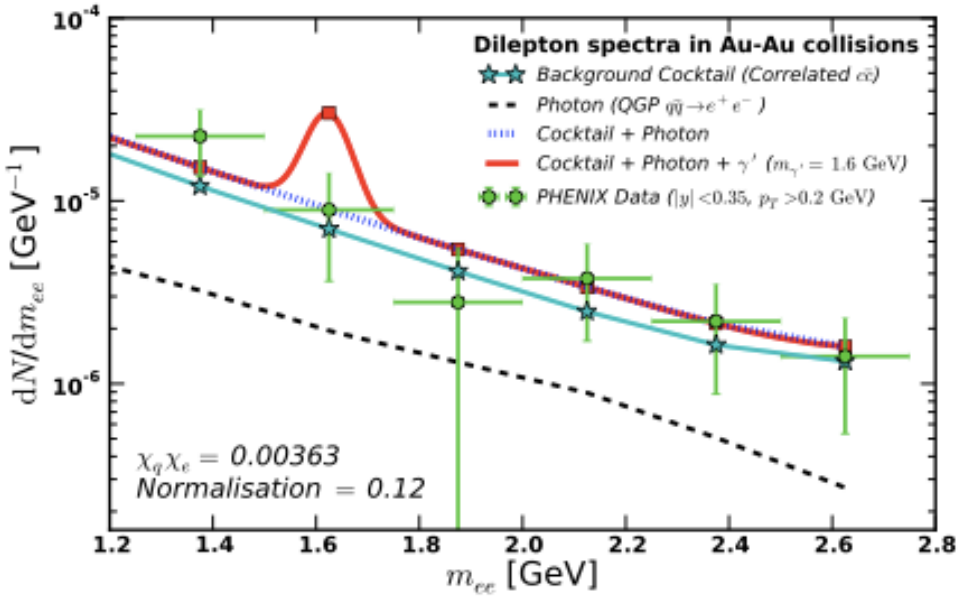


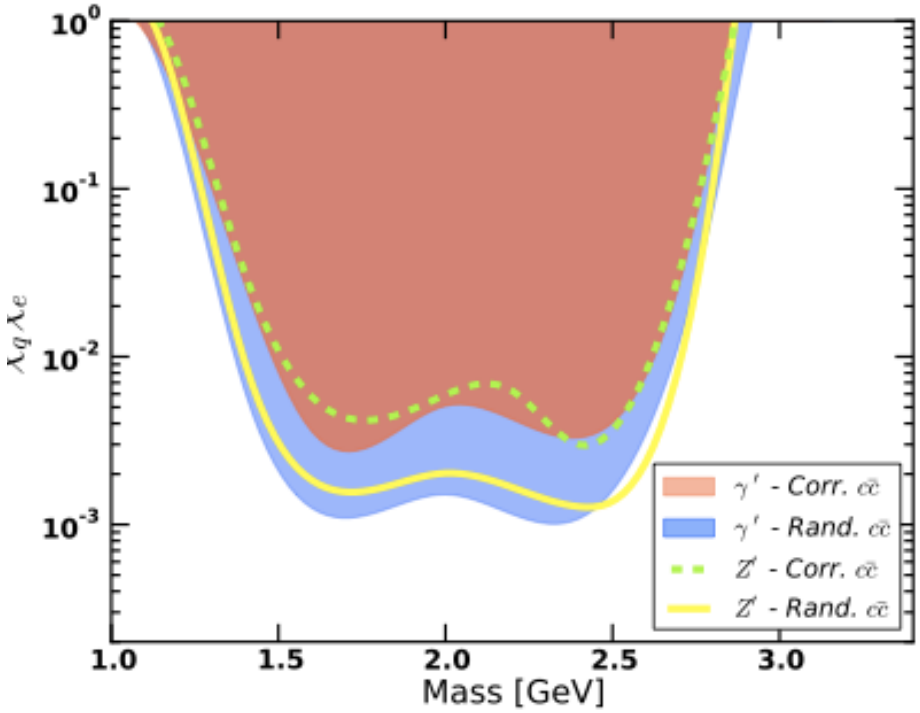
Dark γ'/Z boson?

- GeV-scale dark γ' and Z' in IMR
- Thermal di-electrons from QGP



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

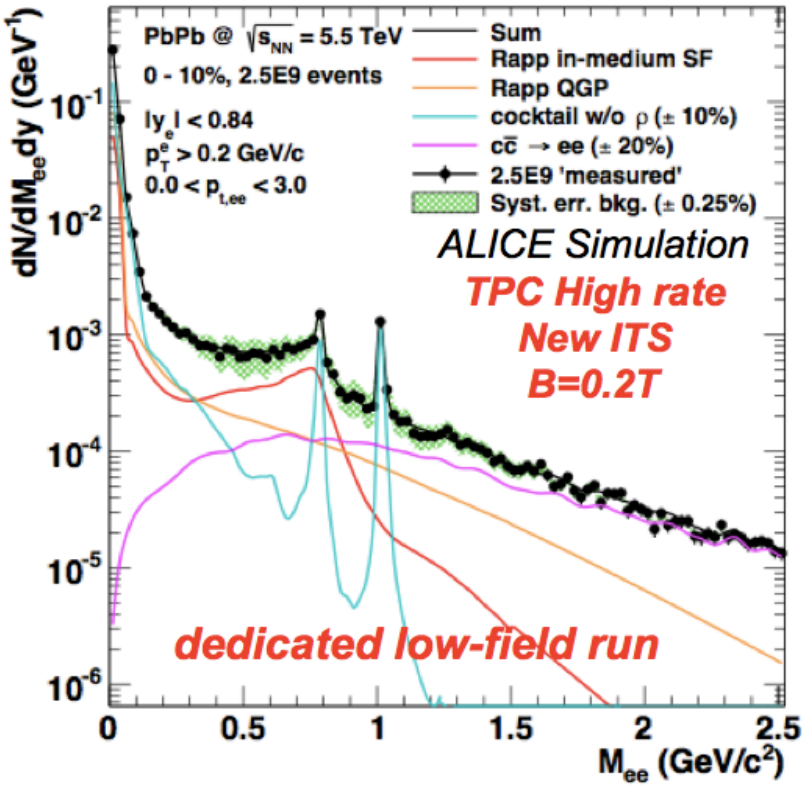




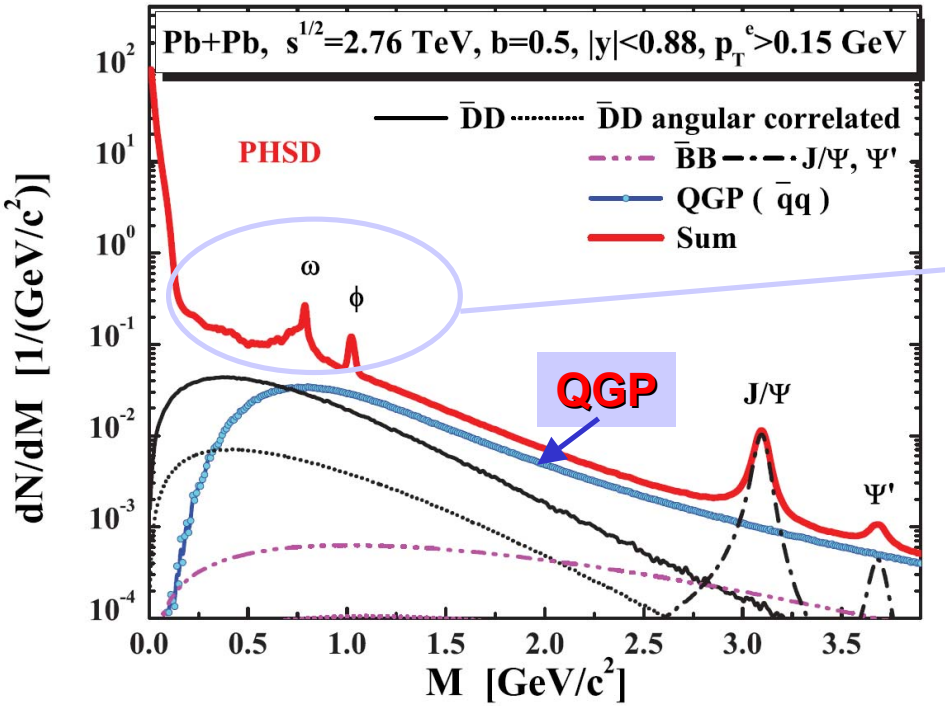
Dark γ'/Z boson?

- GeV-scale dark γ' and Z' in IMR
- Thermal di-electrons from QGP
- Can be studied in the ALICE in Run3/Run4

ALICE, CERN-LHCC-2013-020



E. Bratkovskaya, QM2014



ALICE

Summary and Outlook

- Dark Photon searches in ALICE:
  - Good electron identification and good mass resolution
  - Current Run1 data shows no hint of dark photon signals. ε^2 is larger than ε^2 by PHENIX.
- Future prospects:
  - Run2 will improve x4 in ε^2.
  - ALICE major upgrade for high luminosity in Run3 and Run4 will allow to reach $\varepsilon^2<10^{-7}$ and to search for GeV-scale dark gauge bosons in IMR.

Spare slides