A Large Ion Collider Experiment

Dielectron production in pp collisions at 13 TeV with low B-field

Hot Quarks – Texel
13.09.2018

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For the ALICE collaboration
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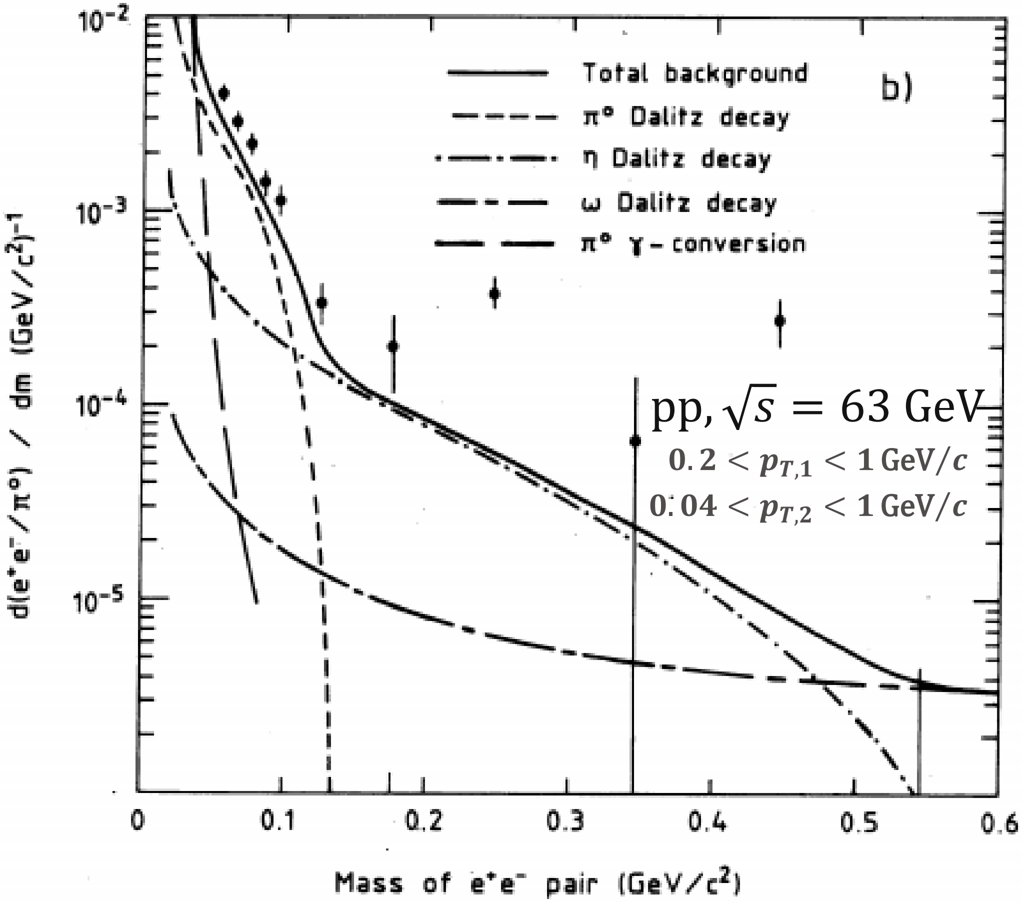
Motivation

‘anomalous’ dileptons in pp



V. Hedberg, PhD thesis, Lund (1987)

CERN ISR – AFS (1987):
Excess of dielectrons over expectation from known hadronic sources in a ‘elementary’ collision system

Low-mass region (LMR) excess:
- $0.05\ GeV/c^2 < m_{ee} < 0.6\ GeV/c^2$
- $p_{\mathrm{T,ee}} < 1$ GeV/c

- No other experiment could probe this region

30 years of Heavy Ions:
(H. J. Specht ,2016):
- Remaining open issue
- “Challenge for the future”

Motivation

Dedicated low-mass dielectron runs

Reduced field of the ALICE L3 solenoid magnet: (B = 0.5 T → 0.2 T)

→ Overall charged-particle acceptance increased

→ Bulk of the dielectron yield is located at low momenta

→ Improve background rejection capabilities

→ Access to low-p_{T} particle production

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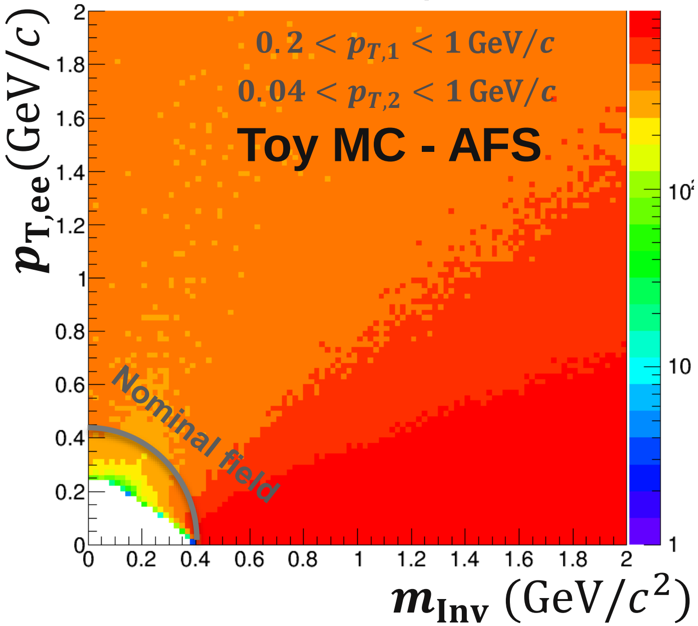
Dielectron acceptance:



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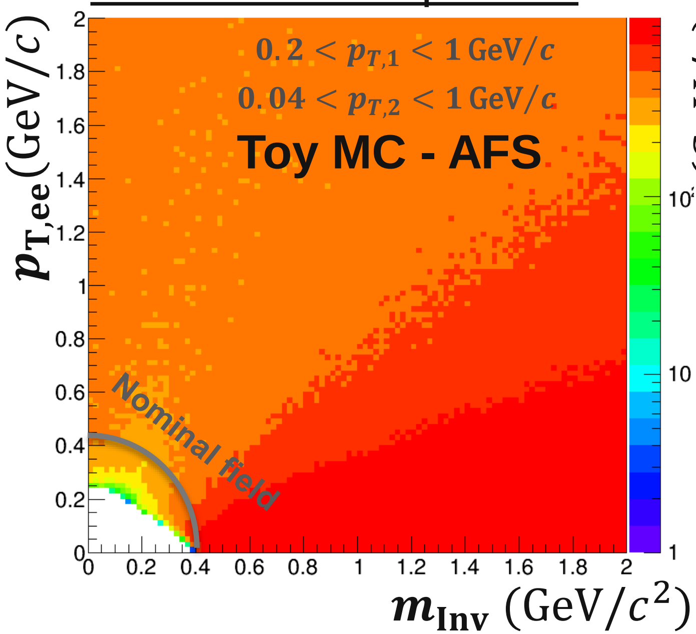
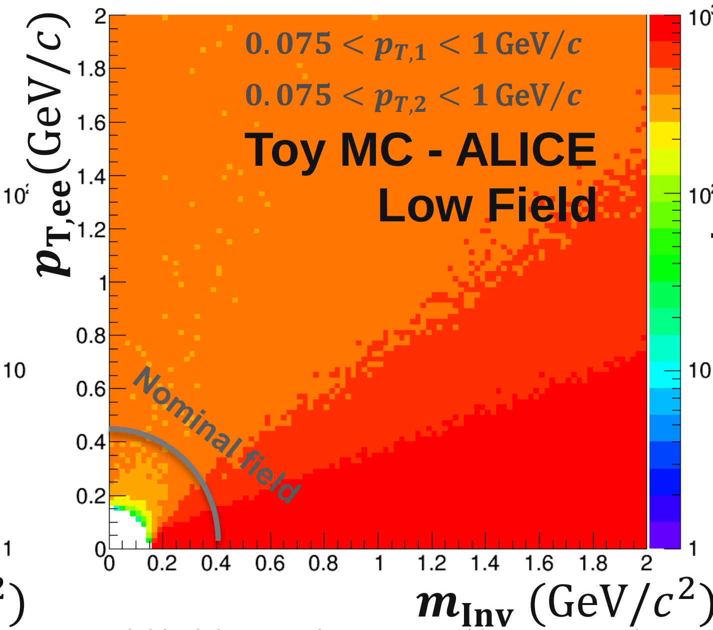
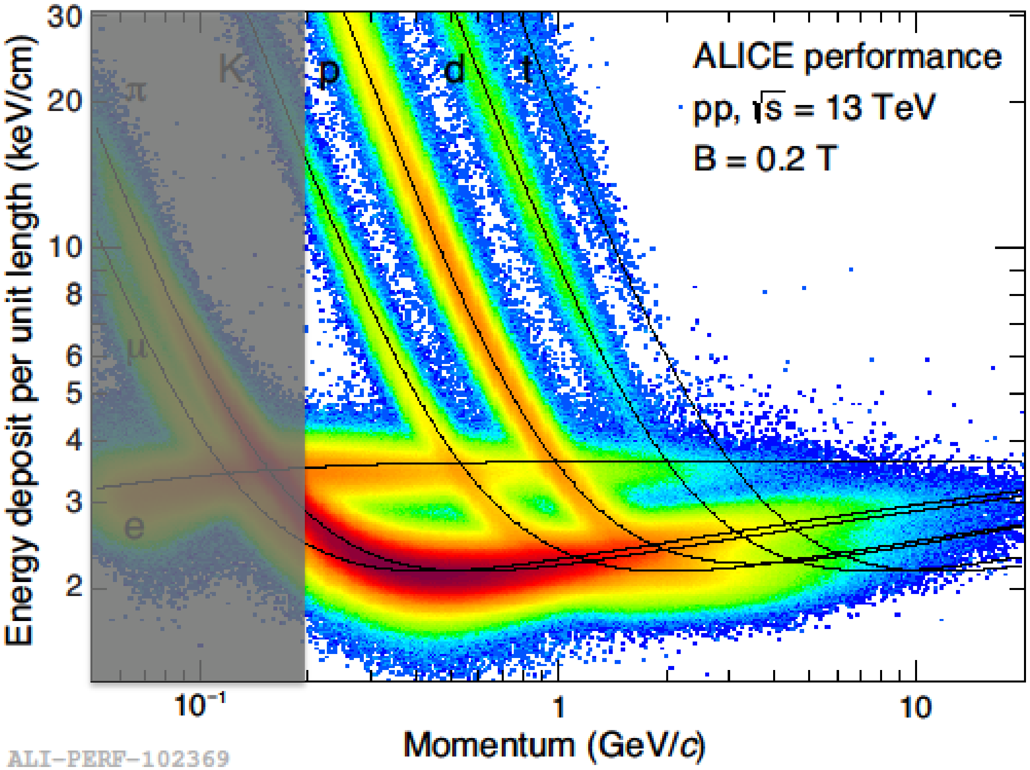




→ Allows us to challenge the AFS measurement for the first time with even better acceptance

Effects of low magnetic field

Particle identification



Specific energy loss in the TPC

Nominal B-field configuration:

- Low-$\boldsymbol{p}$ cut-off at 150 MeV/*c*
  → Limits analysis to $p_{\mathrm{T}} \geq 0.2$ GeV/*c*

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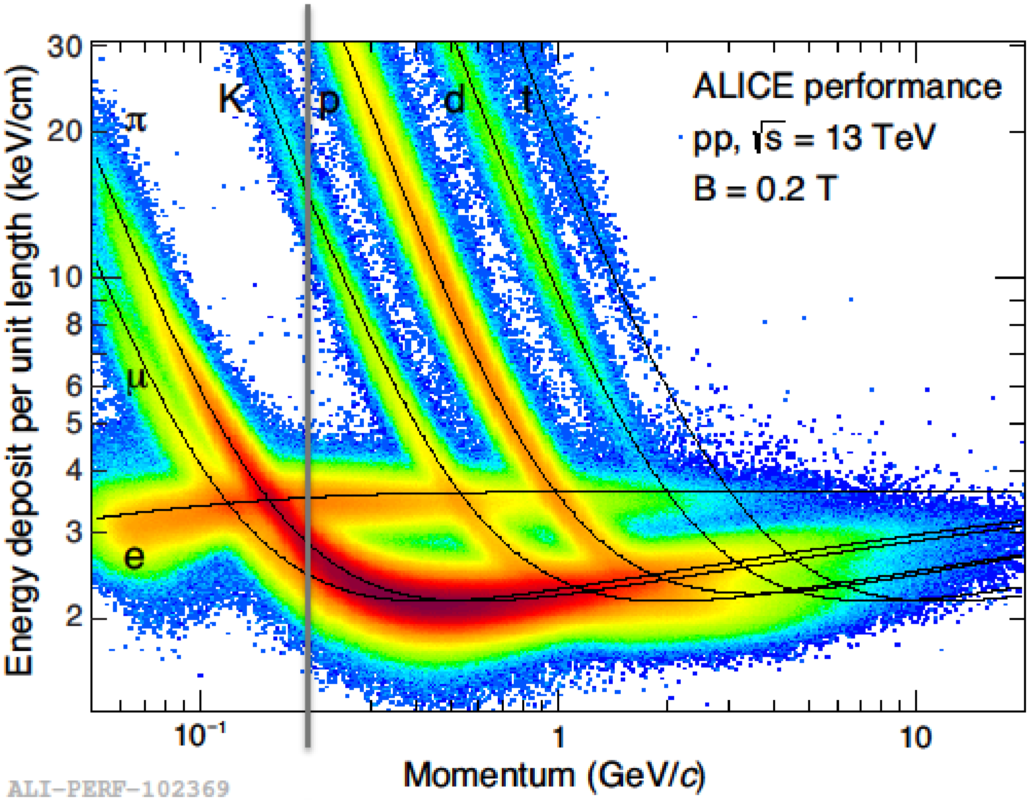


Access with low-B field

Specific energy loss in the TPC

Nominal B-field configuration:

– Low-p cut-off at 150 MeV/c
  → Limits analysis to $p_T \geq 0.2$ GeV/c

Low B-field configuration:

- Enables single-leg p_T-cut of $p_T \geq 0.075$ GeV/c

New Challenge:

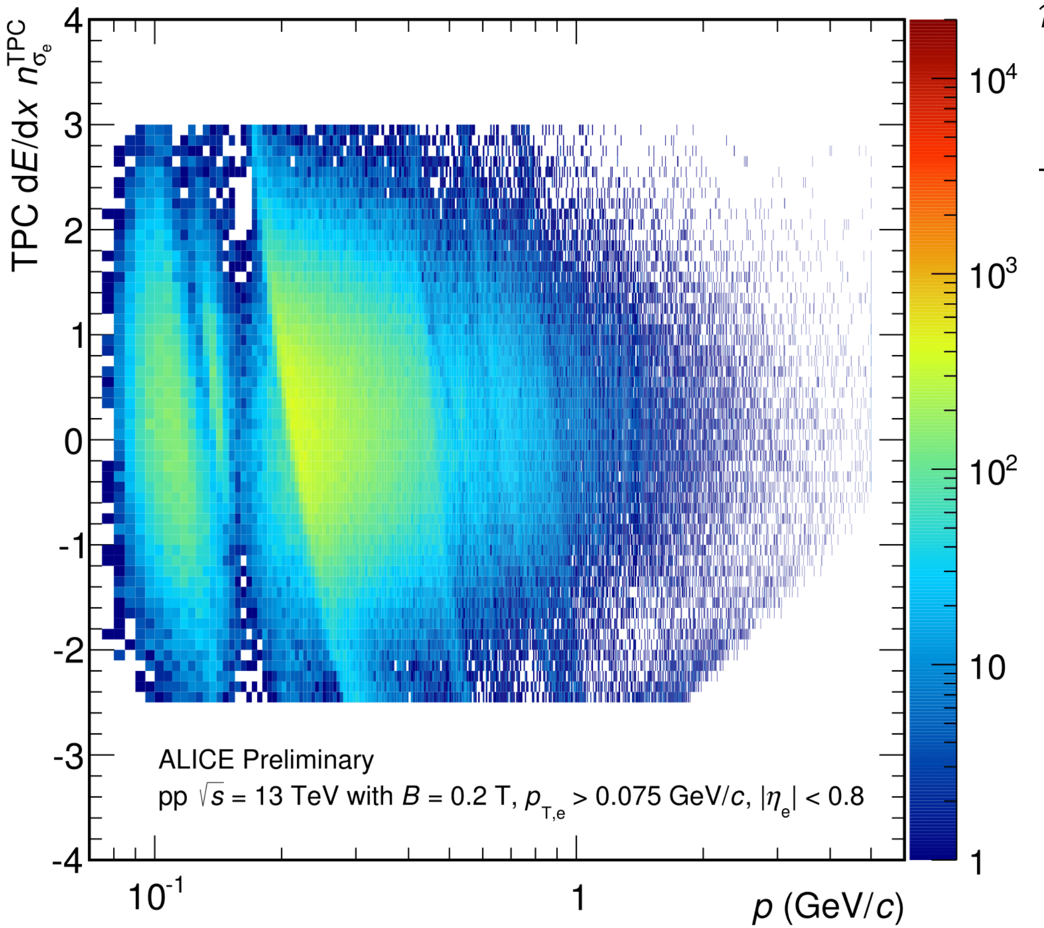
- Pion crossing
- No ITS PID available in RUN 3

→ New eID approach required

Electron identification

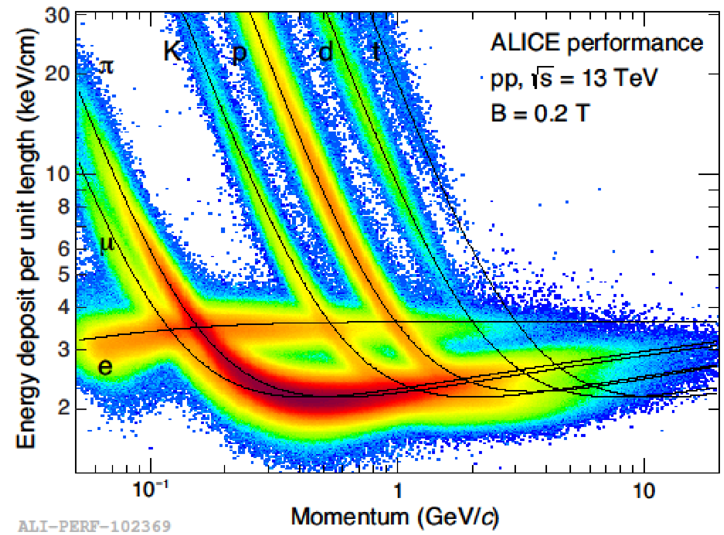
New Scheme

$$n_{\sigma_e} = \frac{\left(\frac{dE}{dx}\right)_{\text{measured}} - \left(\frac{dE}{dx}\right)_{\text{expected}}}{\sigma}$$



ALI-PREL-148876

- Electron 3σ selection using TPC dE/dx & TOF if available
  → Residual hadron contamination



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Electron identification

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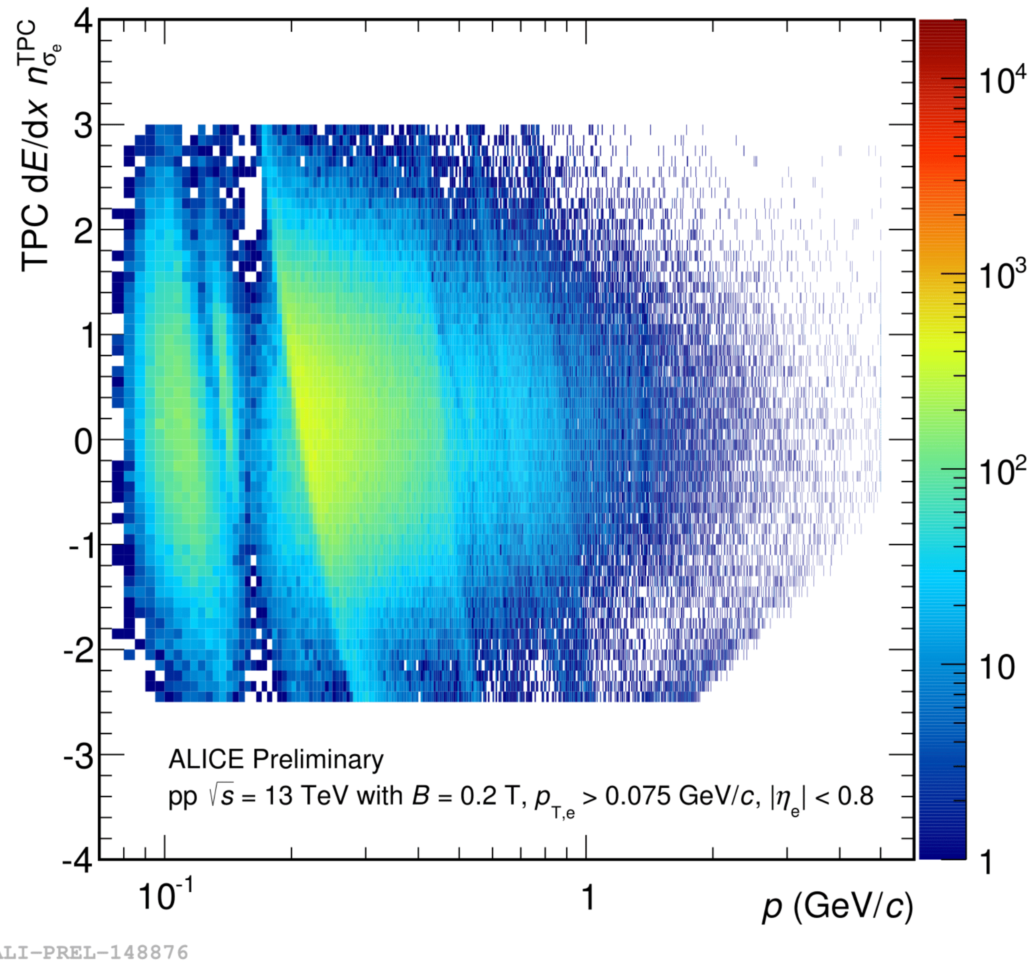

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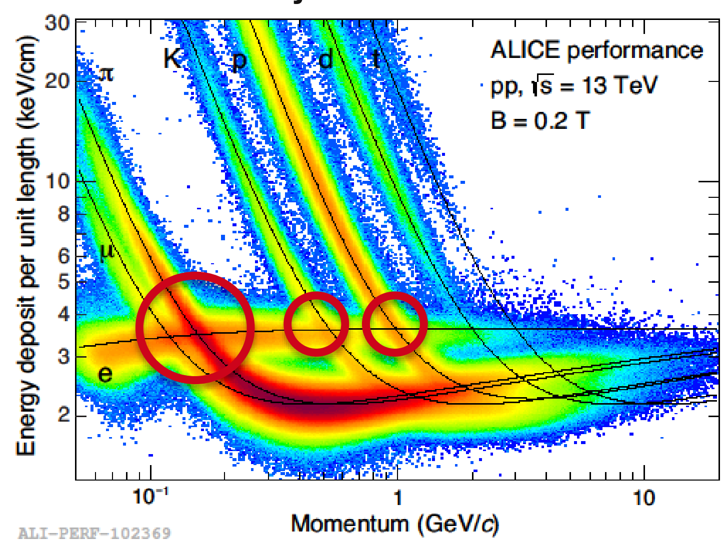
- 3σ hadron rejection in the TPC



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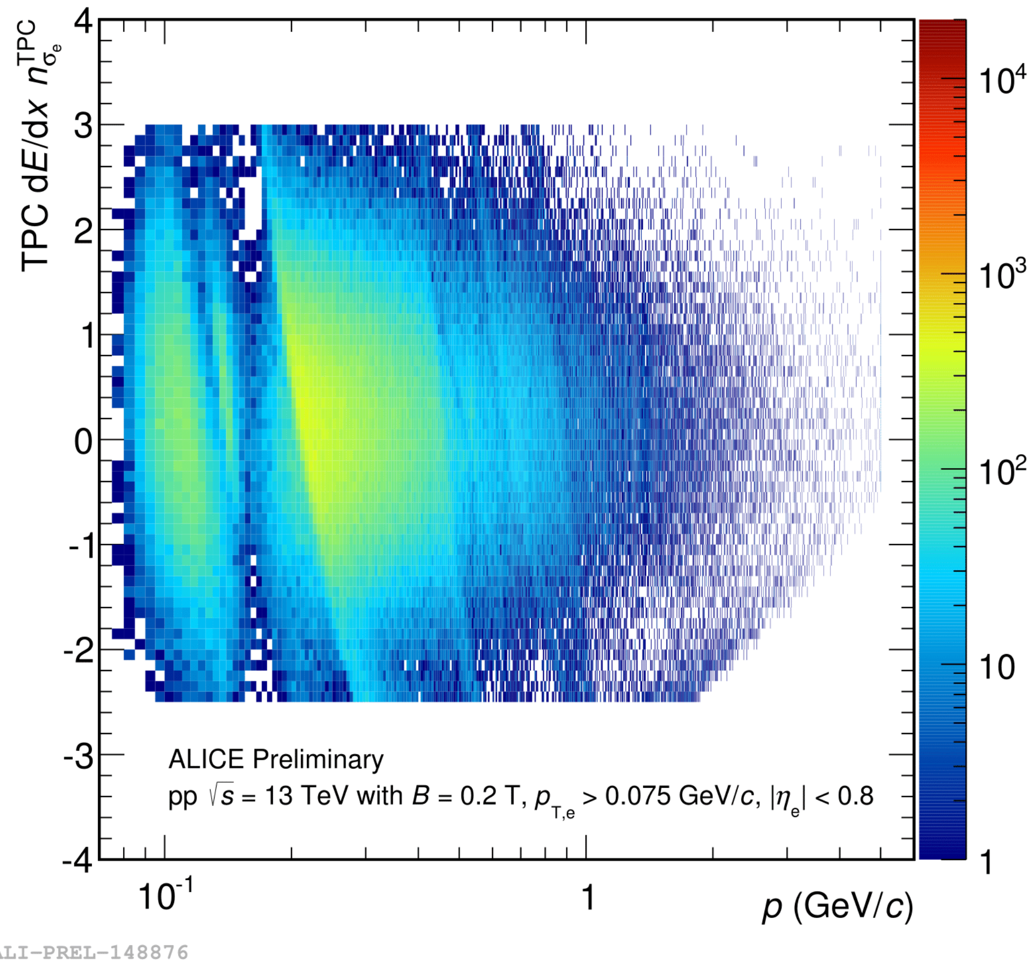

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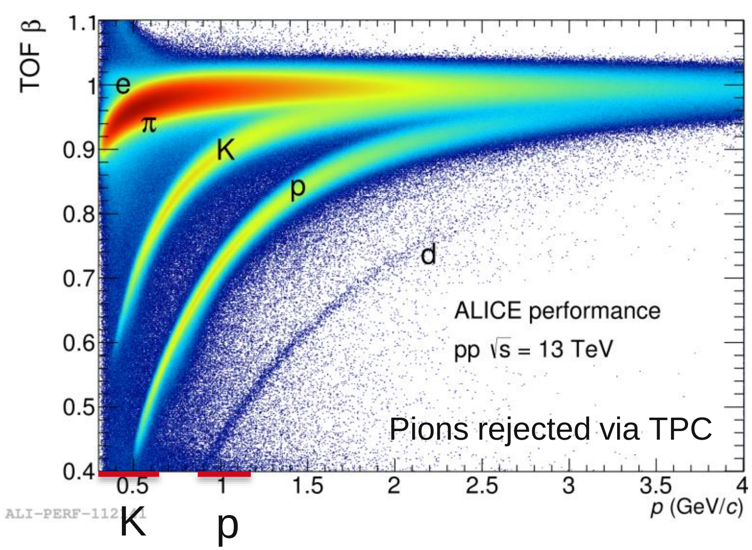
- Electron 3σ selection using TPC dE/dx & TOF if available
  → Residual hadron contamination
- 3σ hadron rejection in the TPC
- TOF info to recover electron



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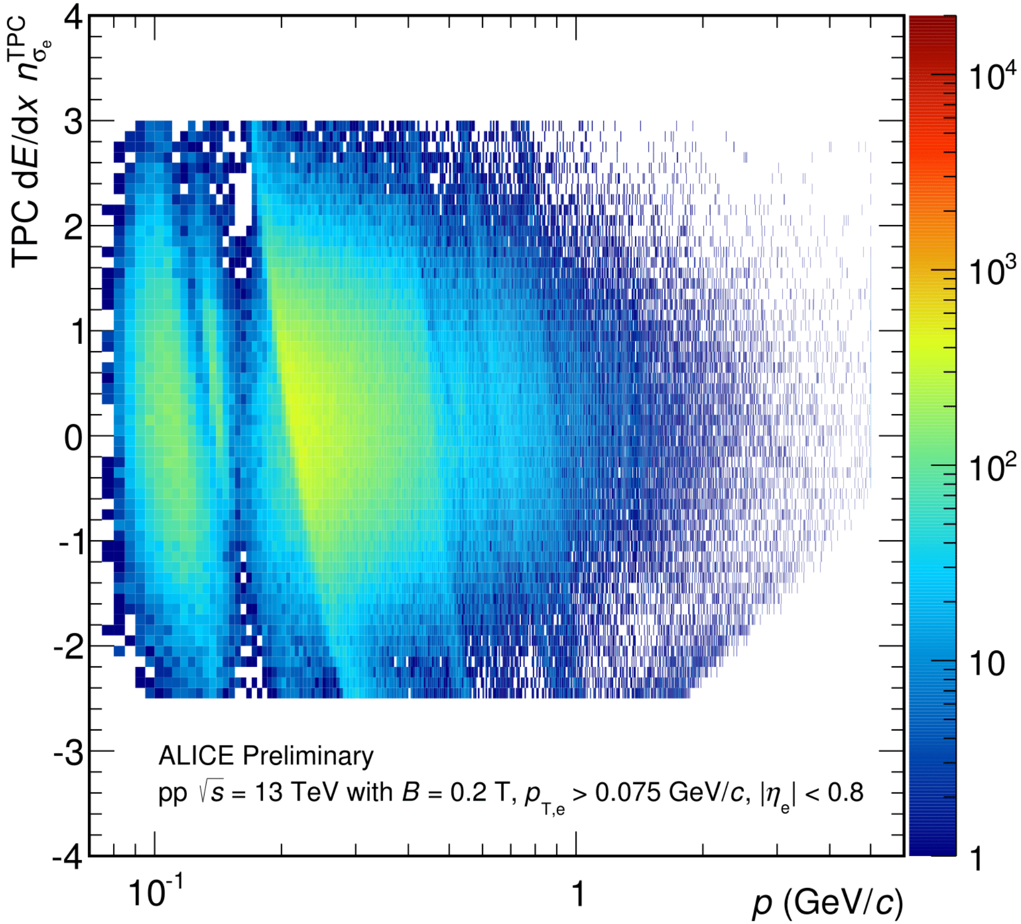


ALI-PREL-148876

$$n_{\sigma_e} = \frac{\left(\frac{dE}{dx}\right)_{\text{measured}} - \left(\frac{dE}{dx}\right)_{\text{expected}}}{\sigma}$$

- Electron 3σ selection using TPC dE/dx & TOF if available
  → Residual hadron contamination
- 3σ hadron rejection in the TPC
- TOF info to recover electron

→ Similar electron purity but higher electron selection efficiency compared to requiring TOF, down to $p_T < 0.075$ GeV/c

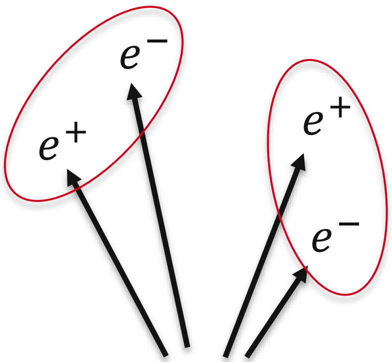
Signal extraction

Combinatorial pairing of all electron and positron candidates:

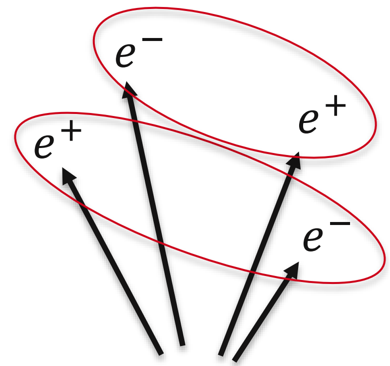
– Unlike-sign (ULS) pairs:
contain real signal, correlated & combinatorial background

– Like-sign (LS) pairs:
contain correlated & combinatorial background

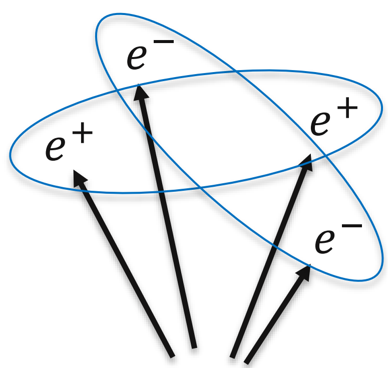
→ Signal **S** = ULS – LS · R
R: rel. acceptance correction factor
R = $\mathrm{ULS}_{\mathrm{mix}}/\mathrm{LS}_{\mathrm{mix}}$



Signal (S)



Background (B)



Estimation

Signal extraction

Combinatorial pairing of all electron and positron candidates:

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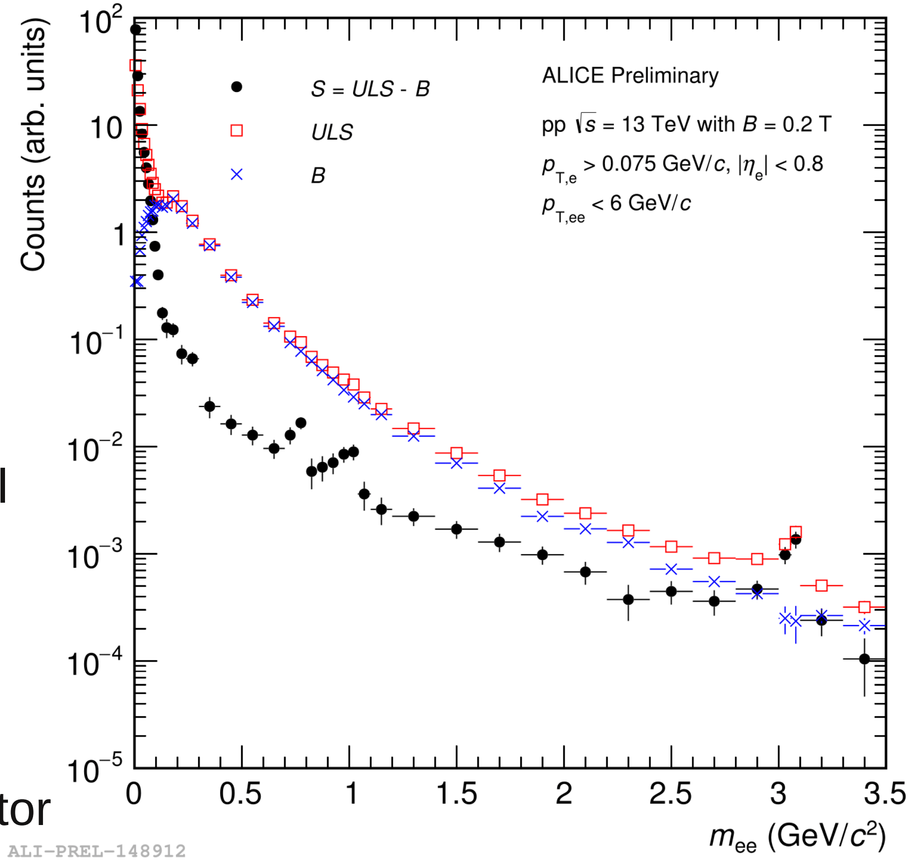
contain real signal, correlated & combinatorial background

– Like-sign (LS) pairs:
contain correlated & combinatorial background

→ Signal **S** = ULS – LS · R
R: rel. acceptance correction factor
$$R = ULS_{mix}/LS_{mix}$$



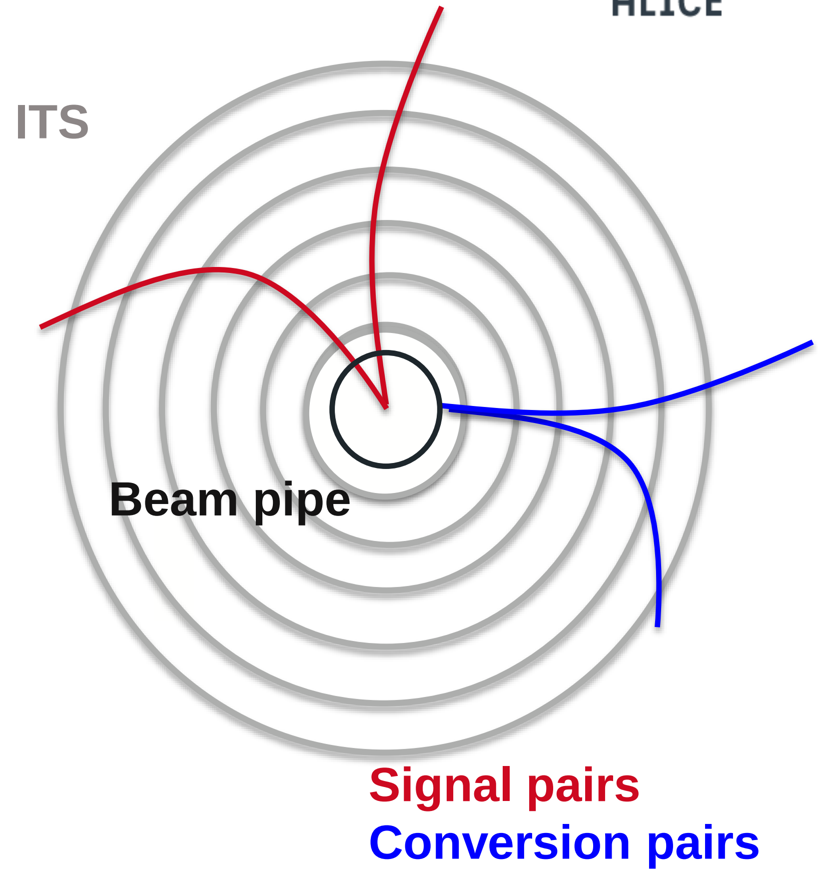
Low S/B: Reduction of combinatorial background key aspect of this analysis

Combinatorial background

Dominated by combinatorial pairs originating from

- π^0-Dalitz decays
- Conversions from beam pipe

Conversion pairs are “close” pairs
→ More likely to share an ITS cluster



Combinatorial background

Dominated by combinatorial pairs originating from

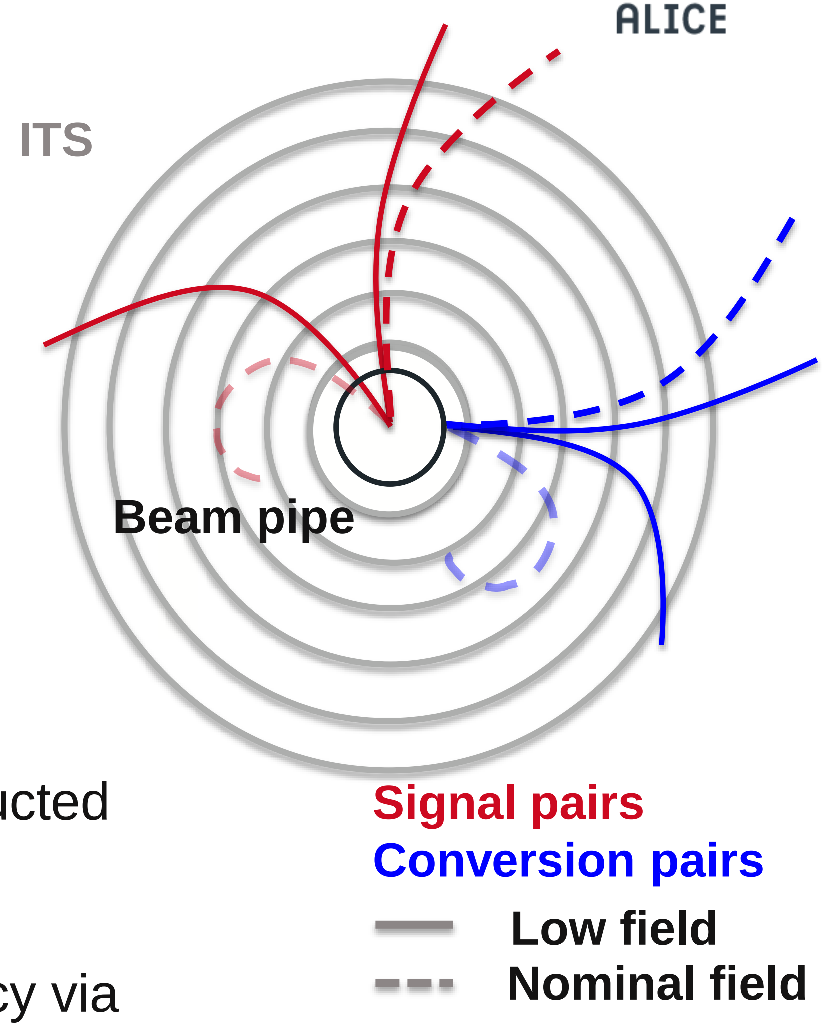
- π^0-Dalitz decays
- Conversions from beam pipe

Conversion pairs are “close” pairs
→ More likely to share an ITS cluster

Low-field configuration:

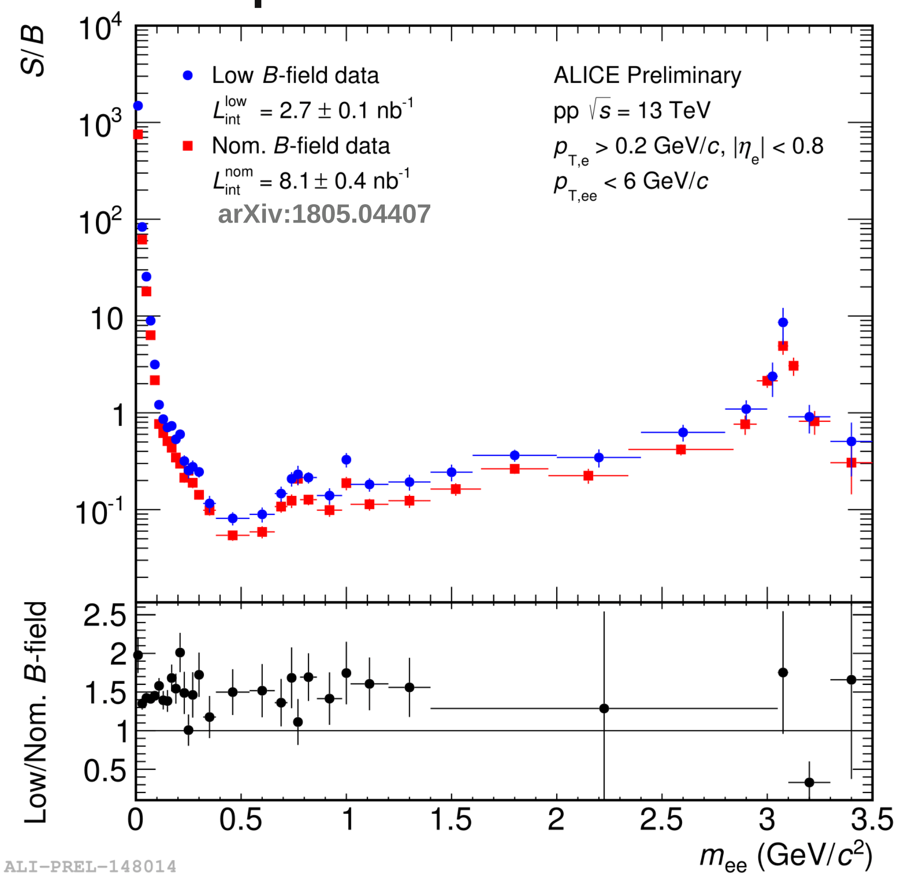
- More conversion pairs get reconstructed (especially asymmetric pairs)

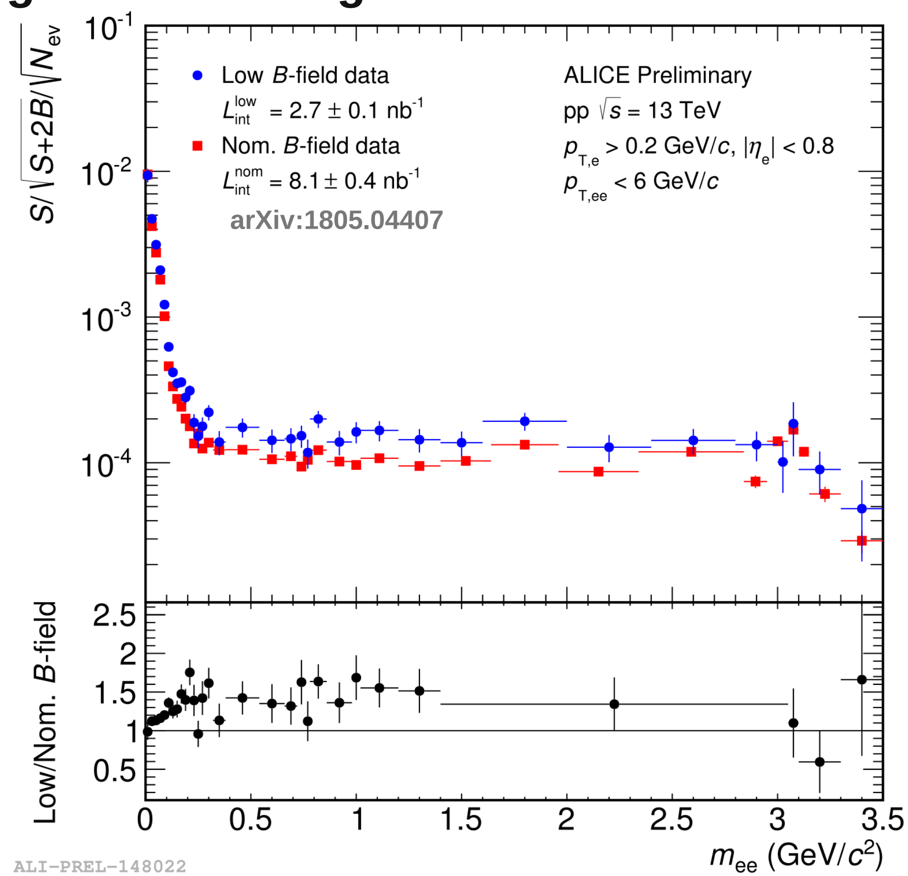
→ Higher conversion rejection efficiency via a veto on shared clusters in the ITS



Effects of low field

Comparison to nominal field setting in S/B and significance



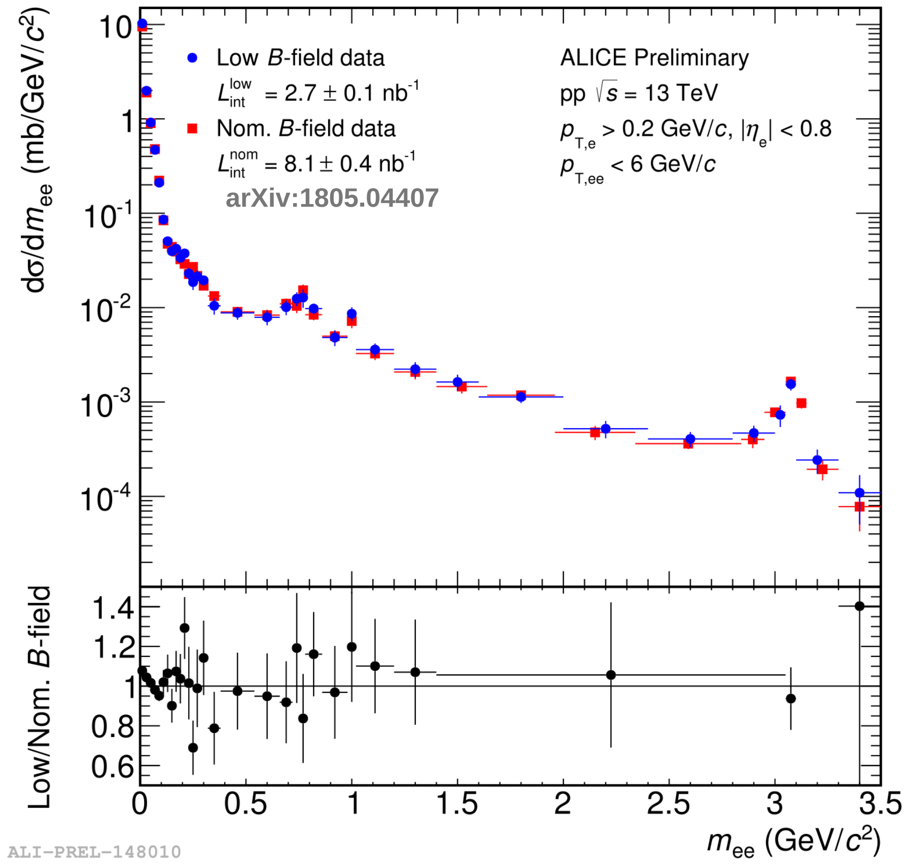


Higher tracking and PID efficiency in **low field**:

- Improvement in S/B especially for low invariant masses
- Clear boost in significance per event: reduction of stat. uncertainty

Corrected spectra

Comparison to nominal-field setting



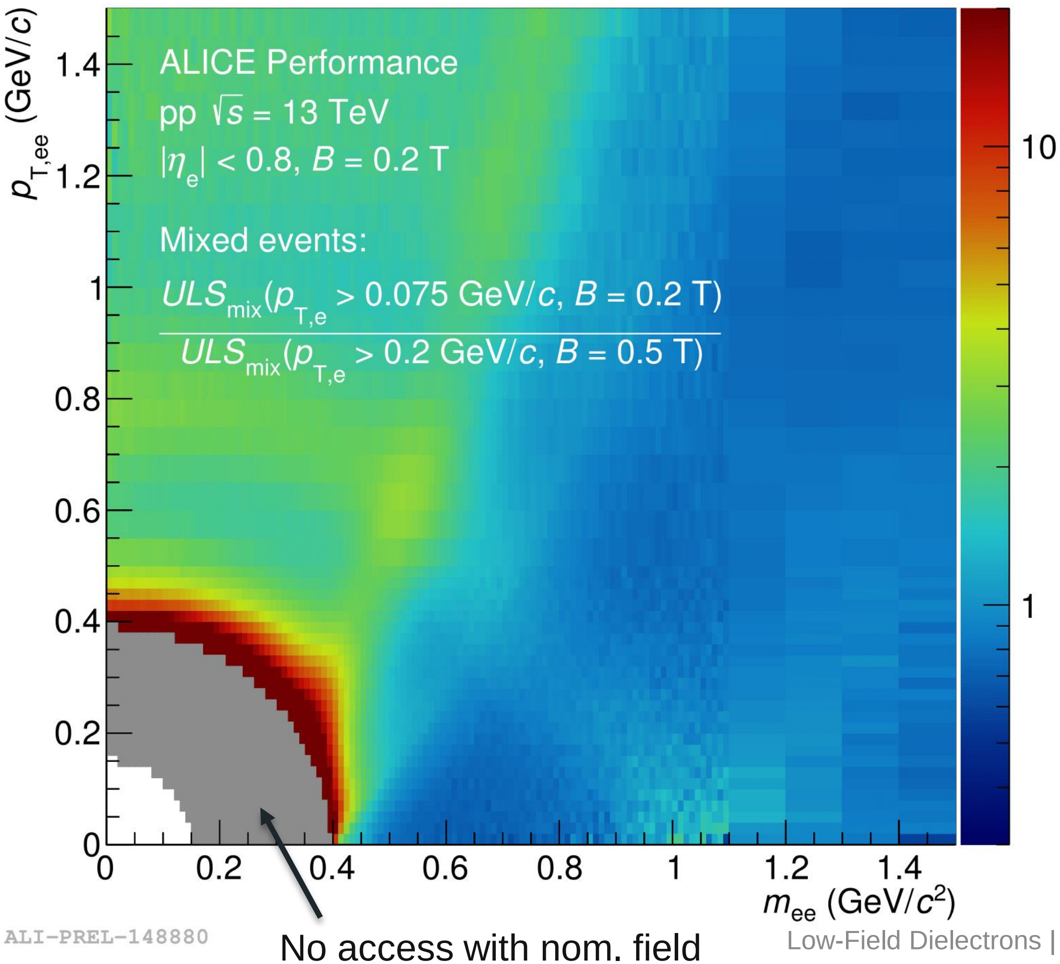
Comparison with published data within same kinematic region: ($p_{\rm T} \geq 0.2$ GeV/c)

- Good agreement within statistical uncertainties
- Effect of low-field configuration on the resolution small within the given statistics
- Similar significance compared to measurement at nominal field (~ $440 \cdot 10^6$ vs. ~ $150 \cdot 10^6$ events)

Low-B-Field Acceptance

Effects of the magnetic field

Mixed events: **Low Field** ($p_{\mathrm{T}} > 75$ MeV/c) / **Nom Field** ($p_{\mathrm{T}} > 200$ MeV/c)

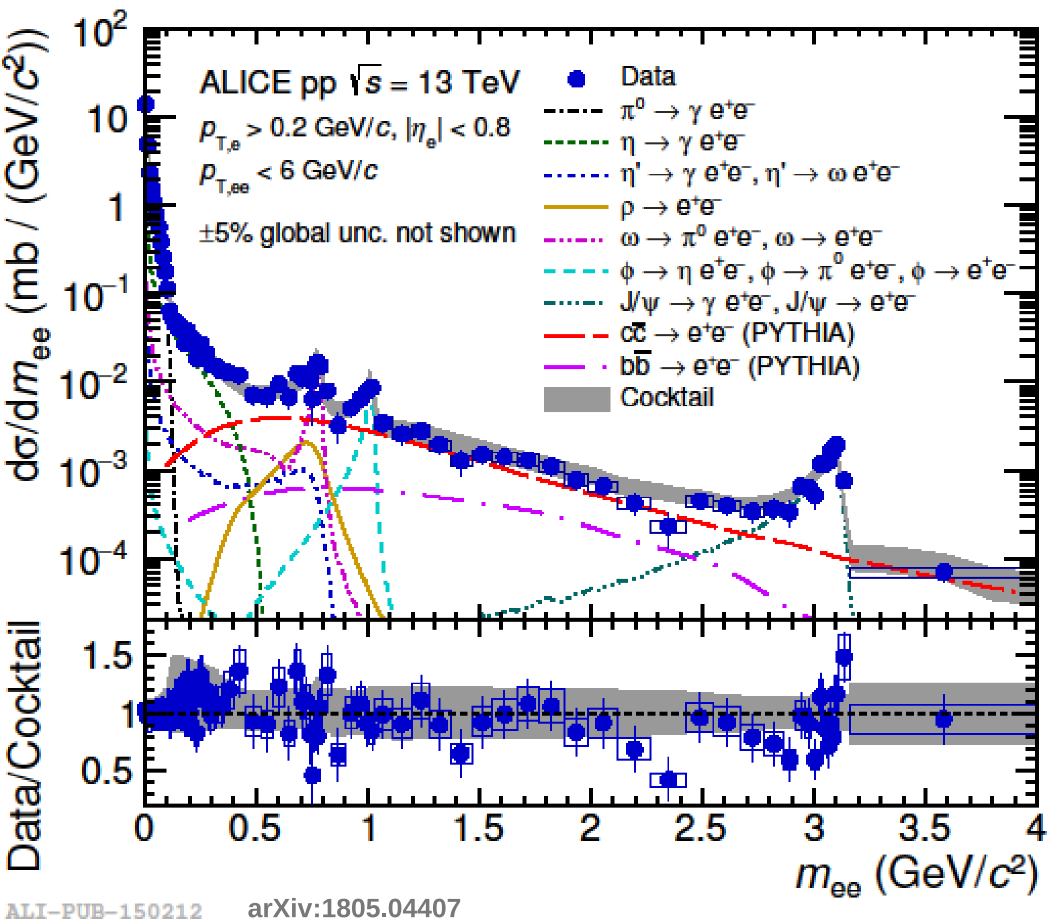


Gain in phase space with low field:

- Acceptance: lower single-leg p_{T}
- Efficiency: TOF

→ Increase sensitivity for soft virtual-photon production

Corrected spectra & hadronic cocktail



arXiv:1805.04407

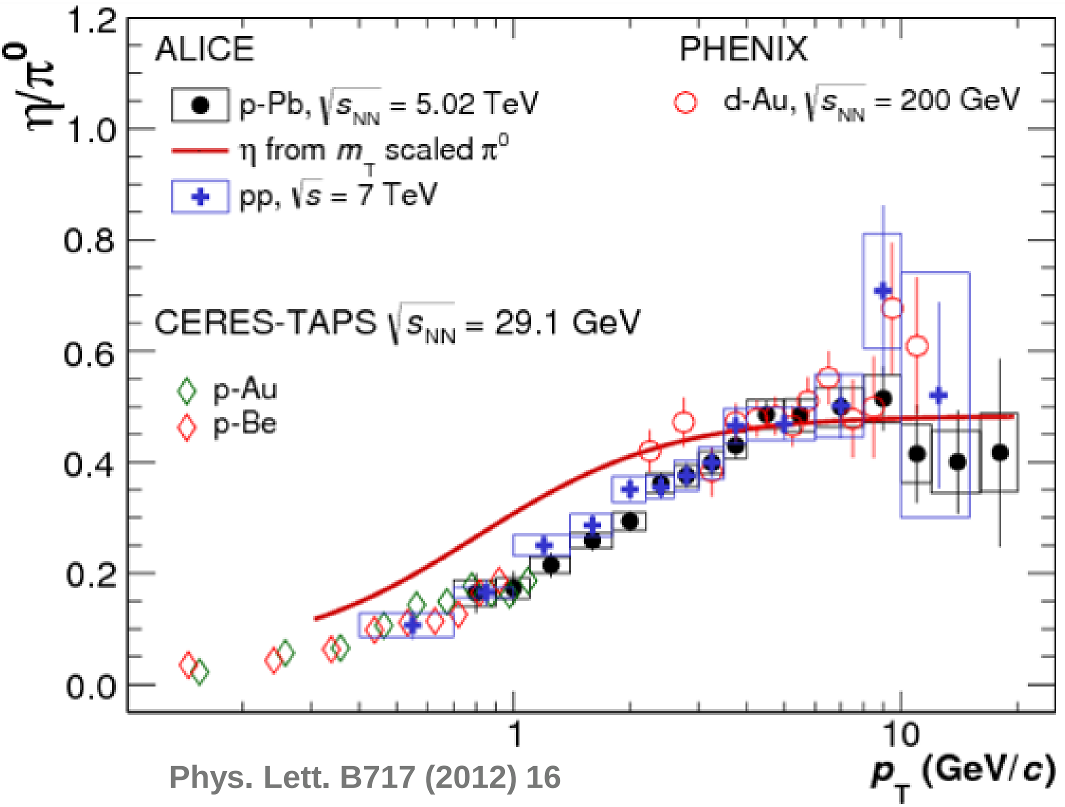
Cocktail: (analogous to nom.-field ana.)

- LF based on 13 TeV $\pi^\pm$ parametrisations combined with particle ratios for η, ρ and ω
- m_T scaling for remaining particles
- HF generated with Pythia6 scaled with FONLL cross sections to 13 TeV
- J/ψ based on 7 TeV parametrisation scaled with FONLL to 13 TeV

→Good agreement within uncertainties

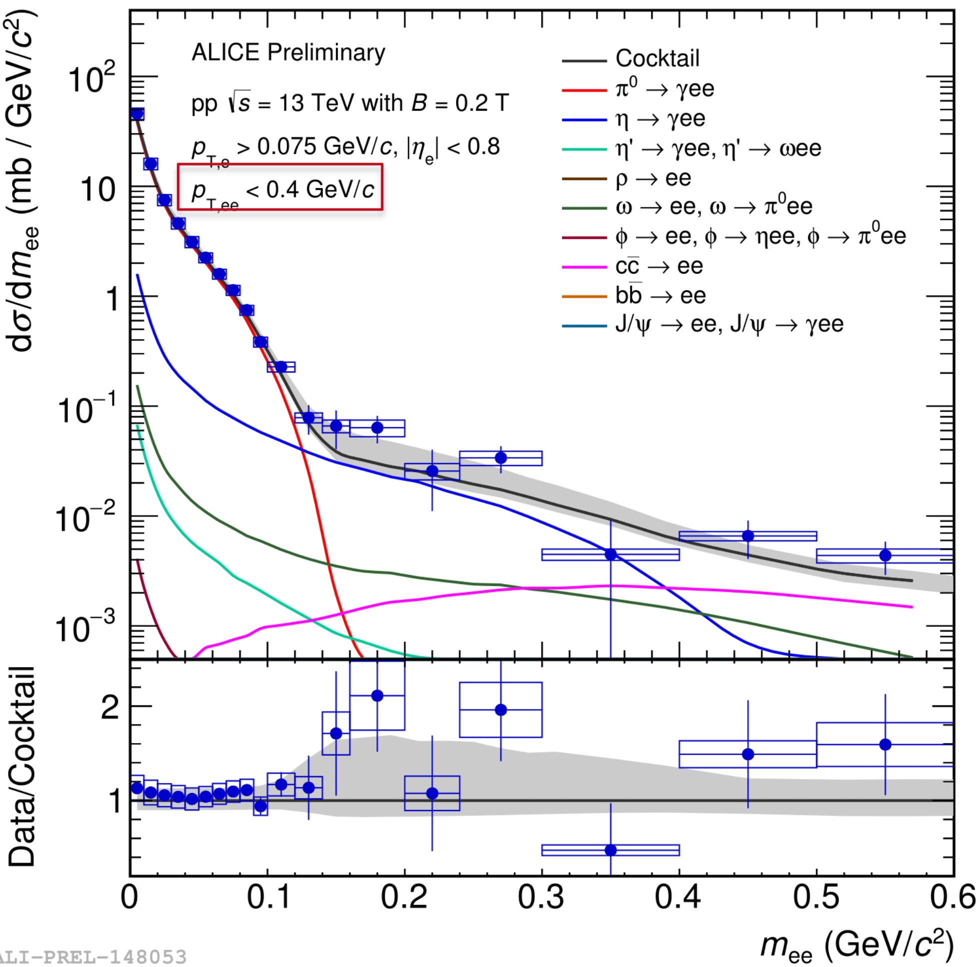
Hadronic Cocktail

Low-p_{T} η parametrization



- η contribution dominant in the LMR
- ALICE measurement only down to $p_T < 0.4\ \mathrm{GeV}/c$
- m_{T} scaling overshoots η at low p_T
- Ceres – Taps measurement used to further constrain the cocktail at low p_{T}
- η/π^0 ratio independent of collision system and energy

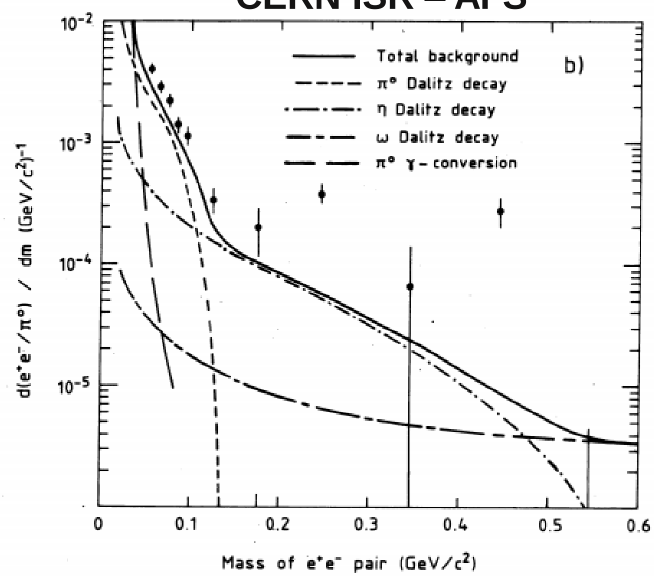
Invariant-mass spectra in LMR



– Hint for enhancement at LHC energies?
→ 2.2σ stat. significance integrated over $0.14 < m_{ee} < 0.6\ \mathrm{GeV}/c^2$ over the central value of the cocktail

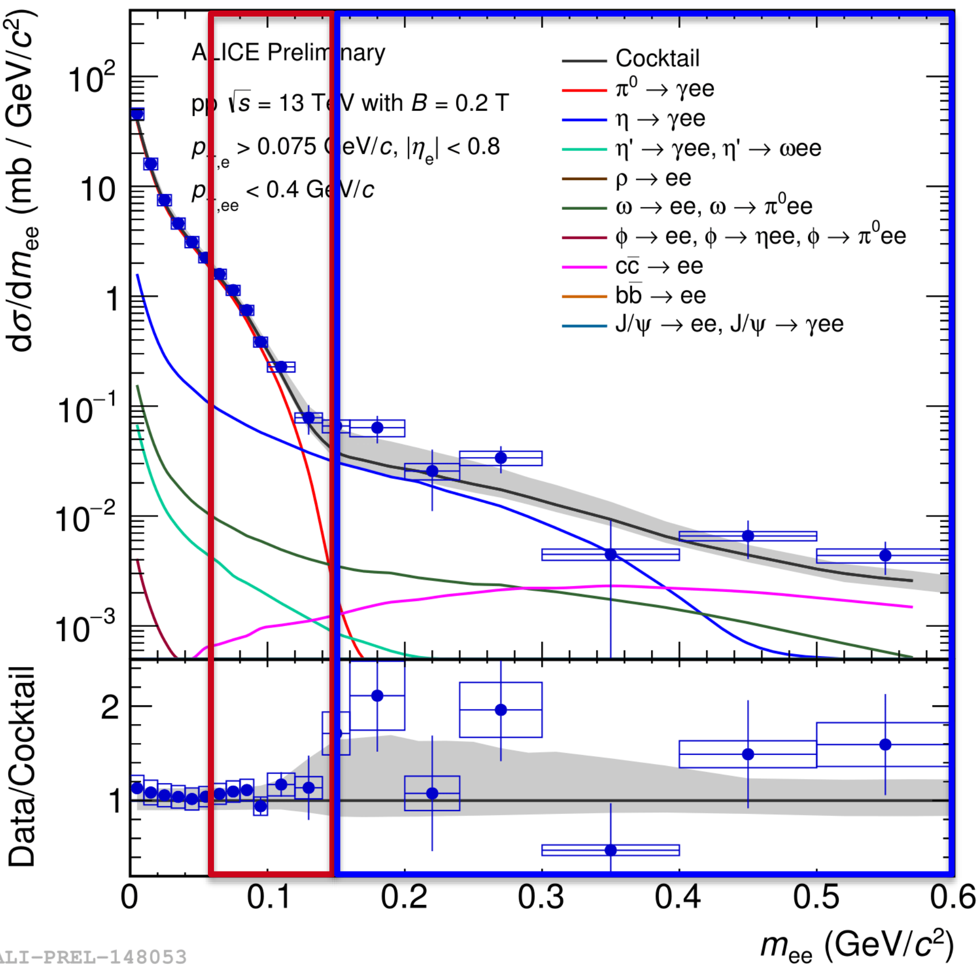
– Cocktail uncertainties from m_T scaling
→ overpredicts η at low p_T

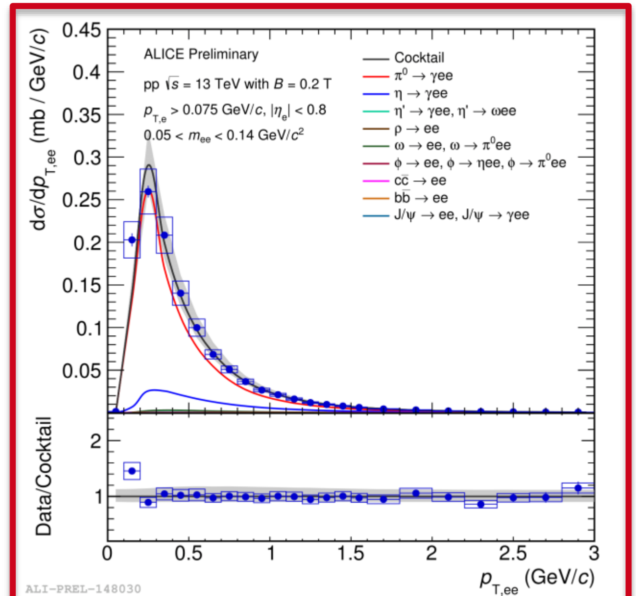
CERN ISR – AFS



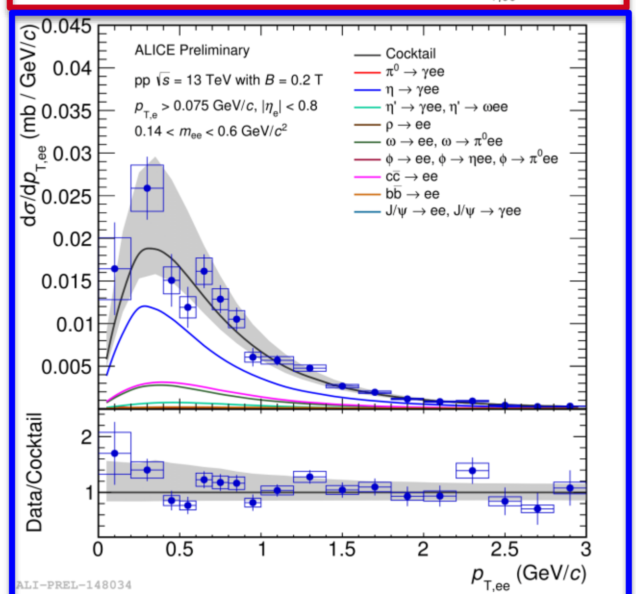
V. Hedberg, PhD thesis, Lund (1987)

Invariant-mass spectra





π dominated region



η dominated region

Conclusion

- First results of the dielectron measurement in pp collisions at $\sqrt{s}$ = 13 TeV with the low-field configuration
- Good agreement within stat. uncertainties with nom.-field analysis
- **Low field**: Increase in significance and S/B
- Low-field gives access to a new phase space at low momenta

→ Sheds new light on the LMR excess seen at the ISR

→ Low-$\boldsymbol{p}_{\mathbf{T}}$ $\boldsymbol{\eta}$ measurement required for a final conclusion

Outlook

- New low-B field data taking in 2018: Increase in statistics by a factor of 3
  - → Expect to reach a stat. significance of about 3σ
- Study multiplicity dependence (seen by AFS)
  - → Constrain for the underlying production mechanism