

# Data Reanalysis Efforts in Electron Positron Alliance



Yen-Jie Lee (MIT)



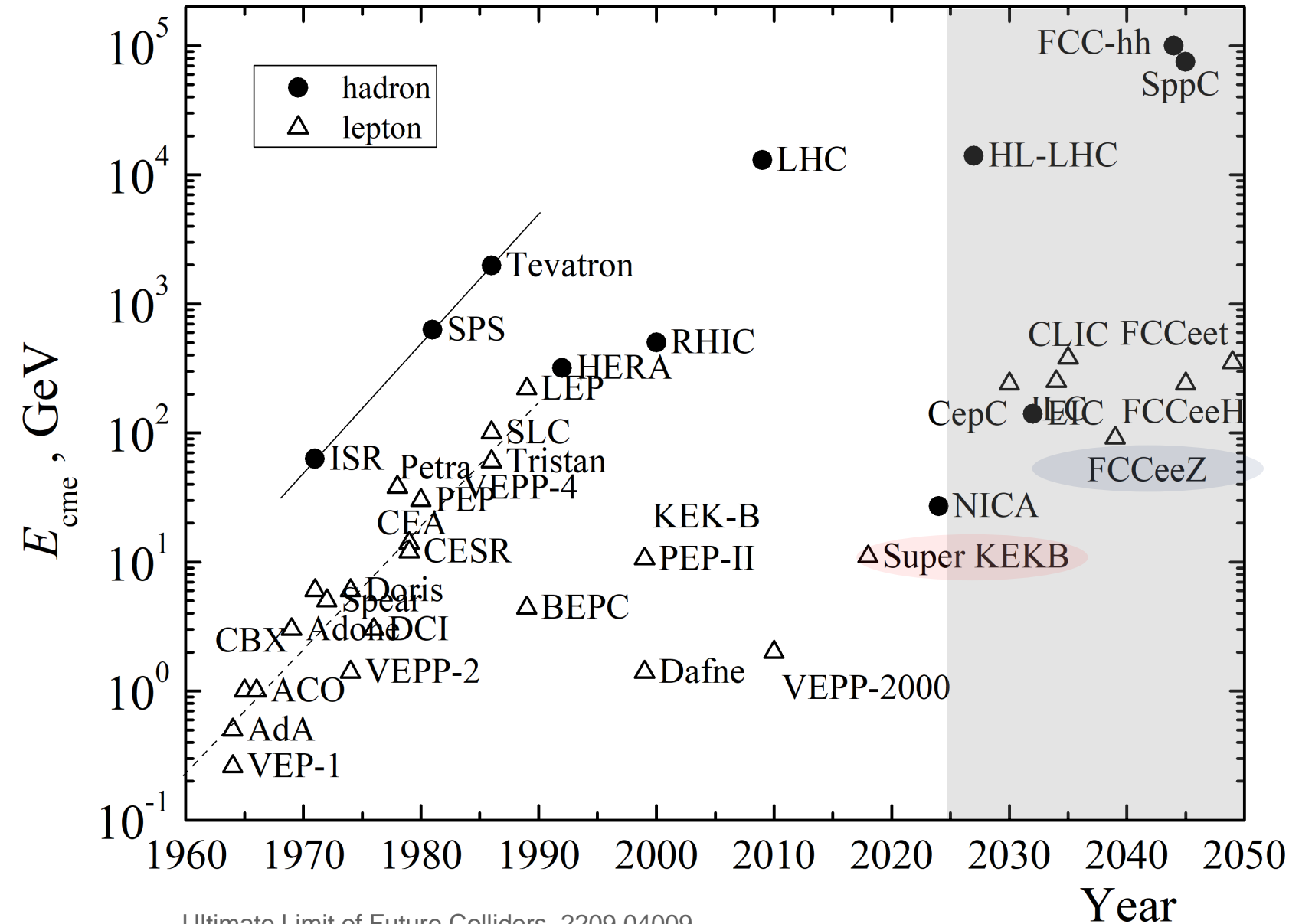
RHIC DAP Round Table Discussion Meeting  
April 9<sup>th</sup> 2026



MIT HIG group's work was supported by US DOE-NP



# Landscape of $e^+e^-$ Colliders



Ultimate Limit of Future Colliders, 2209.04009

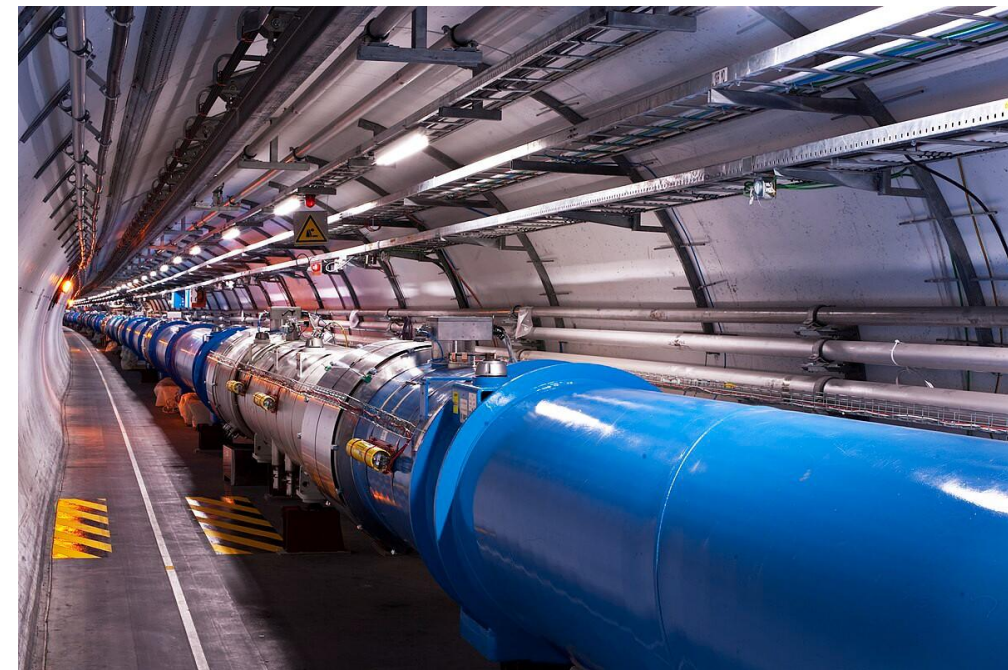
Operational  $e^+e^-$  machines  $\leq 11$  GeV

Previous  $e^+e^-$  machines with  $\sqrt{s} \geq m_Z$  used for precision QCD. Proposals for new colliders in future decades (For instance, FCCee in 2040s)

Archived data combined with **modern techniques** and exp/the collaborations for new insights into those questions key goal of  $e^+e^-$  alliance



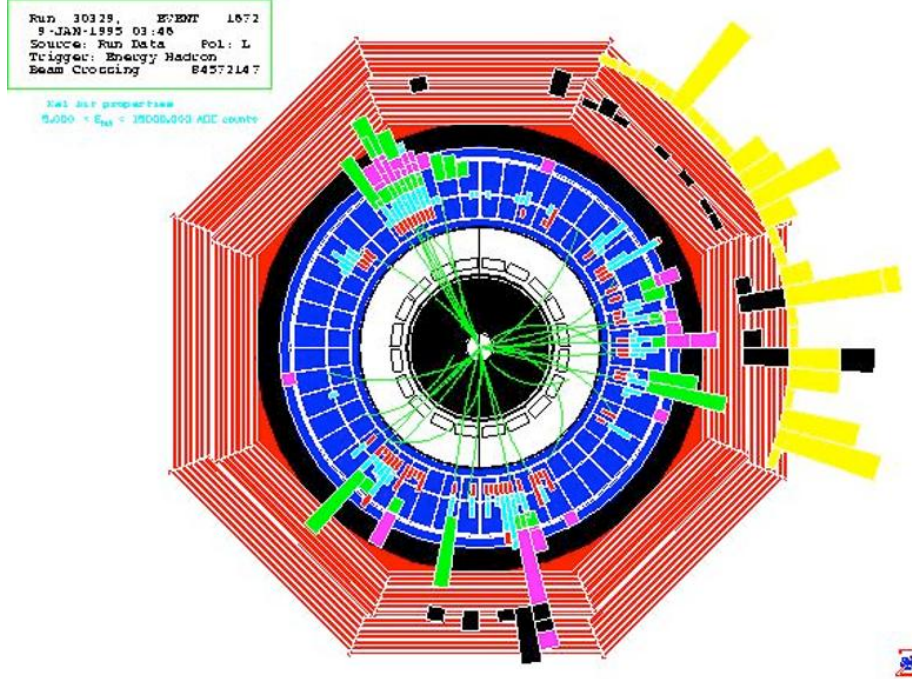
# Re-visiting LEP Archived Data



Tunnel (1983-1988) —————> LEP collider (1989 - 2000) —————> LHC (2010 - )

- 30 years ago in LHC tunnel there was Large Electron Positron (LEP) Collider. Large samples at Z-pole and across range of  $\sim 40\text{-}200$  GeV, via high energy WW runs and radiative return
- The data from the experiments were archived (**and still state-of-art!**), presenting an exciting opportunity to revisit them in the future with new techniques and insights

# Opportunities with JADE and SLD Data



Event display from the SLD detector from the mid 1990s. Electron-positron collisions are into/out of the page and the debris is captured by a series of detectors.

Complementary to LEP dataset. Currently SLD data is available but not yet the simulation



JADE detector at the PETRA III accelerator collected data from 1979 to 1986.

Collision energy from **12 to 46.7 GeV**

Full simulation framework and data available

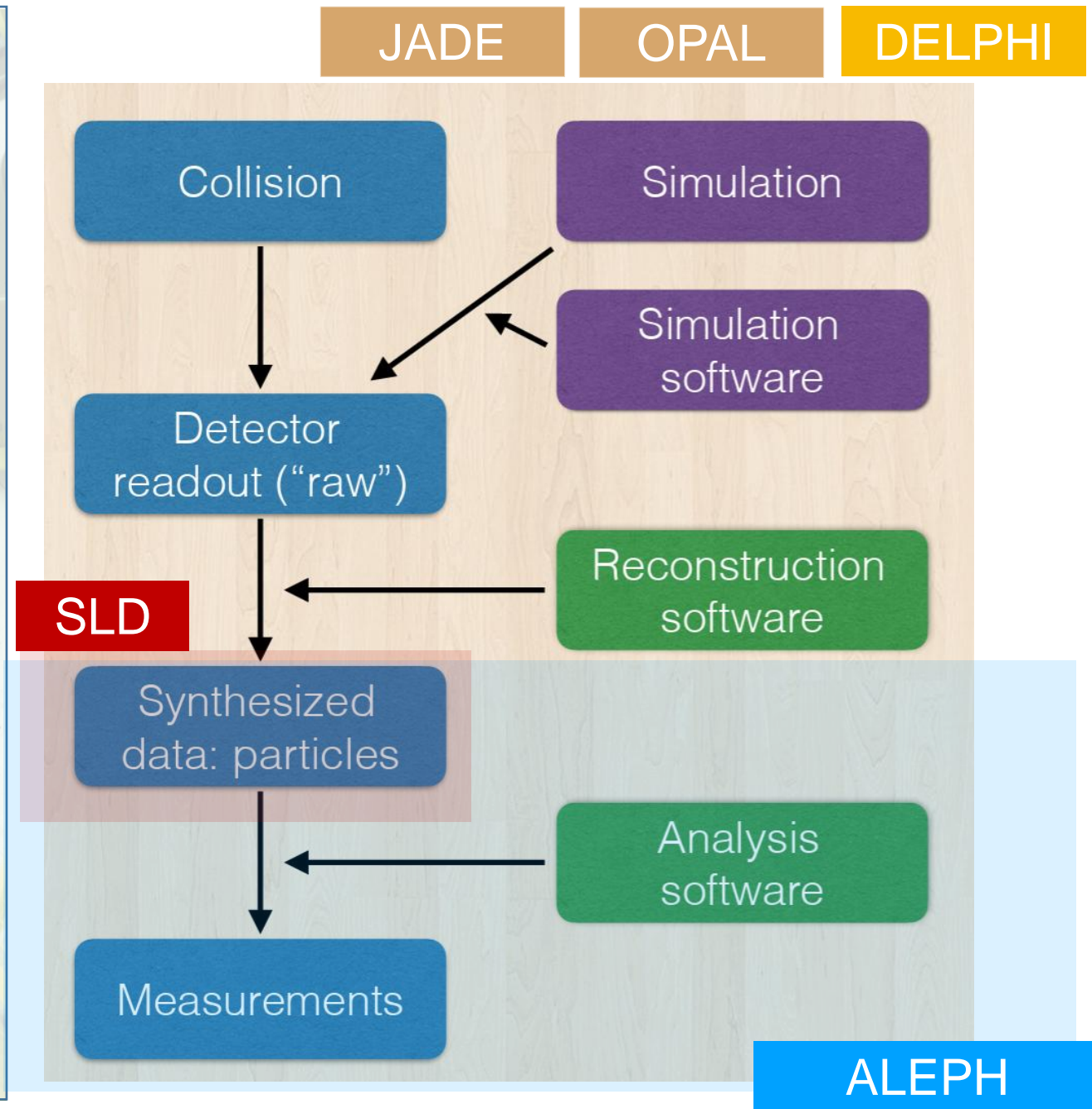
# Electron Positron Alliance

**Build a community** that is actively working on the curation, standardizing and reanalysis of archived electron-positron collision data

Enable **direct collaboration** between **experimentalists, analyzers and theorists**



Weekly group analysis meeting since 2017  
11 LEP notes and journal publications posted on arXiv  
2 journal publications with the Belle Collaboration  
> 70 presentations in conferences / workshops



# Electron-Positron Alliance



The Electron-Positron Alliance

About Papers Talks Links

Maximize scientific impact of collected data

Designed and maintained by Yi (Luna) Chen, Last updated Sep 21, 2025.

<https://ee-alliance.org>

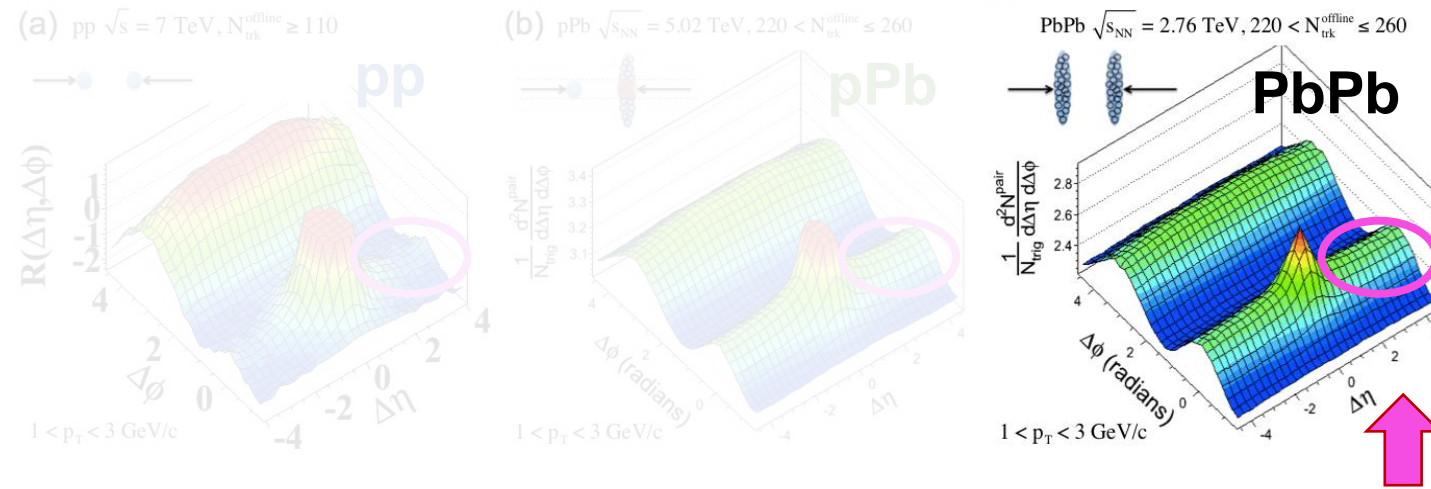


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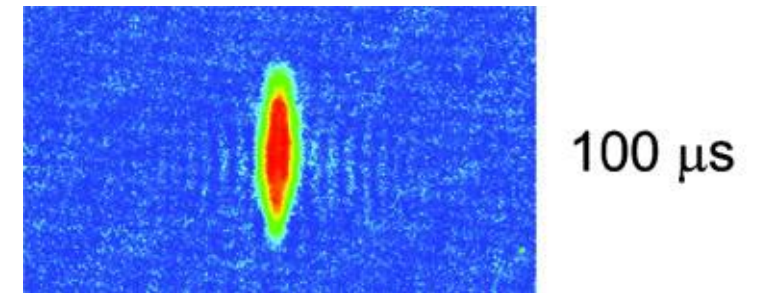
Data Reanalysis Efforts in Electron Positron Alliance



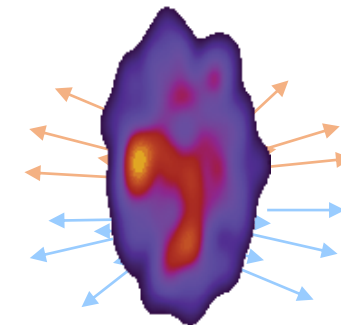
# Example I: High Density QCD



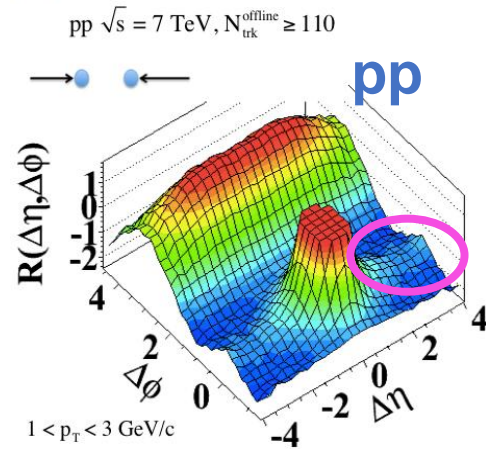
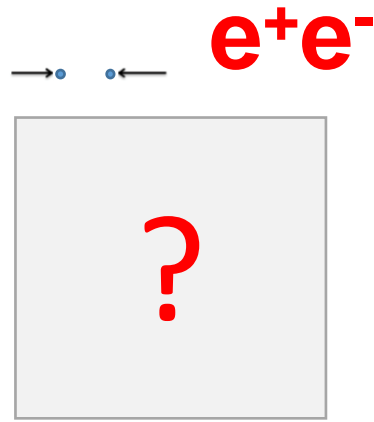
- “Ridge” in **Lead-Lead** collisions: Hydrodynamics Flow



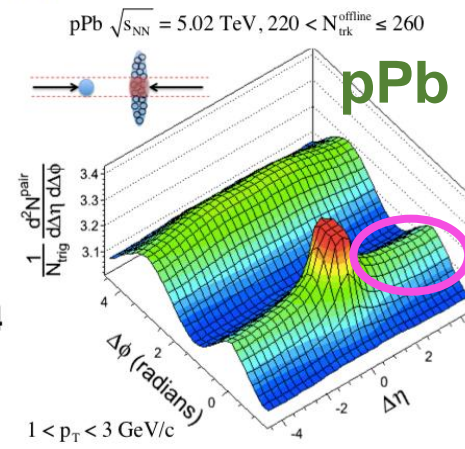
Quark Gluon Plasma



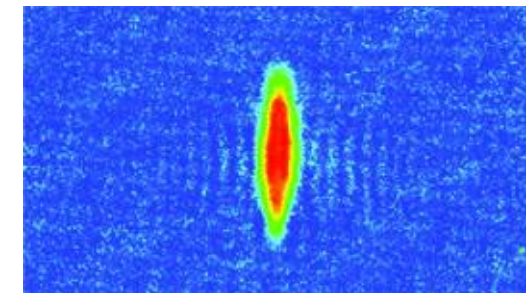
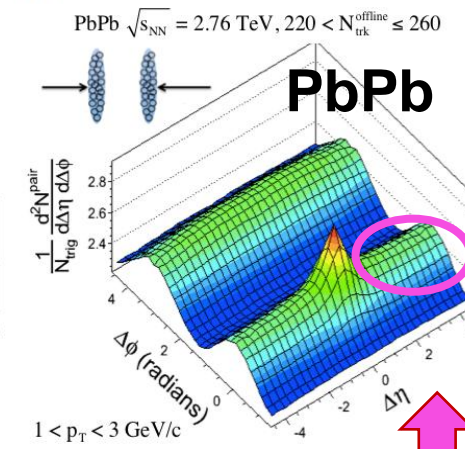
# “Flow Signal” in Small System



JHEP 1009 (2010) 091

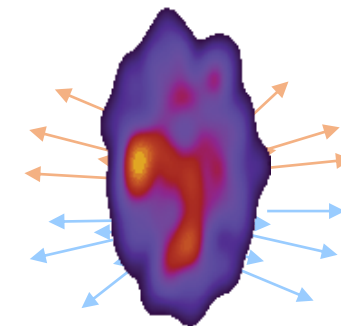


PLB 718 (2013) 795



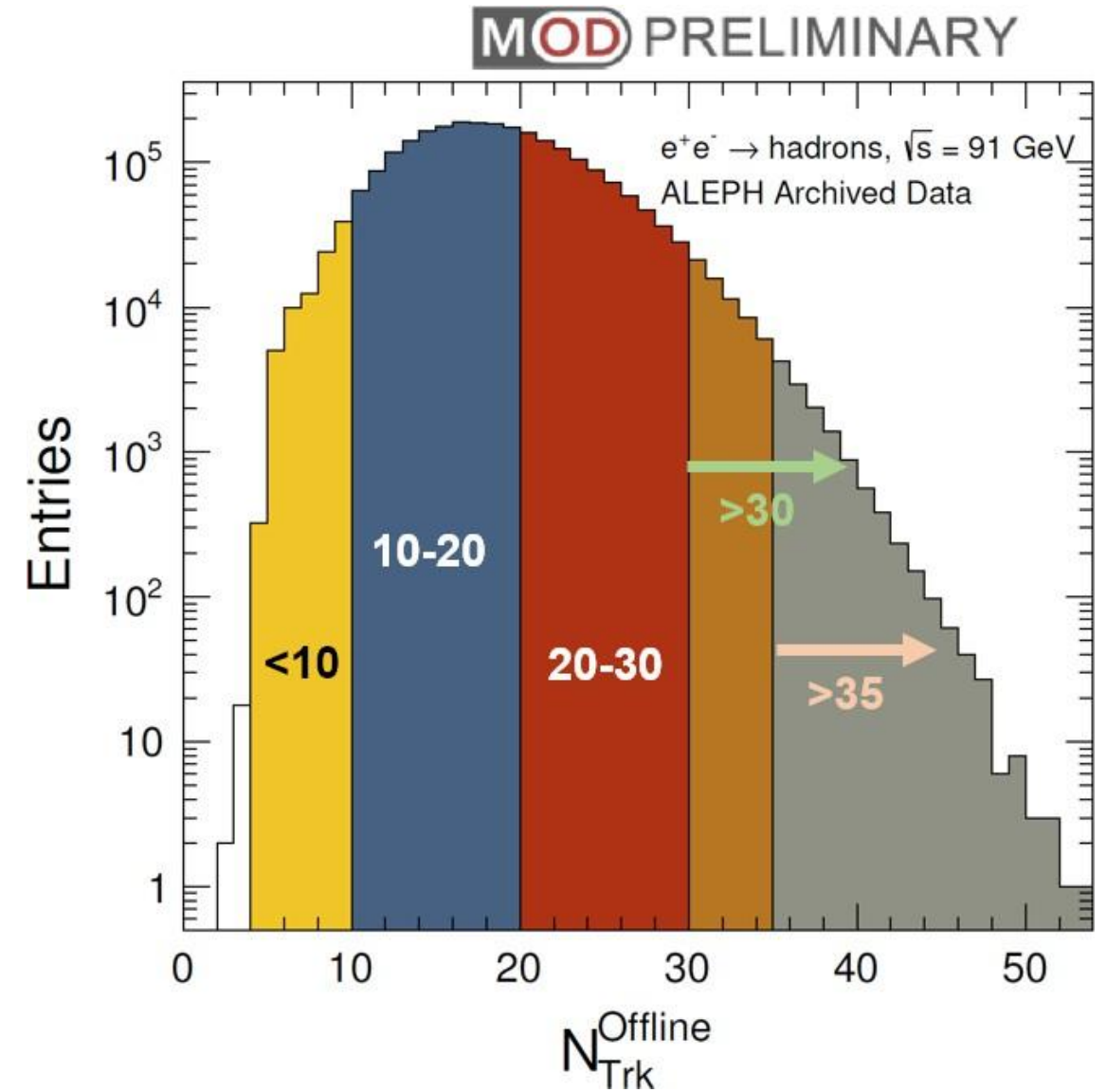
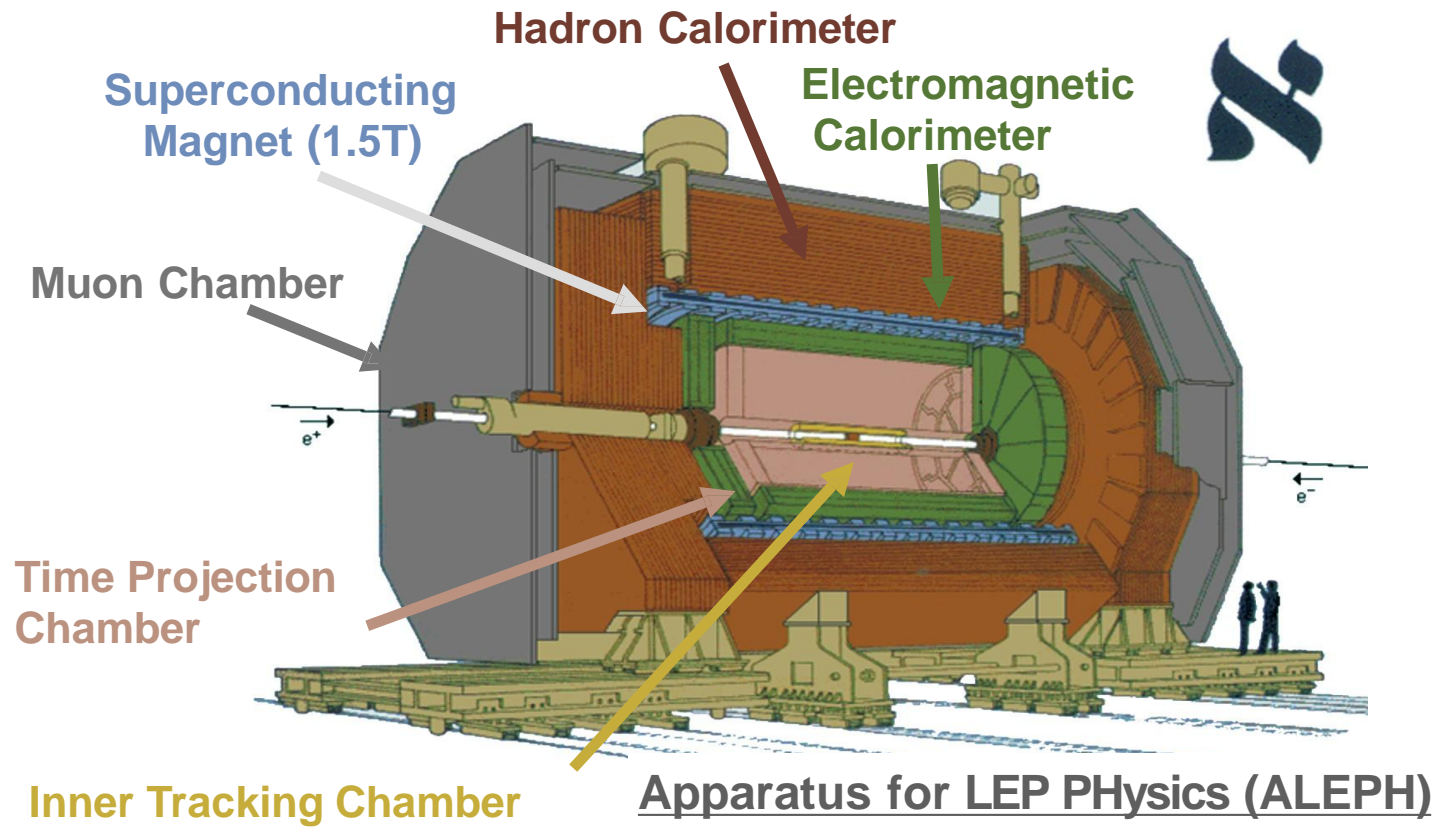
100  $\mu\text{s}$

Quark Gluon Plasma

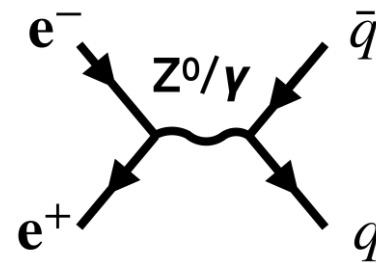


- “Ridge” in **Lead-Lead** collisions: Hydrodynamics Flow
- Observed in **high particle multiplicity** **proton-proton** (2010) and **proton-lead** (2013) collisions!!!
- What will happen to the smallest collision system: **Electron-positron** collision?

# ALEPH Experiment



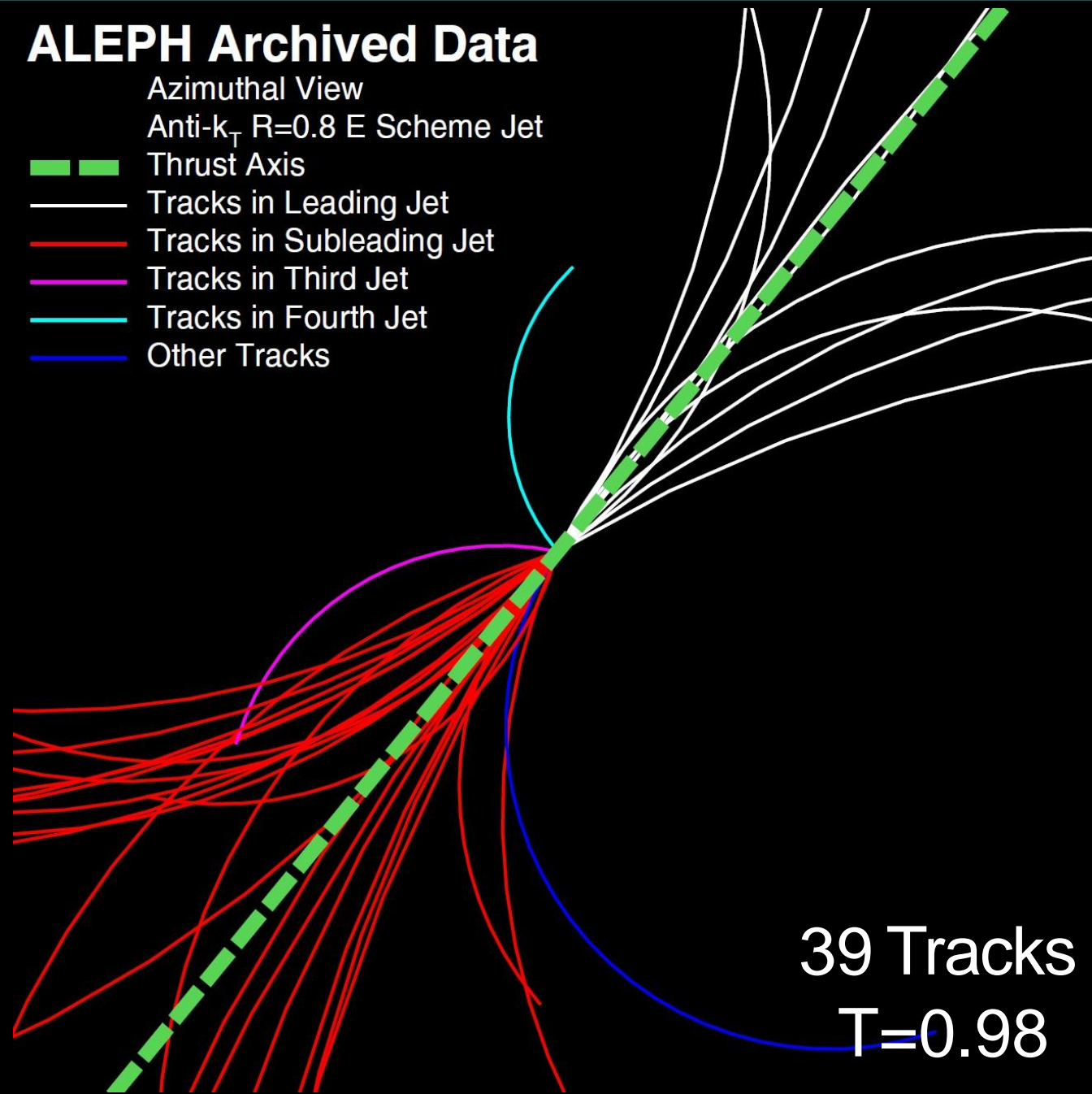
- LEP1  $e^+e^-$  data at Z pole (91 GeV) taken between 1992-1995
- Approximately 2.5 million hadronic events were recorded



# High Thrust Event in e<sup>+</sup>e<sup>-</sup> Collisions

## ALEPH Archived Data

- Azimuthal View
- Anti-k<sub>T</sub> R=0.8 E Scheme Jet
- Thrust Axis
- Tracks in Leading Jet
- Tracks in Subleading Jet
- Tracks in Third Jet
- Tracks in Fourth Jet
- Other Tracks



ALEPH archived data  
LEP1  $\sqrt{s} = 91$  GeV

39 Tracks  
 $T=0.98$

39 Tracks  
 $T = 0.98$

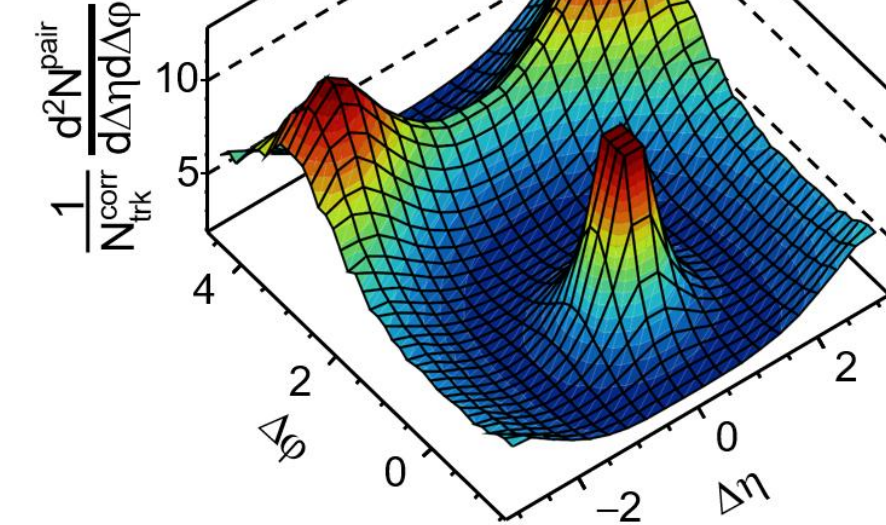
# Two Particle Correlation with LEP1 ALEPH Data

ALEPH  $e^+e^- \rightarrow \text{hadrons}$ ,  $\sqrt{s} = 91\text{GeV}$

$N_{\text{trk}} \geq 30$ ,  $|\cos(\theta_{\text{lab}})| < 0.94$

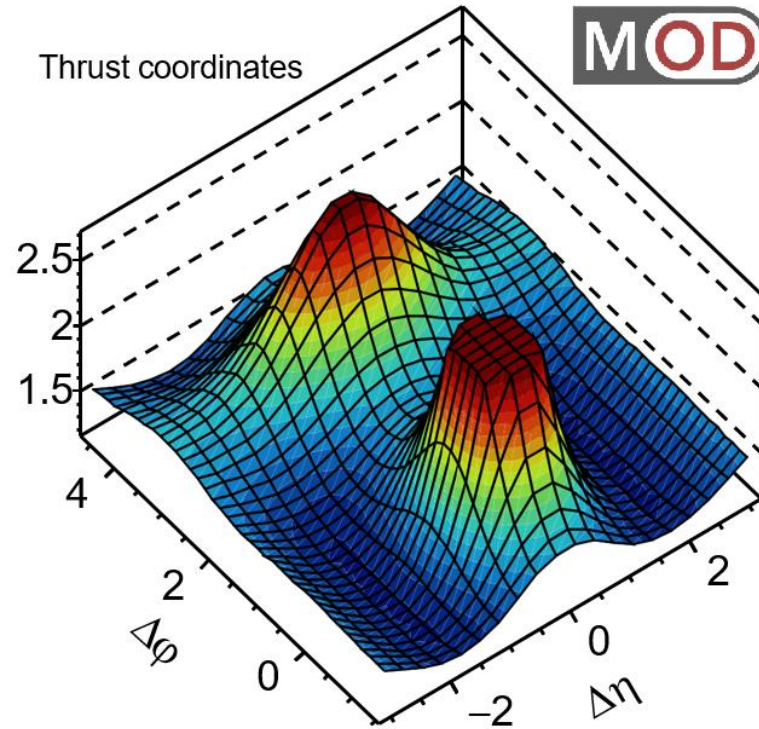
$p_{\text{T}}^{\text{lab}} > 0.2 \text{ GeV}$

Lab coordinates

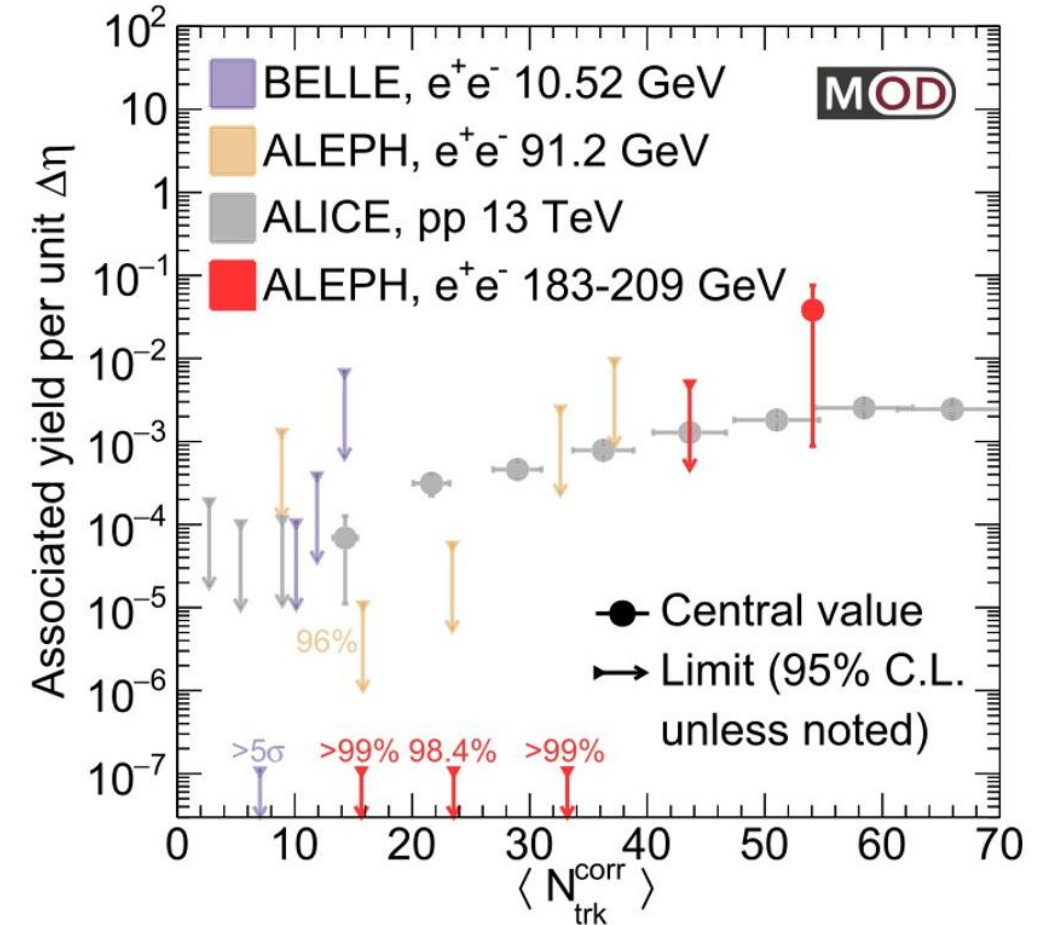


Lab Frame

Thrust coordinates

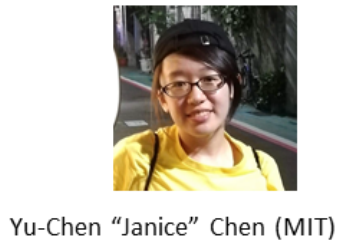
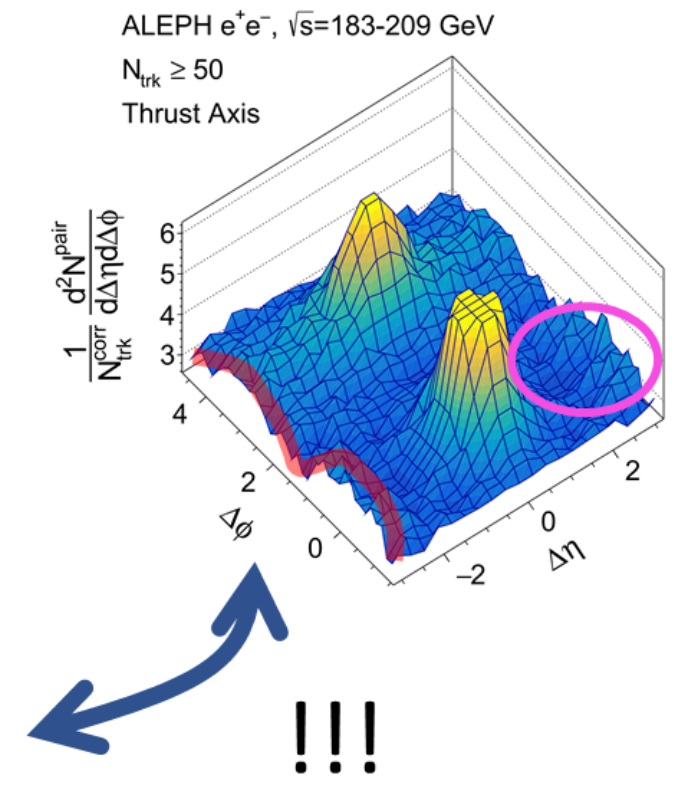
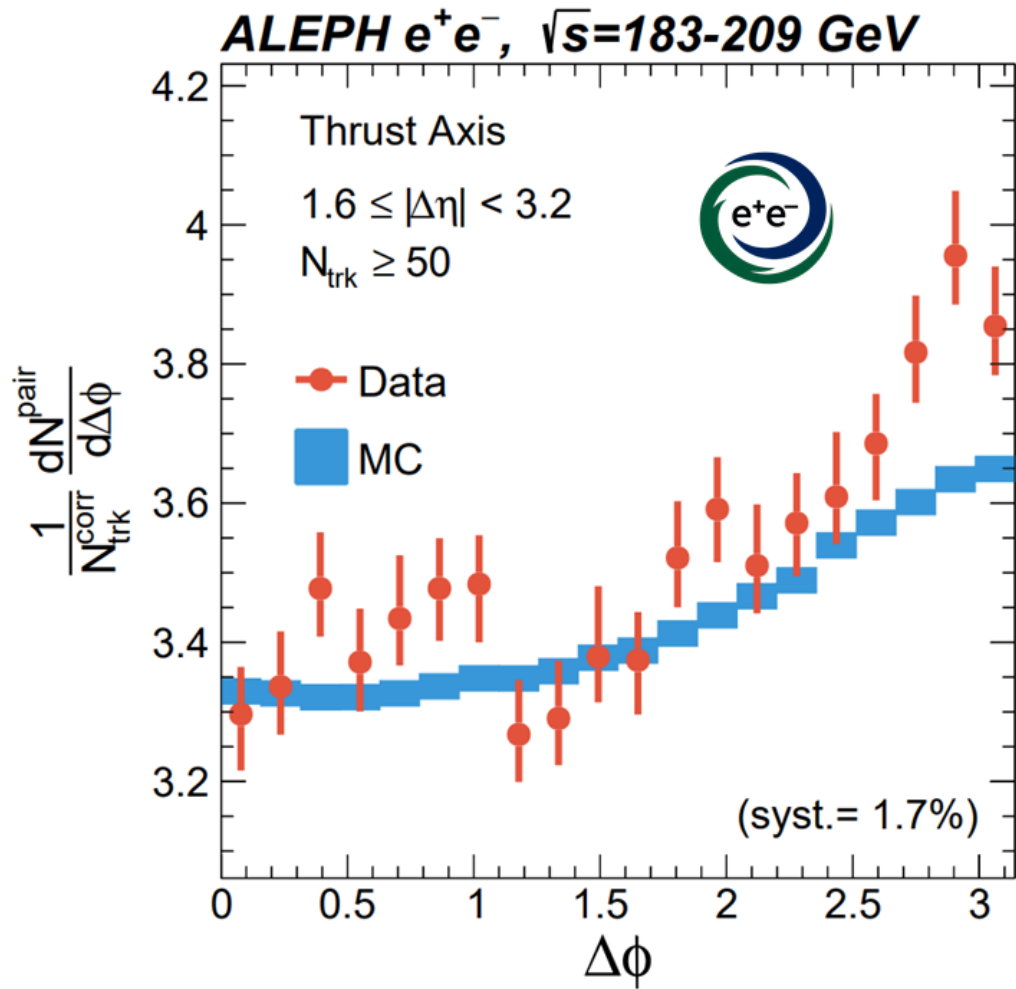
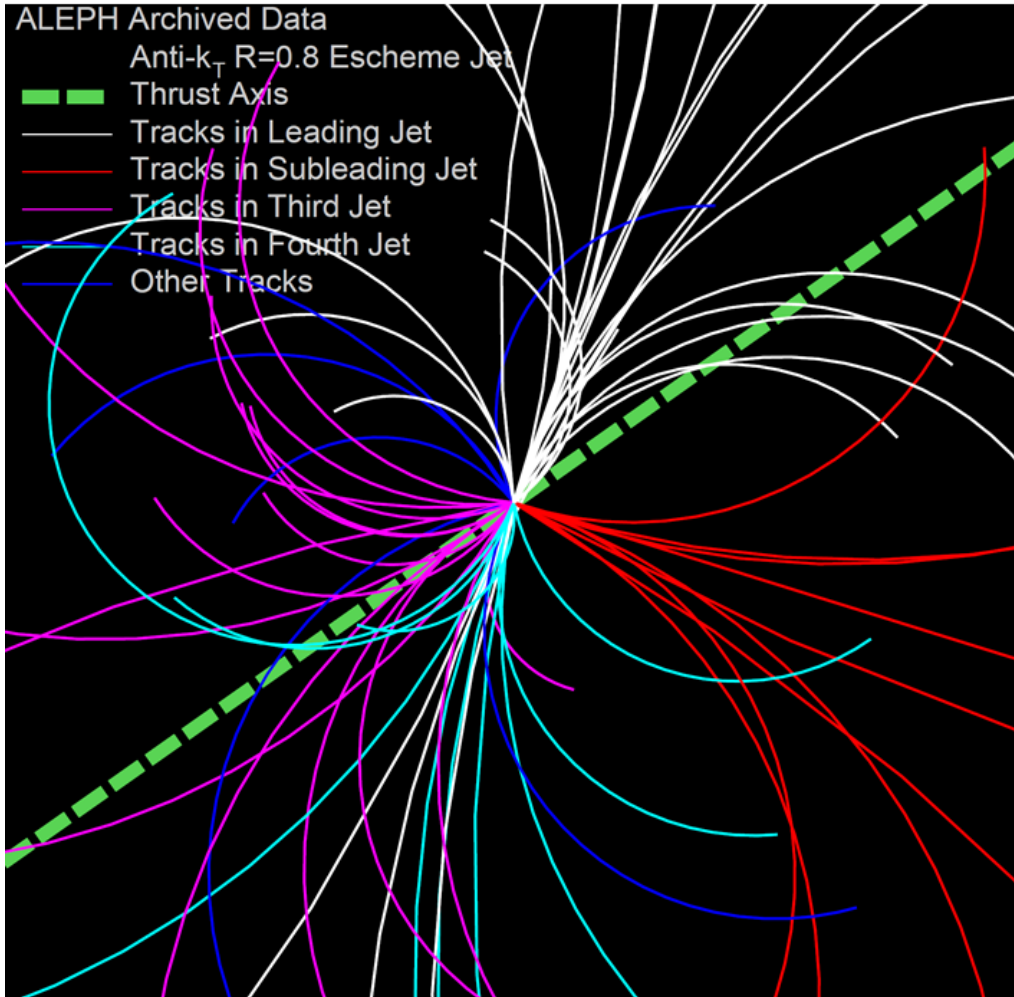


Thrust Frame



- No significant ridge like signal in Z pole data
- New reference to pp collisions

# Two particle correlation with LEP2 ALEPH data



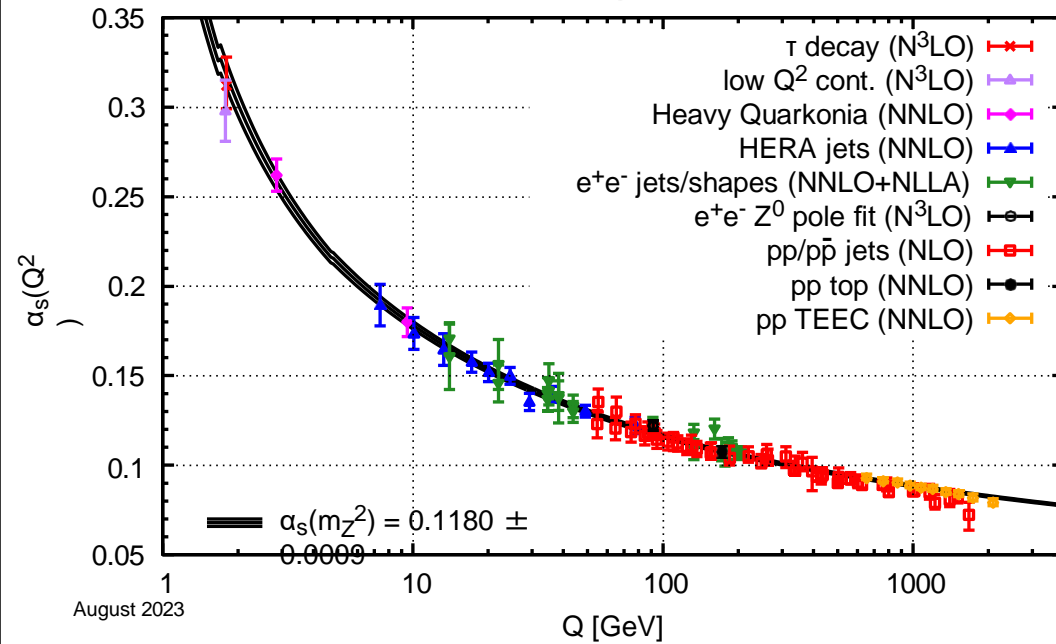
- A long-range near-side correlation signal shows up at high multiplicity!
- A narrower away-side spectrum at  $\Delta\phi \sim \pi$  in data

arXiv:2312.05084  
PLB 856 (2024) 138957

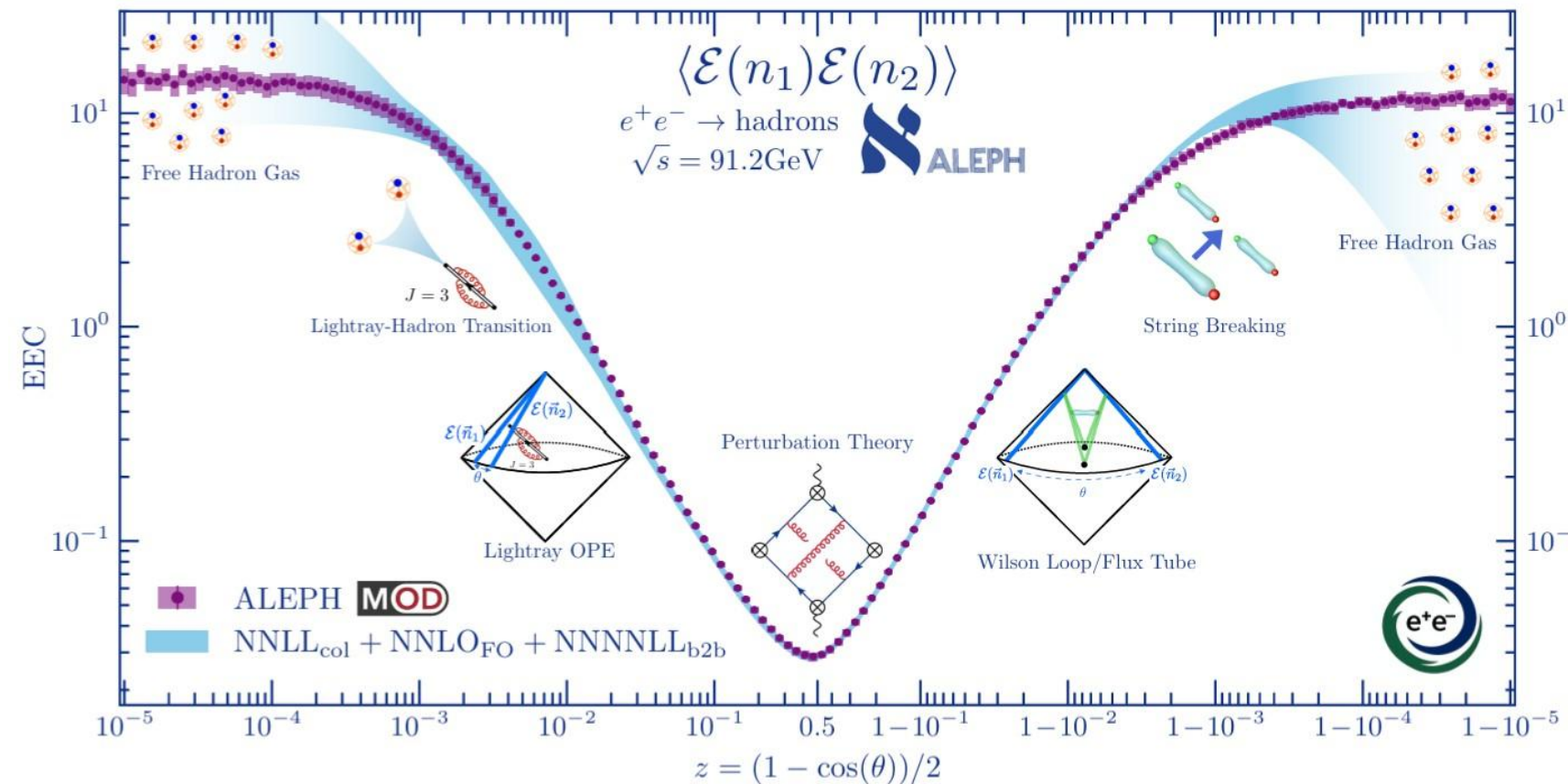


# Example: Precision QCD

## QCD Interesting Across Scales



## Perturbative (P) and Non-Perturbative (NP) QCD New Physics in QCD Systems



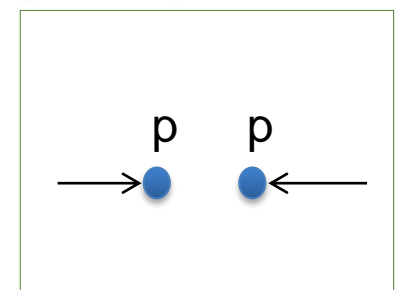
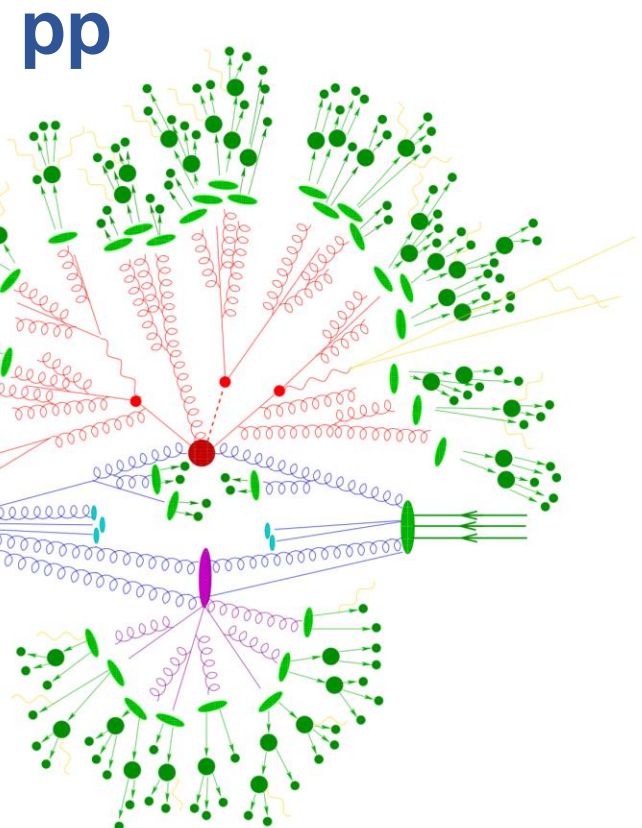
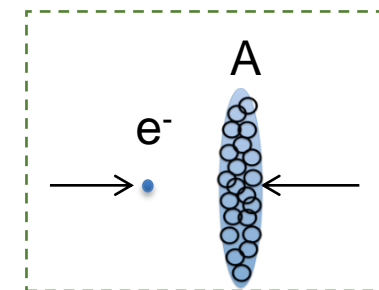
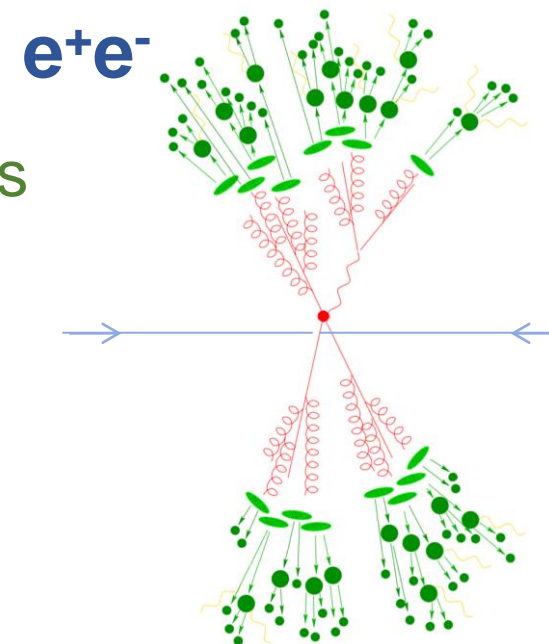
- ▶ Quantum Chromodynamics (QCD), theory of strong force, central to Standard Model (SM)
- ▶ Study of QCD across wide energy scales, spanning P/NP regimes, of global importance
- ▶ Precision QCD enables discovery of new phenomena in strongly interacting systems

# Jet in Electron-Positron Annihilation

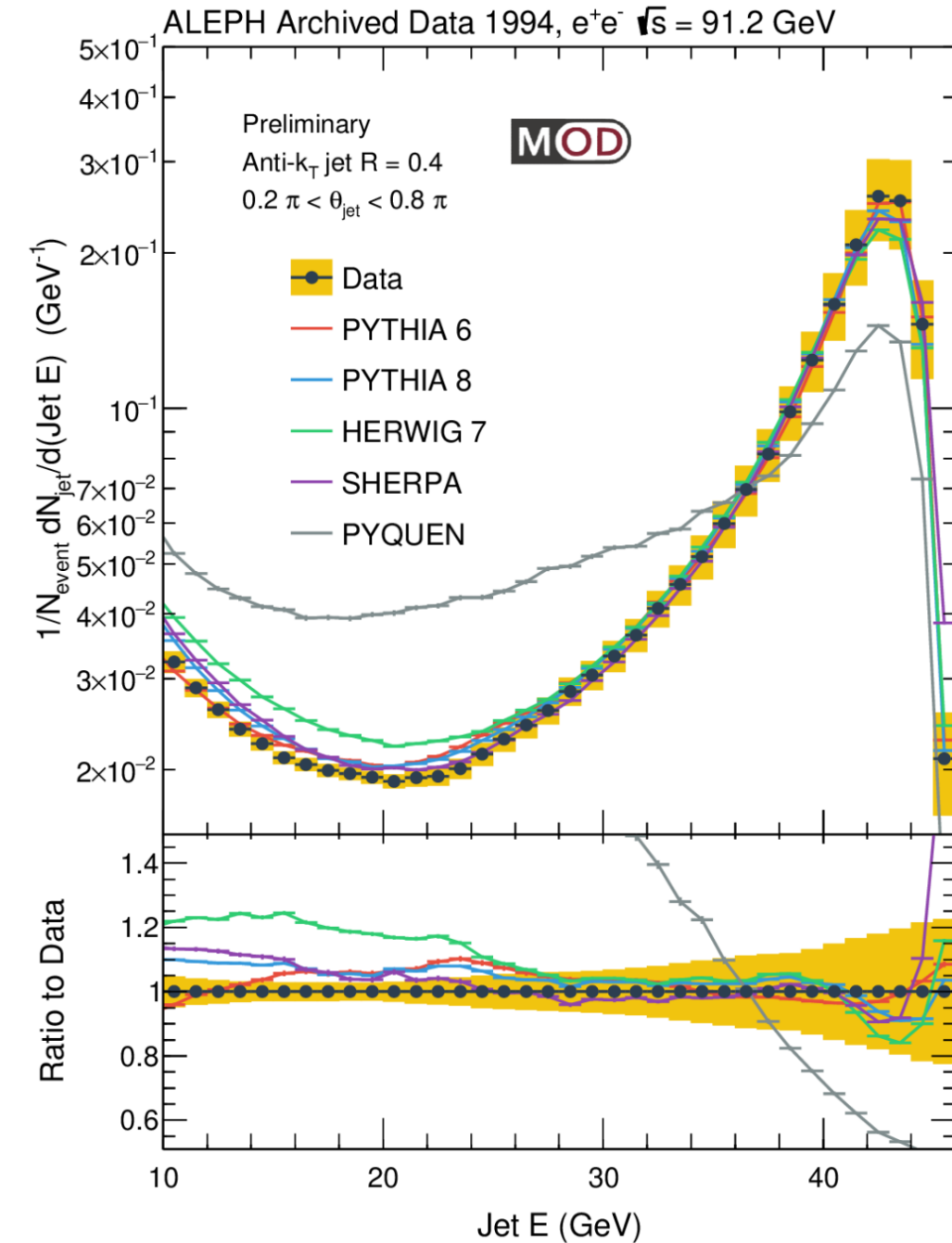
- Jets in  $e^+e^-$  with identical algorithms as those used in hadron colliders are of great interest
    - No gluonic initial state radiation
    - No complications of parton distribution functions
    - No beam remnants and multi-parton interactions
- Cleanest test of pQCD and phenomenological models

- Serve as a reference for the **pp** and future **EIC (ep/eA)** measurements

- Inform the QCD studies at the future FCC.

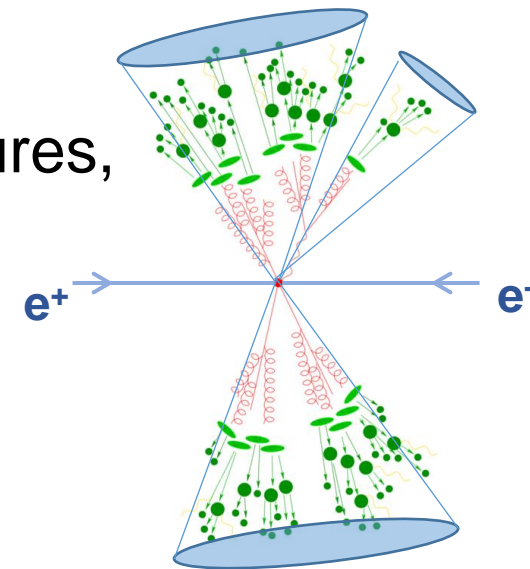
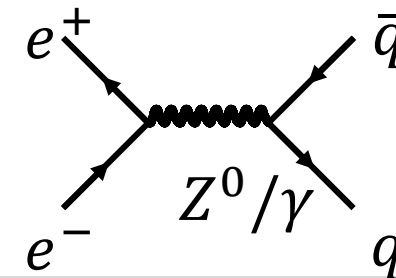


# Inclusive Jet Spectrum vs. Generators

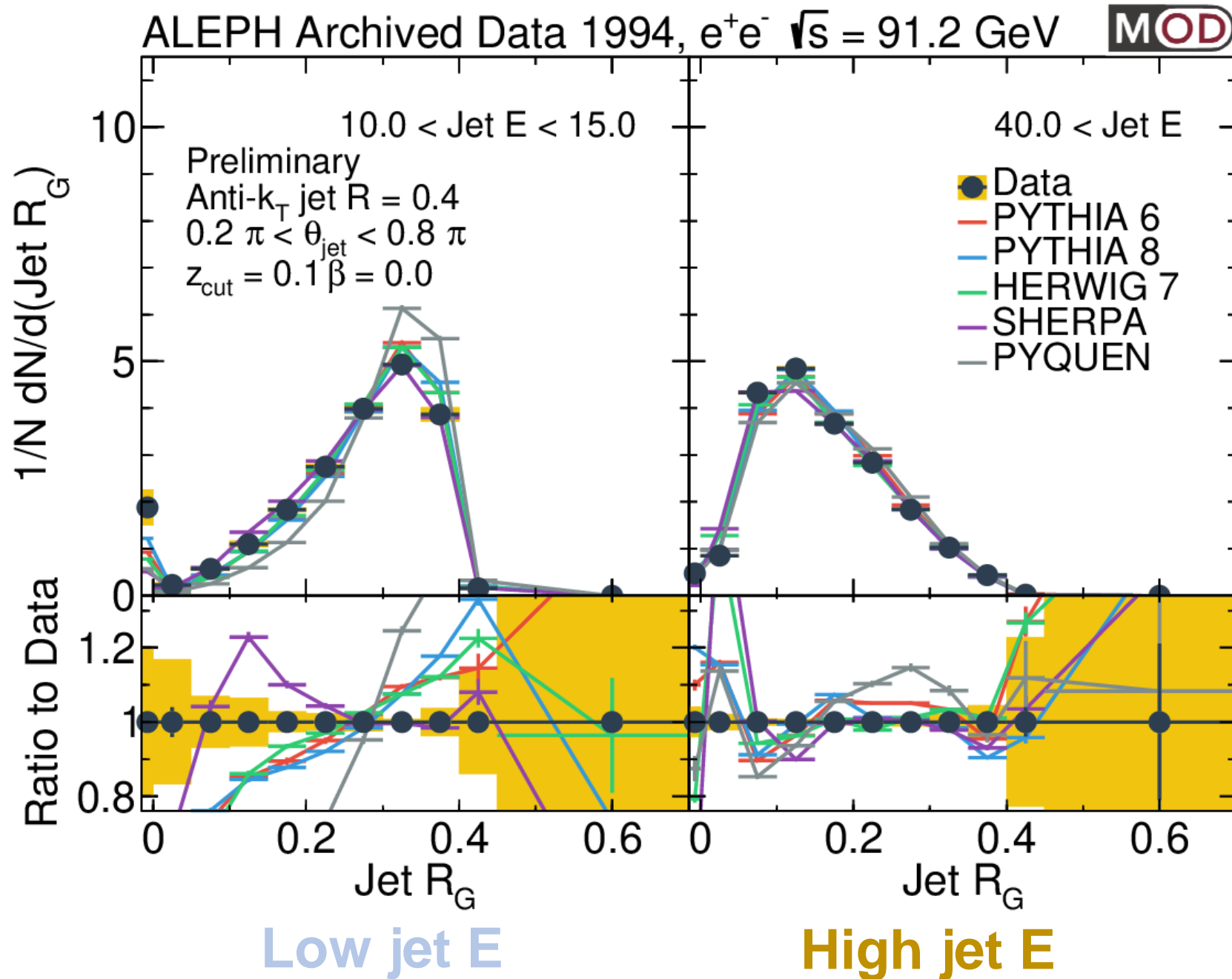


- The closest observable to the jet spectra analyses in hadron-hadron collisions!
- Peak at around 43 GeV: from  $Z \rightarrow q\bar{q}$  and parton shower of the (anti-)quark **almost fully captured by the anti- $k_T$  algorithm with  $R=0.4$**
- Minimum at around 20 GeV
- At low E: increase due to a large number of jets from soft emissions or combinatorial
- Generators capture those general features, overpredict the spectra at low jet E

MITHIG-MOD-21-001  
[arXiv:2111.09914](https://arxiv.org/abs/2111.09914)  
JHEP 06 (2022) 008



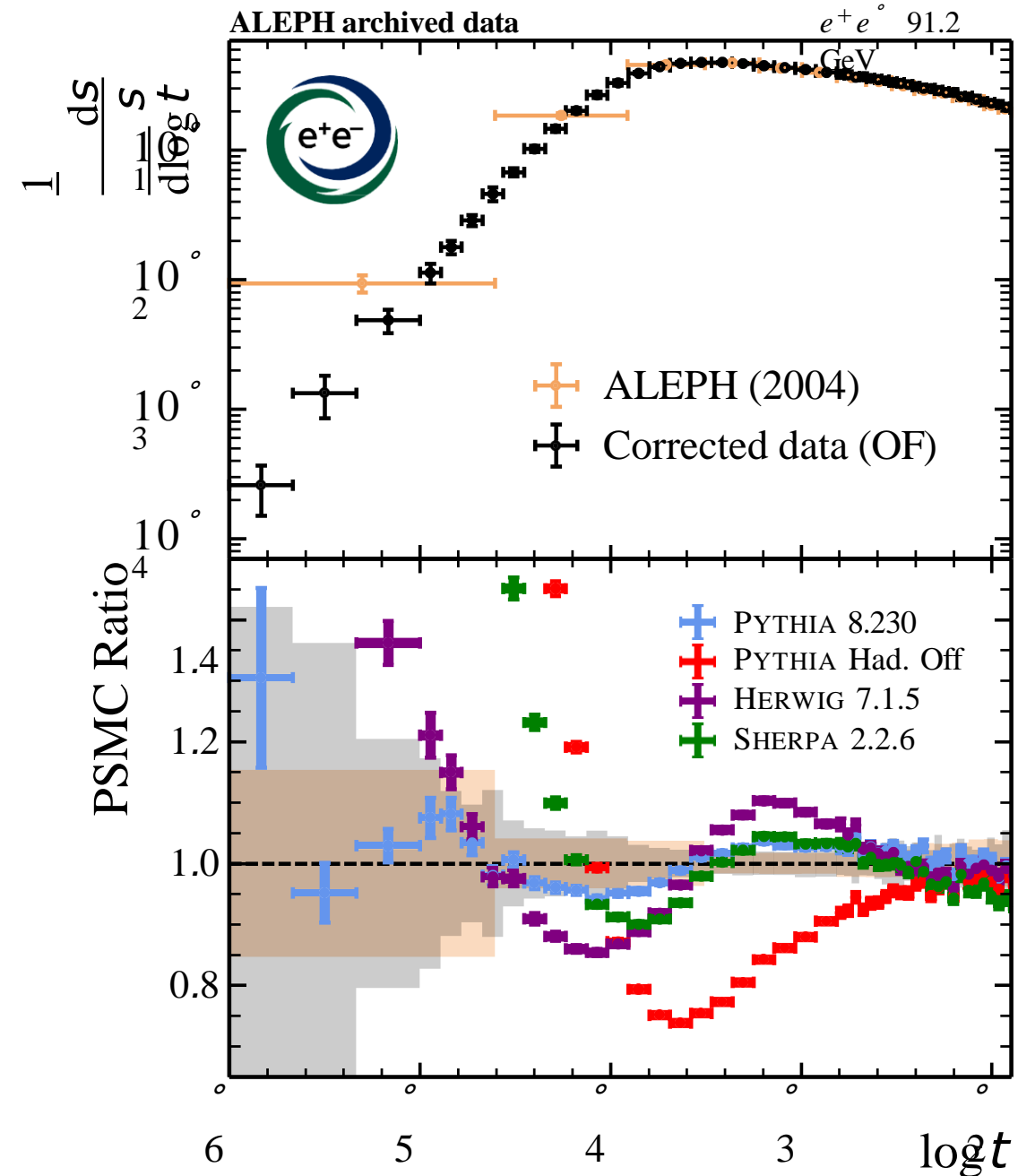
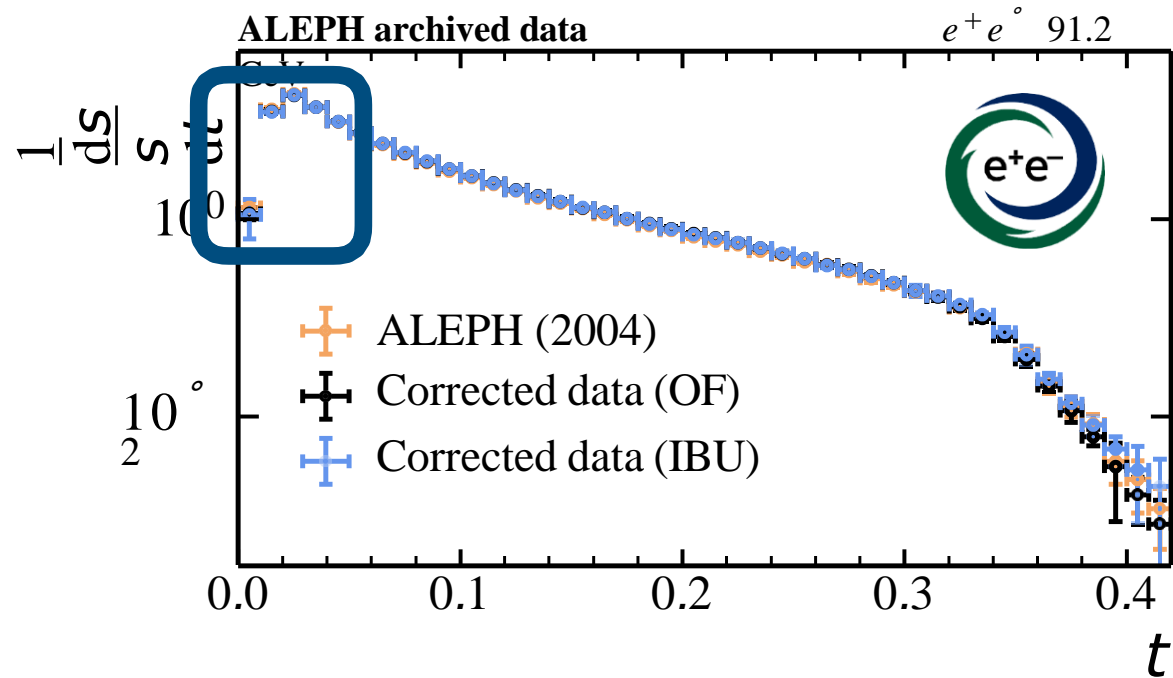
# Groomed Jet Radius $R_G$ vs. Event Generators



- **High jet E** (mainly quark jets):
  - Peak at smaller  $R_G$  value
  - Generators give a better description of the data
- **Low jet E** (mainly from soft emissions and combinatorial):
  - Peak at larger  $R_G$  value as one would expect
  - **SHERPA** gives a better description of the data
  - **PYTHIA 6**, **PYTHIA 8**, **HERWIG**, and **PYQUEN** overpredict the  $R_G$

MITHIG-MOD-21-001  
[arXiv:2111.09914](https://arxiv.org/abs/2111.09914)  
 JHEP 06 (2022) 008

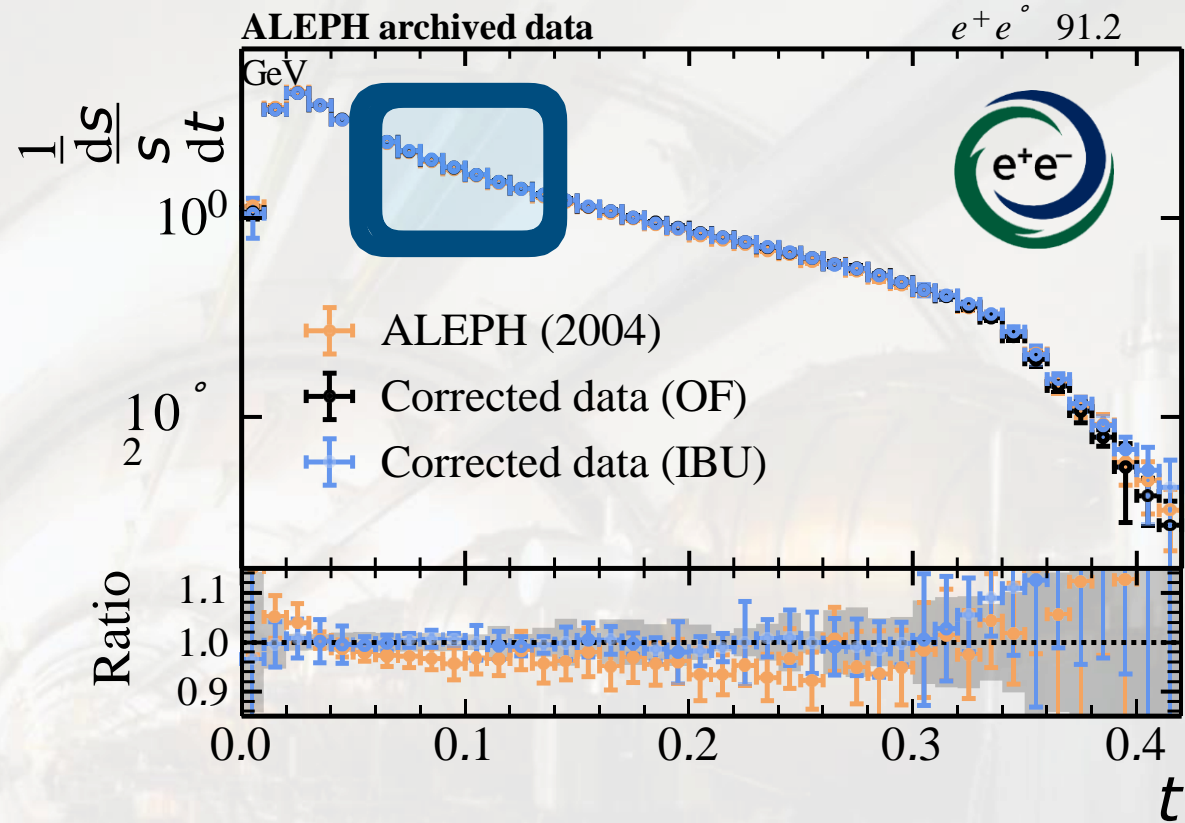
# Probing the Non-Perturbative Regime



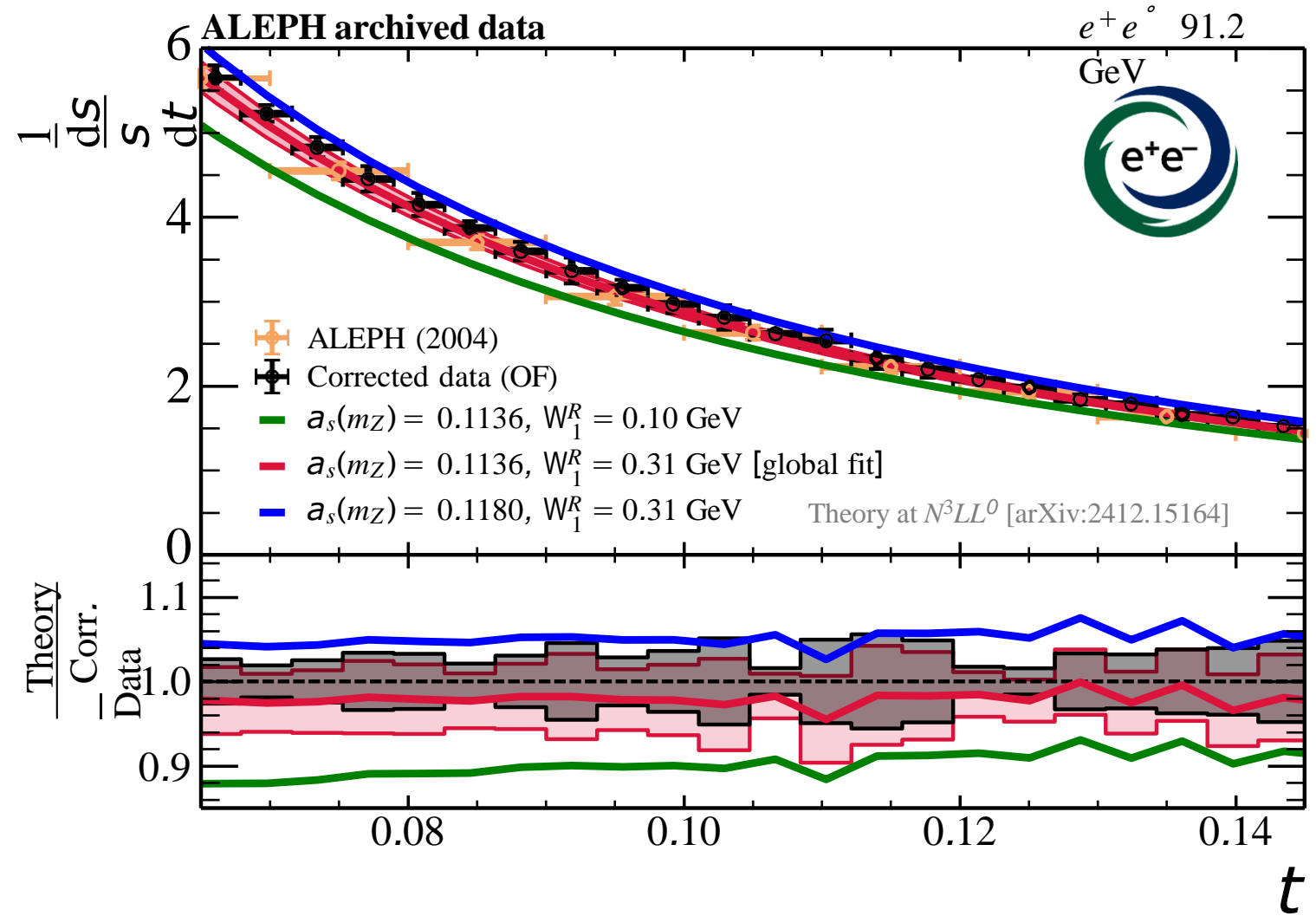
- Use unbinned result to expand NP regime
- Approaching  $\tau \sim \Lambda_{\text{QCD}}/\sqrt{s}$  which translates to  $\log \tau \sim \log (\Lambda_{\text{QCD}}/m_Z) \sim -6.12$
- Discrimination power between MC models of the parton hadronization and shower

Pythia 8.230 with the Lund string hadronization model and pT ordered dipole shower (blue), identical Pythia 8.230 except with hadronization disabled (red), Herwig 7.1.5 with the cluster hadronization model and angular-ordered shower (purple), and Sherpa 2.2.6 with the Lund string hadronization model (via Pythia8) and the dipole shower (green)

# Probing the Strong Coupling Constant

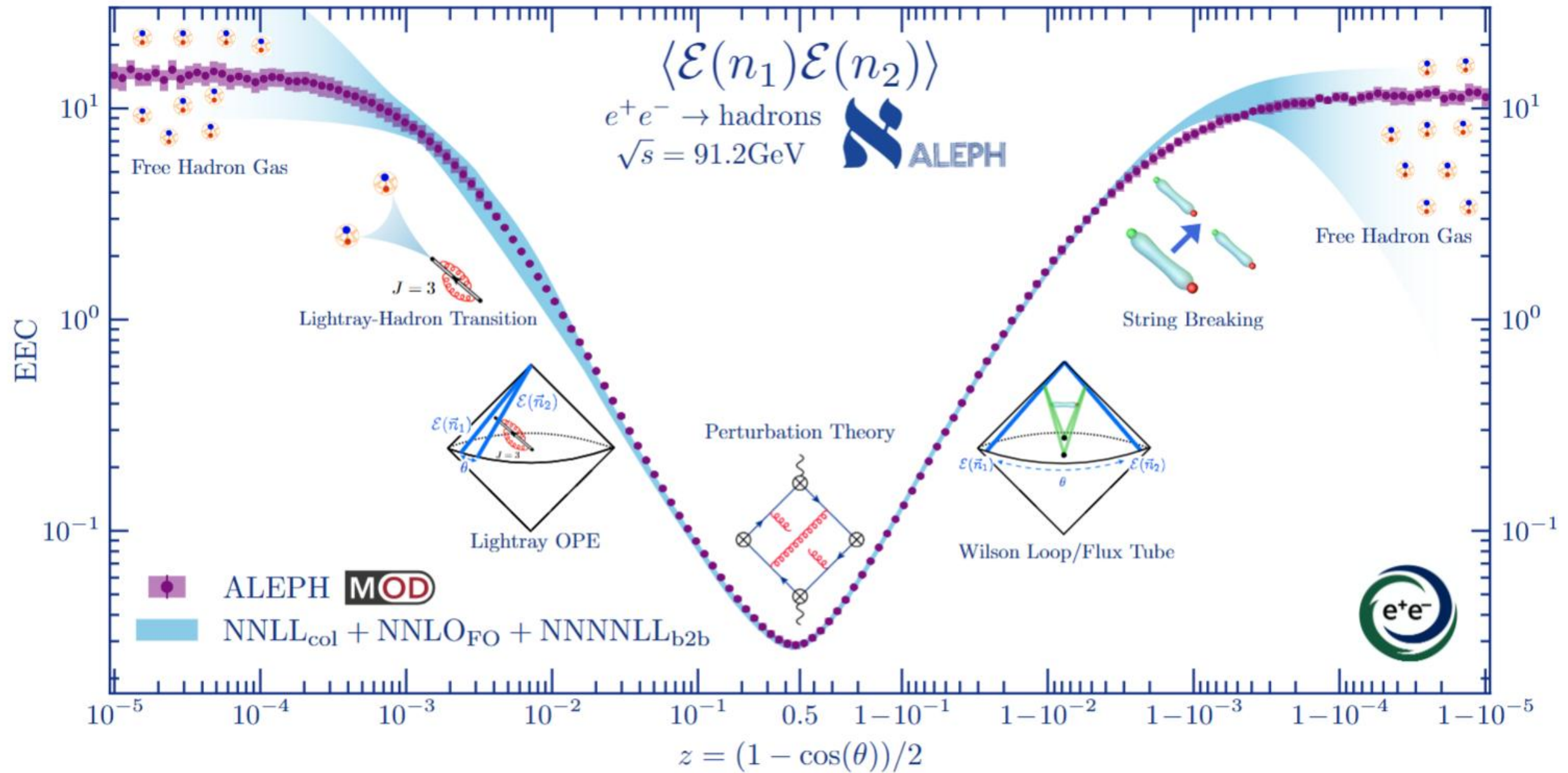


- Re-bin to compare with new theory result
- Potential agreement with theory global fit  $\alpha_S(m_Z) = 0.1136$  (excluding this result) and world average  $\alpha_S(m_Z) = 0.1180$  for fixed  $\Omega_1^R = 0.31$  GeV (first moment of NP shape function)
- Motivates a new fit with the measurement



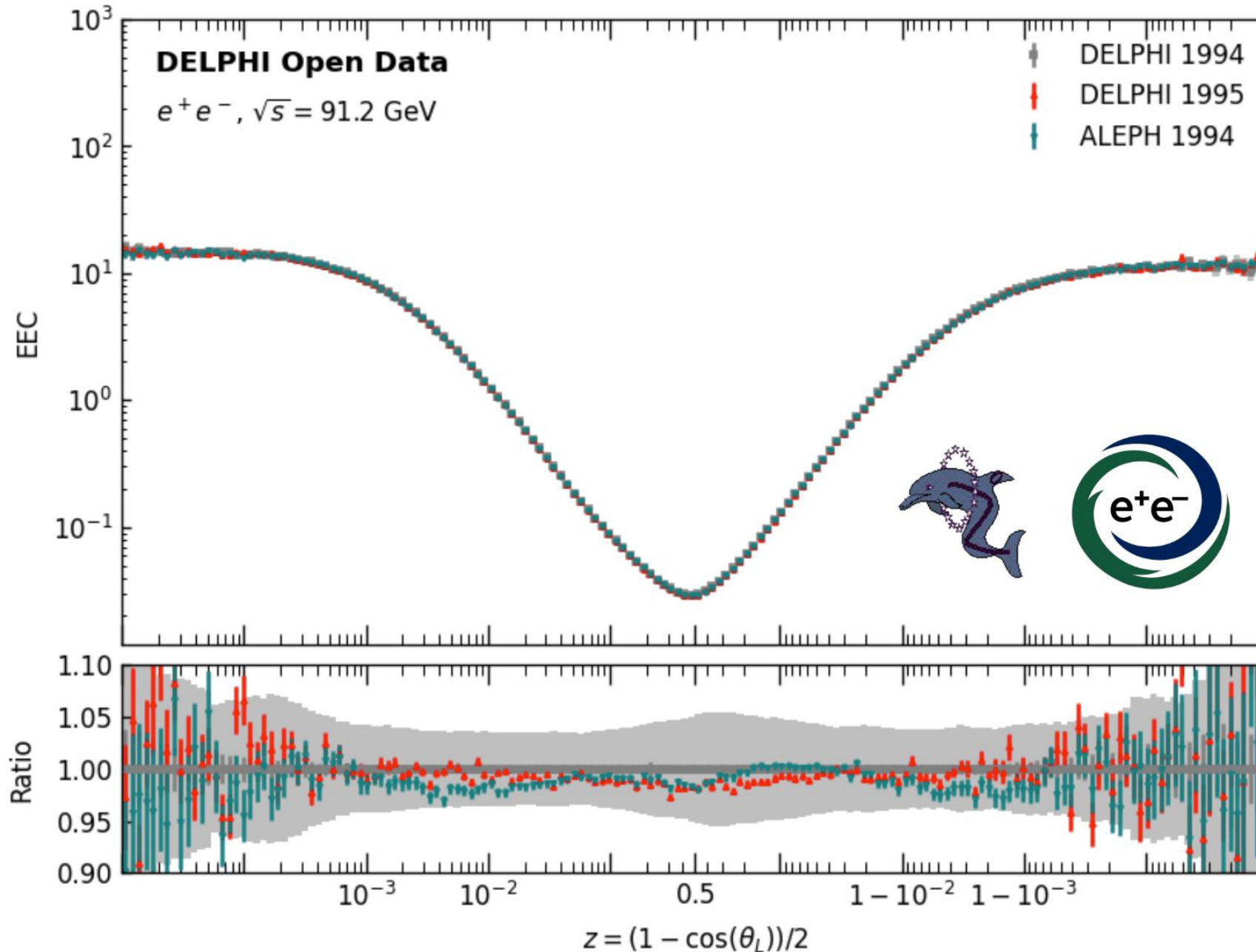
Thanks to Miguel Benitez and Iain Stewart  
 On Determining  $\alpha_S(m_Z)$  from Dijets in  $e+e-$  Thrust, [2412.15164](https://arxiv.org/abs/2412.15164)

# Result: Fully Corrected EEC in $e^+e^-$ vs Theory



Theory curves: Max Jaarsma, Yibei Li, Ian Moutl, Wouter Waalewijn, HuaXing Zhu

# Reanalysis with DELPHI and ALEPH Data



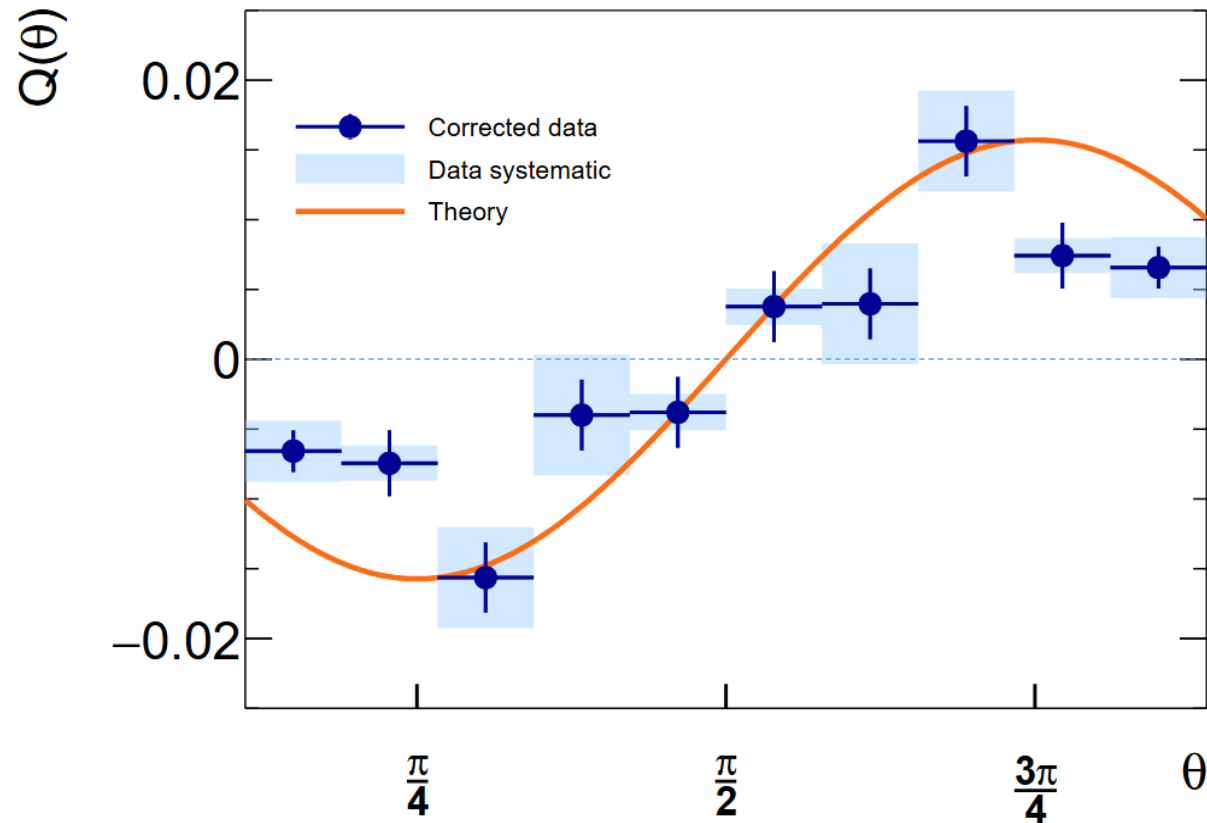
[\[ee alliance, DELPHI Analysis Note: arXiv:2510.18762\]](https://arxiv.org/abs/2510.18762)

- Can also compare to the 2-point energy correlator for all charged particles using archived  $e^+e^-$  data from DELPHI.
- Access to original DELPHI GEANT simulation, can perform much better tests of prior dependence, etc.
- **Power of the recycling frontier!!**



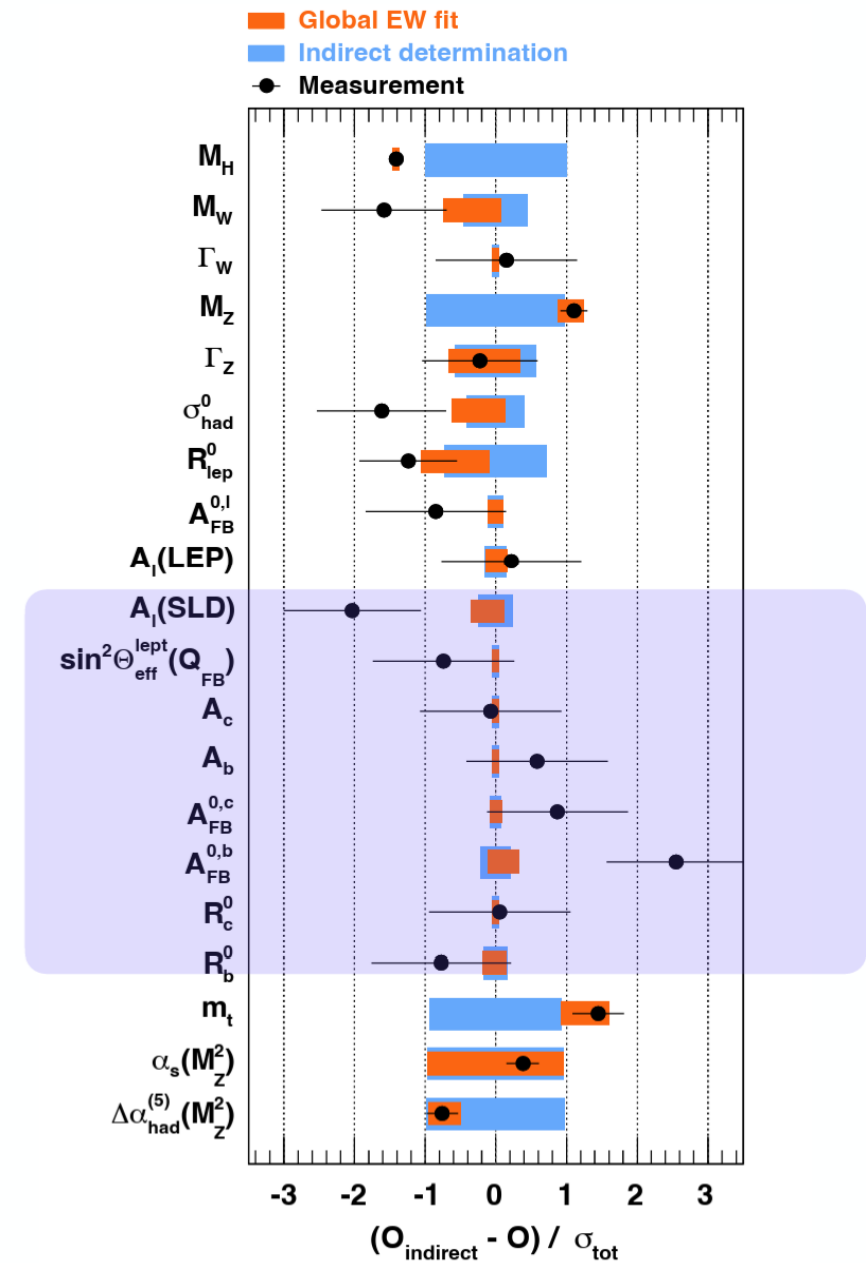
Yi Chen (Vanderbilt U.)

# Example 3: Precision Electroweak Measurements

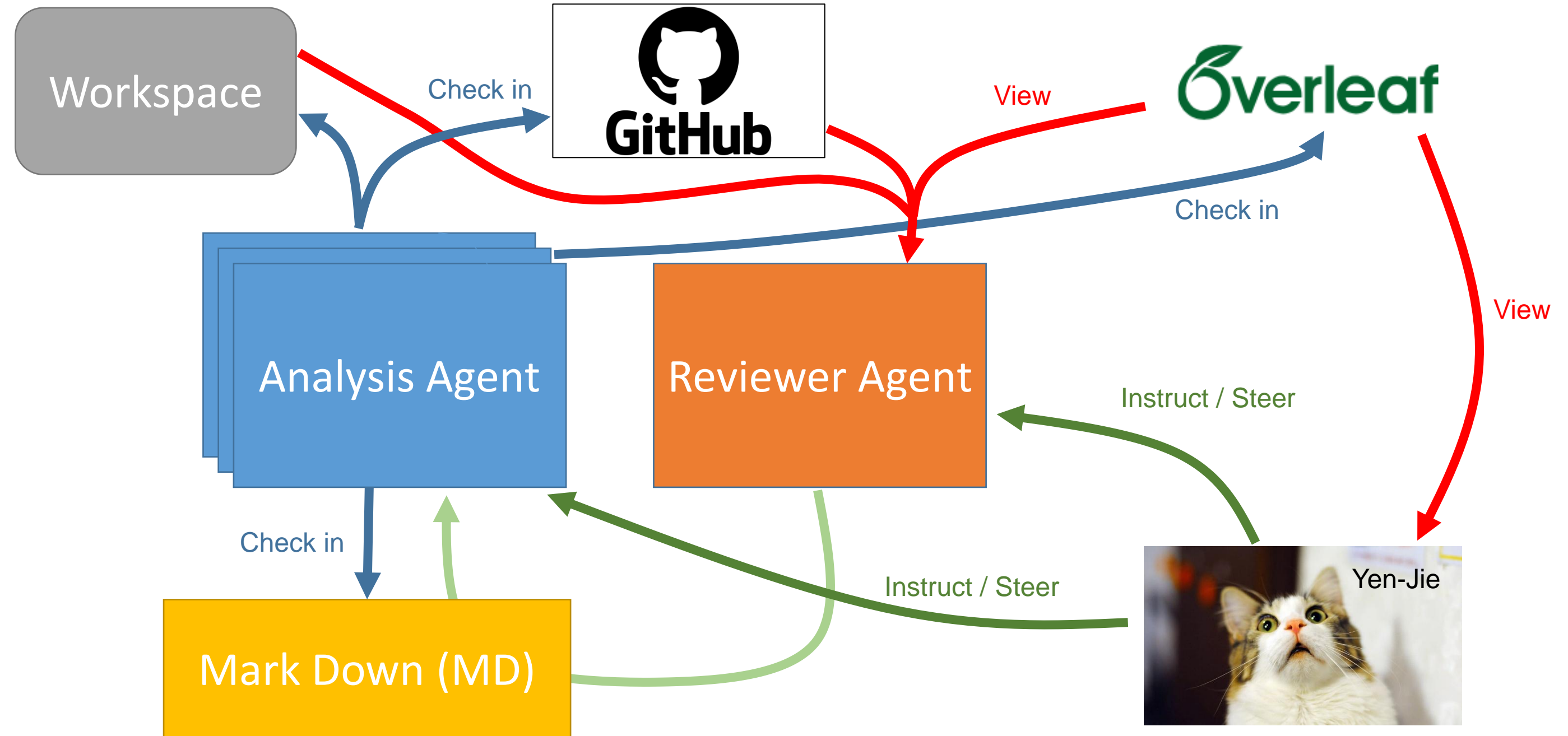


**DELPHI Agentic Analysis on Chiral Symmetry breaking effect**  
 Idea from KITP chalk board drawing to preliminary Result in 3 days

In collaboration with Kyle Lee and Ian Moutl



# Multi-Agent Working Mode



# Summary

- Electron-Positron Alliance aims to build a community, to curate and to reanalyze the legacy archived  $e^+e^-$  data with modern techniques and new ideas
- Enabled direct collaboration between experimentalist and theorists
- We aim to analyze the **state-of-art** data and to bridge the gap between now (2026) and FCC-ee (2040s)
- Open up **new science opportunities** from past investments
  - High Density QCD
  - Precision QCD
  - Precision Electroweak
  - Quantum Entanglement
  - ...
- Ideal playground for agentic AI method (See Luna Chen's talk)



# Backup Slides



# Hadronic Event Selection

The same event selection criteria used in ALEPH 2004 QCD paper

## - Track Selections:

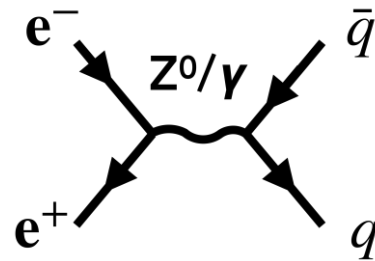
- Number of TPC hits for a charged tracks  $\geq 4$
- $|d_0| \leq 2$  cm
- $|z_0| \leq 10$  cm
- $|\cos\theta| \leq 0.94$  (corresponding to  $|\eta| \leq 1.74$ )
- $p_T \geq 0.2$  GeV ( $p_T$  with respect to beam axis)
- $\chi^2/ndf < 1000$

## - Neutral Hadron Selections:

- ECAL/HCAL objects
- $E \geq 0.4$  GeV
- $|\cos\theta| \leq 0.98$

## - Event Selections:

- Number of good charged particles  $\geq 5$  (including charged hadrons and leptons)
- Number of good charged+neutral  $\geq 13$
- $E_{\text{charged}} \geq 15$  GeV
- $|\cos\theta_{\text{sphericity}}| \leq 0.82$



## Charged particle multiplicity

