Summary of the CERN workshop on α_s from Thrust

Gherardo Vita

ALPHAS-2025, Aussois - December 17 2025

General Philosophy and Goals

- Create a community effort to address key open questions in strong coupling determinations at lepton colliders

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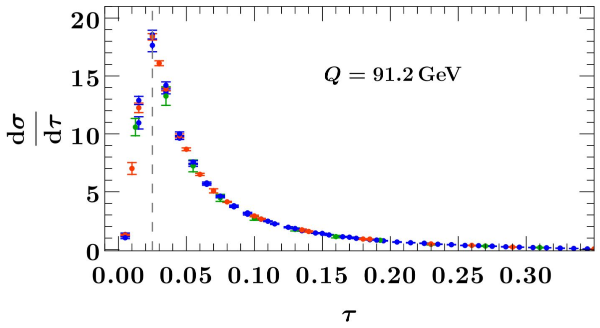
- Create a community effort to address key open questions in strong coupling determinations at lepton colliders
- Reconcile

Very high precision data from lepton colliders



Availability of sophisticated theory tools

(N^4LL resummation, $O(as^3)$ fixed order, "analytic" treatment of hadronization effects, renormalon subtractions, hadron mass effects, 3jet power corrections, etc.)

Discrepancies between analyses

- Central value
- Uncertainties
- Systematics, known unknowns, and unknown unknowns

General Philosophy and Goals

- Create a community effort to address key open questions in strong coupling determinations at lepton colliders

- What are the assumptions in a theory framework for a given fit setup?
- Can we agree on what assumptions are reasonable for a given fit setup?
- What tests can we perform/show to validate assumptions made?

General Philosophy and Goals

- Create a community effort to address key open questions in strong coupling determinations at lepton colliders
- Start simple
  - Fix observable: **thrust**
  - Focus on subset of aspects:
    - 2 jet vs 3 jet power corrections
    - Hadron mass effects
    - Data
    - Resummation Space

General Philosophy and Goals

- Create a community effort to address key open questions in strong coupling determinations at lepton colliders
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Many other interesting aspects we won't focus on at this round:

- Anomalous scaling of 3 jet power corrections
- Renormalon subtraction
- Scheme dependence of non-perturbative inputs
- Other event shapes
- Theory correlations
- ….

…but we had to start from somewhere

Strong coupling from thrust at lepton colliders

https://indico.cern.ch/e/asthrust2025

November 27 – 28, 2025 - CERN

Organizers: Alexander Huss, Pier Francesco Monni, Gherardo Vita

Day 1 (Morning) - 3 jet Power Corrections

Day 1 (Afternoon) - Hadron Mass Effects

Day 1 (Afternoon) - Data

Day 2 - Impact of Resummation Space Choice and pert. uncertainties

Schedule

Thu, November 27

9:00 AM → 9:30 AM	Coffee	4/2-011 - TH common room	
10:00 AM → 12:00 PM	Impact of 3-jet power corrections	4/S-030	
10:00 AM	Talk by Giulia Zanderighi/Paolo Nason		15m
10:15 AM	Talk by Vicent Mateu		15m
10:30 AM	Discussion		1h 30m
2:00 PM → 4:00 PM	Hadron-mass effects: Hadron-mass effects and universality aspects of power corrections across observables	4/S-0...	
2:00 PM	Talk by Iain Stewart		15m
2:15 PM	Talk by Giulia Zanderighi/Paolo Nason		15m
2:30 PM	Discussion		1h 30m
3:30 PM → 4:00 PM	Coffee	4/2-011 - TH common room	
4:00 PM → 6:00 PM	Experimental measurements and new analyses of LEP data	4/S-030	
4:00 PM	ALEPH Thrust Measurement		30m
4:30 PM	DELPHI Thrust Measurement		20m
4:50 PM	ALEPH EEC and 2PC measurements		10m
5:00 PM	Discussion		1h
6:00 PM → 7:00 PM	Reception		

Fri, November 28

9:00 AM → 9:30 AM	Coffee	4/2-011 - TH common room	
9:30 AM → 12:00 PM	Impact of resummation space choice	4/3-006 - TH Conference Room	
9:30 AM	Talk by Giancarlo Ferrera		10m
9:45 AM	Talk by Miguel Benitez		10m
10:00 AM	Talk by Luca Buonocore		10m
10:15 AM	Discussion		1h 45m
1:30 PM → 3:00 PM	Impact of resummation space choice	4/3-006 - TH Conference Room	
1:30 PM	Discussion		1h 30m
3:00 PM → 3:30 PM	Coffee	4/2-011 - TH common room	
3:30 PM → 5:00 PM	Organisation and next steps	4/3-006 - TH Conference Room	

Plenty of time for discussion

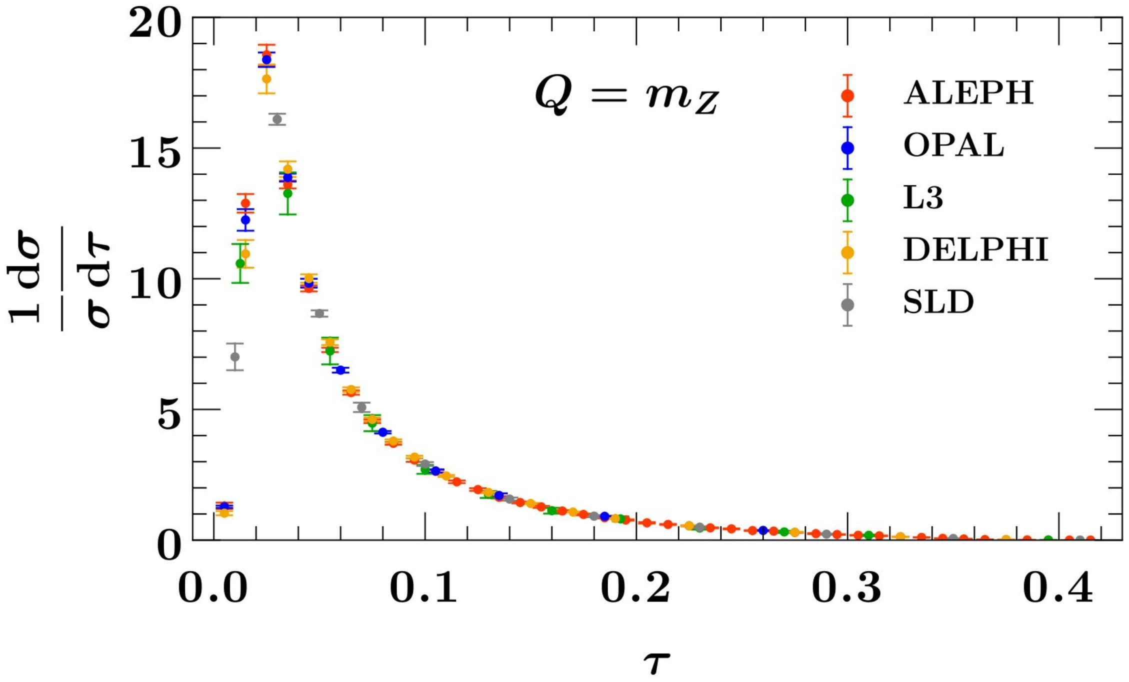
TODO List

Throughout the workshop we decided on exercises to be carried out by the different groups

Highlights

Data

- Data at Z pole for thrust are extremely precise

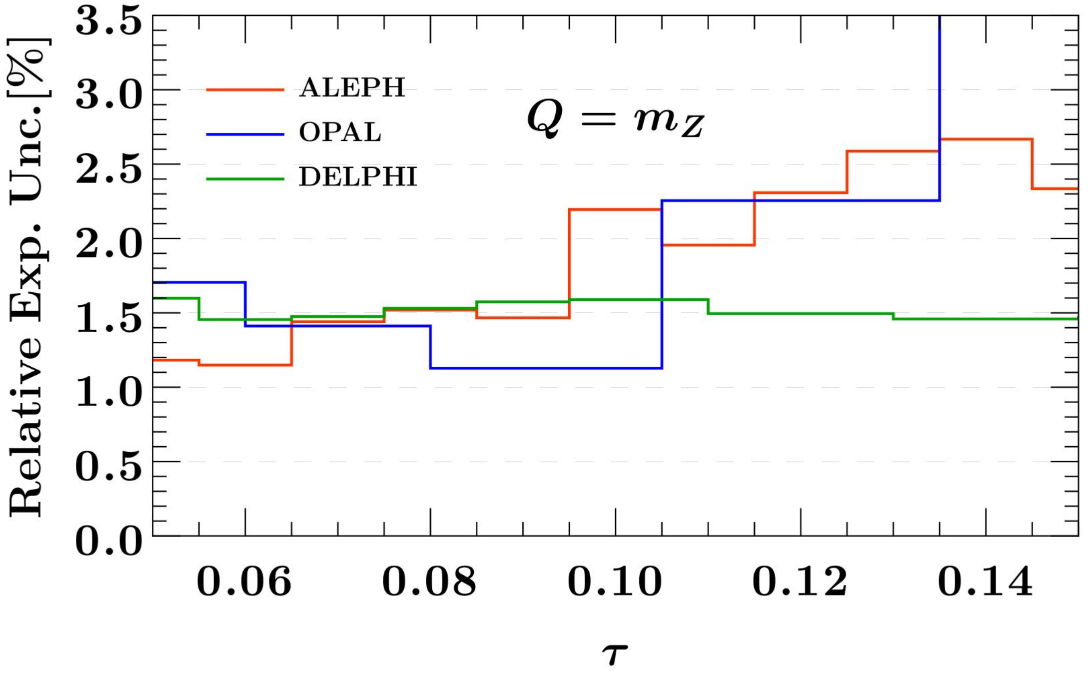


Data

- Data at Z pole for thrust are extremely precise

~1.5% accuracy in each bin in dijet perturbative region

$\tau \in [0.05\text{-}0.15]$



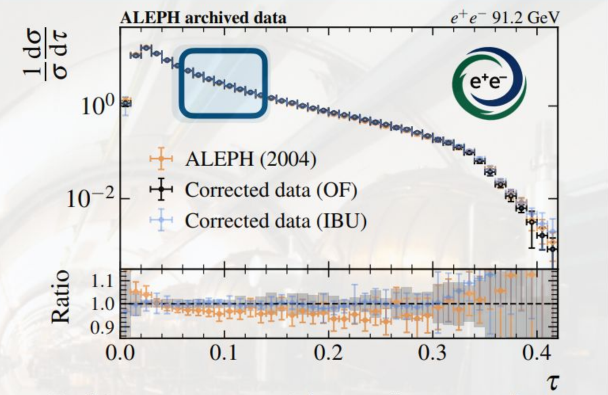
Data

- LEP reanalysis presented by the e+e- alliance
- Sizable differences compared to LEP time analyses
- Same or bigger impact of many of the theory systematics on alphas fits

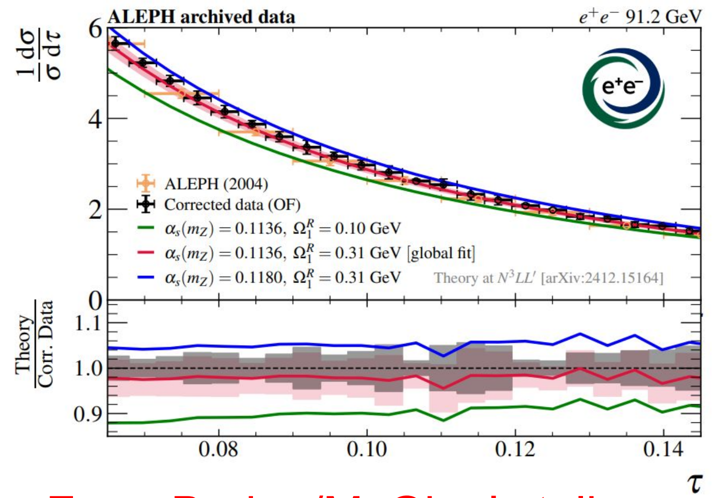
More from Antony on this later

ALEPH Reanalysis:

- systematic shift on thrust in fit range
- could lead towards larger alpha_s and/or smaller O1



- 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 Ω_1^R = 0.31 GeV (first moment of NP shape function)
- Motivates a new fit with the measurement

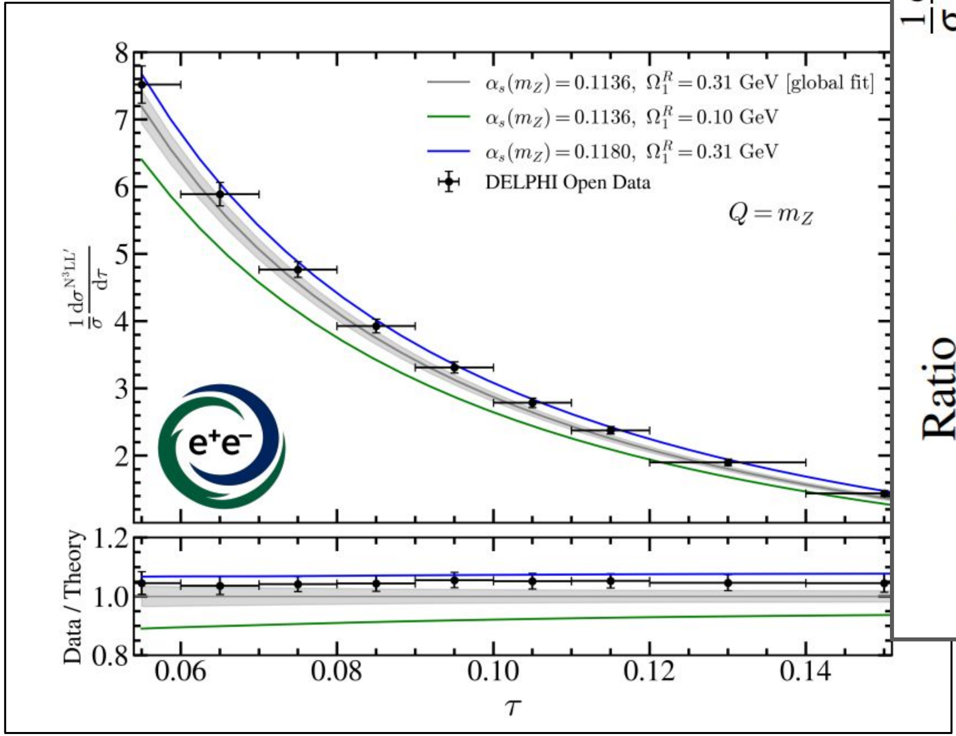


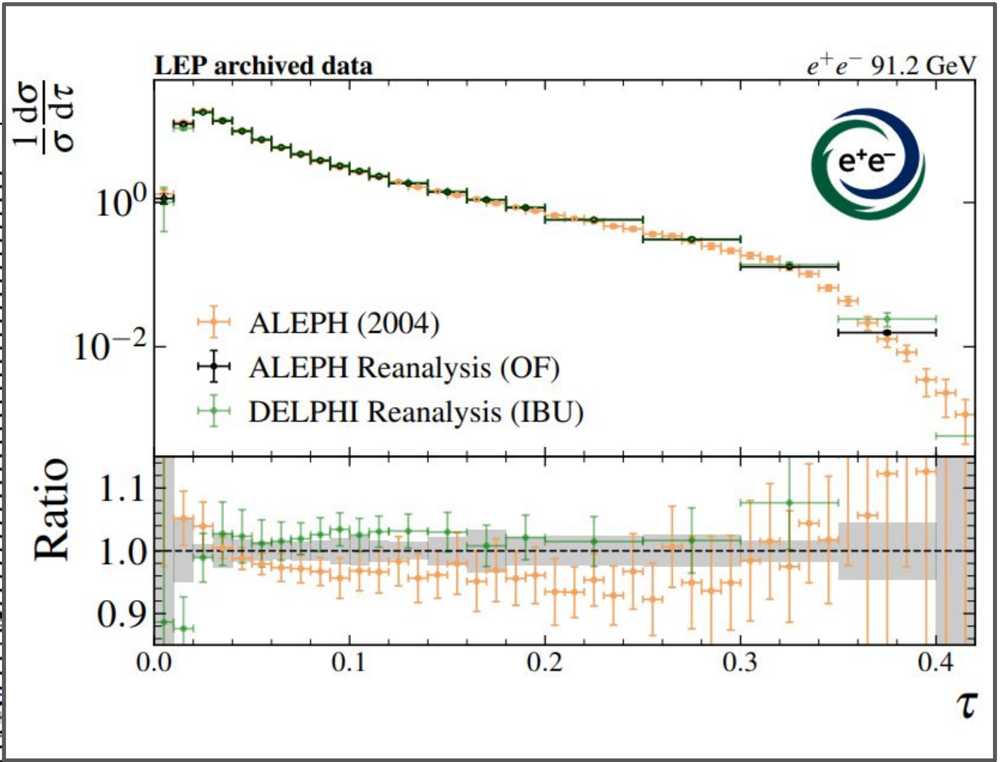
From Badea/McGinn's talk

Data

DELPHI Reanalysis:

even stronger shift



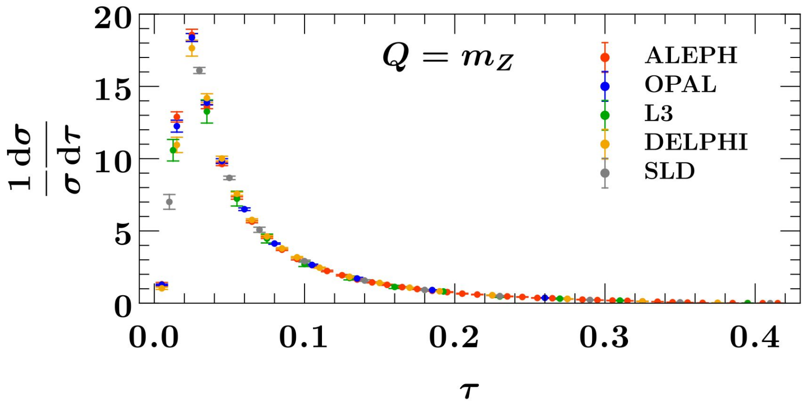


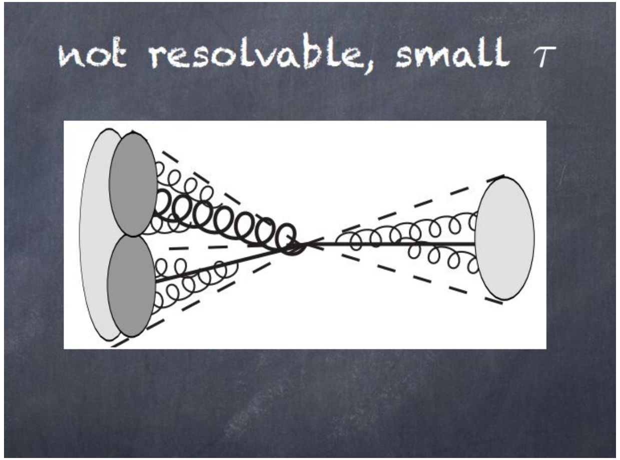
From Jingyu Zhang's talk

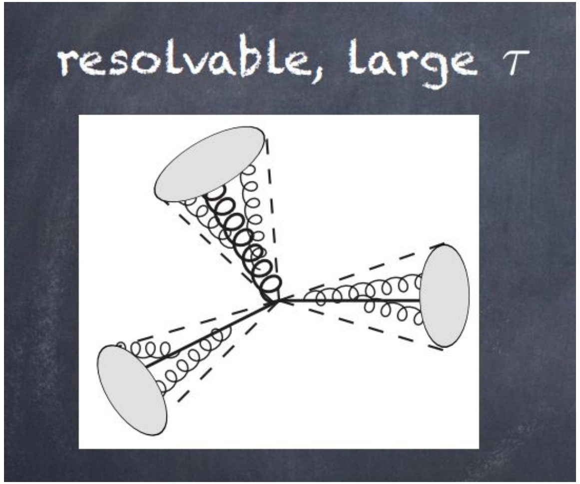
Data

- Overall, fantastic exchange between theory and experiments
- Ongoing constructive discussion regarding future steps
  - Priority list of observables: T, C, heavy jet mass, y3
  - Correlation matrix simultaneously for different observables
  - Include LEP 1, 2 and if possible also lower energy data (Belle)
  - Mass scheme unfolding in experimental reanalysis (E vs p-scheme)

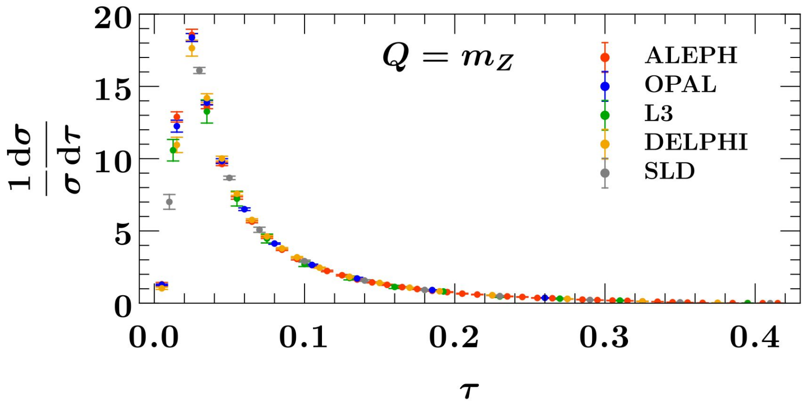
2-jet vs 3-jet Power Corrections

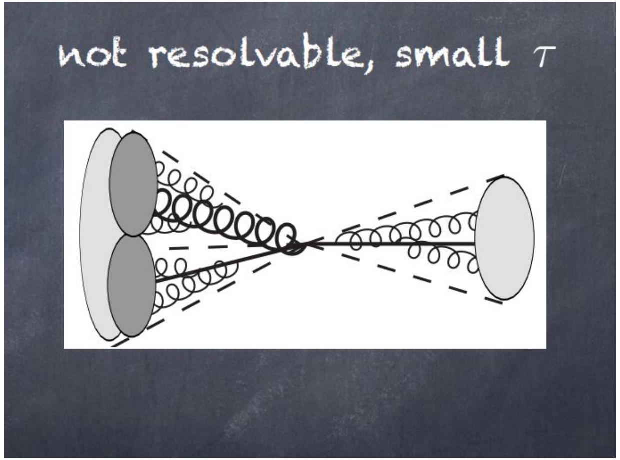






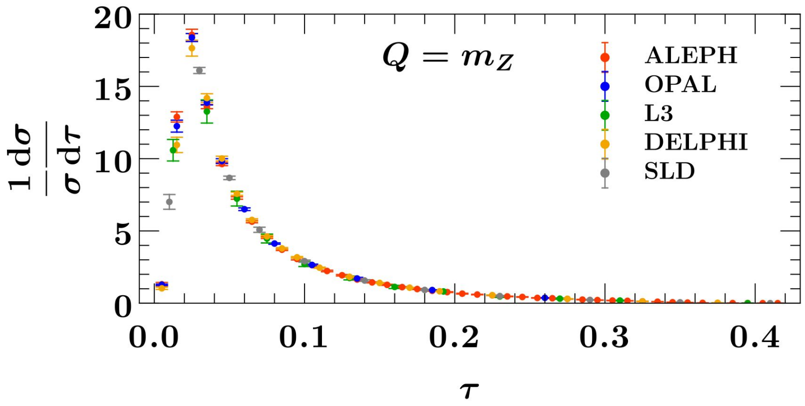
2-jet vs 3-jet Power Corrections



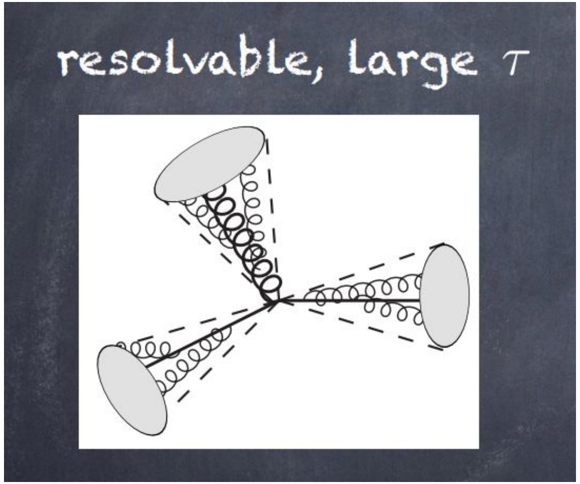


=> Leading Non Perturbative effect is constant (τ-independent) shift

2-jet vs 3-jet Power Corrections



Leading Non Perturbative effect depends on $\boldsymbol{\tau}$



2-jet vs 3-jet Power Corrections

2025 results

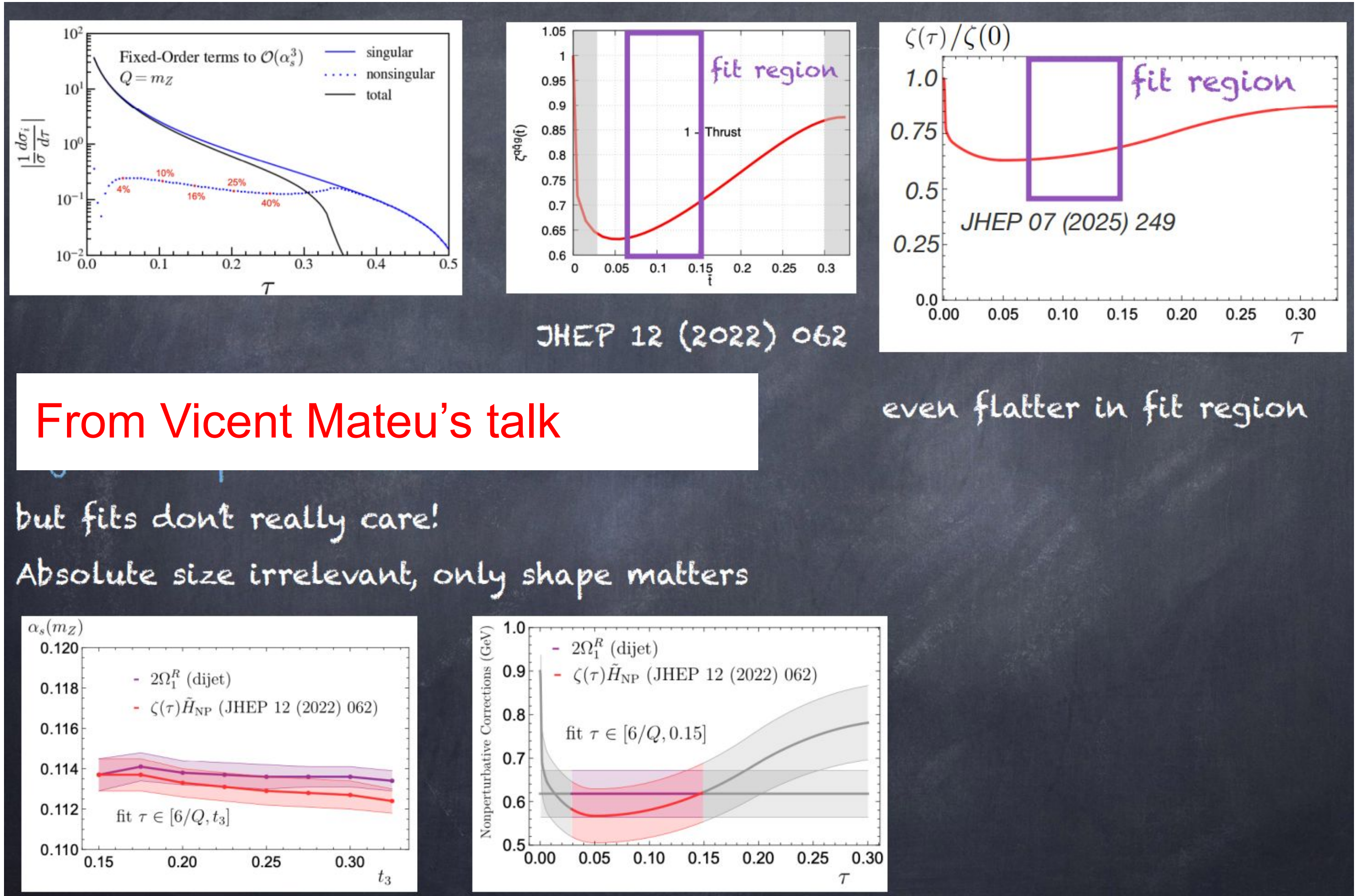
Three-jet power corrections $\zeta(v)$ versus two-jet power corrections $\zeta(0)$

From Giulia's talk

	$\alpha_s(M_Z)$							
	CTy3		C		T		y_3	
Variation	$\zeta(v)$	$\zeta(0)$	$\zeta(v)$	$\zeta(0)$	$\zeta(v)$	$\zeta(0)$	$\zeta(v)$	$\zeta(0)$
default	0.1181	0.1161	0.1169	0.1139	0.1168	0.1158	0.1155	0.1154
$\mu_R = \mu_0/2$	0.1167	0.1155	0.1141	0.1105	0.1159	0.1128	0.1122	0.1131
$\mu_R = 2\mu_0$	0.1167	0.1150	0.1212	0.1184	0.1208	0.1191	0.1157	0.1161
std scheme	0.1173	0.1153	0.1164	0.1118	0.1152	0.1148	0.1150	0.1149
p scheme	0.1160	0.1141	0.1164	0.1118	0.1152	0.1148	0.1137	0.1135
D scheme	0.1199	0.1173	0.1190	0.1153	0.1205	0.1170	0.1168	0.1166
$C_{ll} = 1.5$	0.1165	0.1143	0.1151	0.1116	0.1154	0.1133	0.1142	0.1142
$C_{ll} = 3$	0.1177	0.1159	0.1221	0.1116	0.1180	0.1172	0.1156	0.1154
non-pert scheme (b)	0.1193	0.1163	0.1191	0.1176	0.1185	0.1184	0.1154	0.1154
non-pert scheme (c)	0.1189	0.1167	0.1195	0.1172	0.1192	0.1191	0.1154	0.1154
minus non-pert error	0.1187	0.1161	0.1173	0.1139	0.1165	0.1158	0.1157	0.1154
plus non-pert error	0.1189	0.1161	0.1172	0.1139	0.1172	0.1158	0.1153	0.1154

$$\alpha_{s,\text{with }\zeta(0)} = \alpha_{s,\text{with }\zeta(v)} - 0.002$$

2-jet vs 3-jet Power Corrections



For thrust fits this does not seem to lead to big effects.

In particular dijet perturbative region

$\tau \in [0.05\text{-}0.15]$

2-jet vs 3-jet Power Corrections

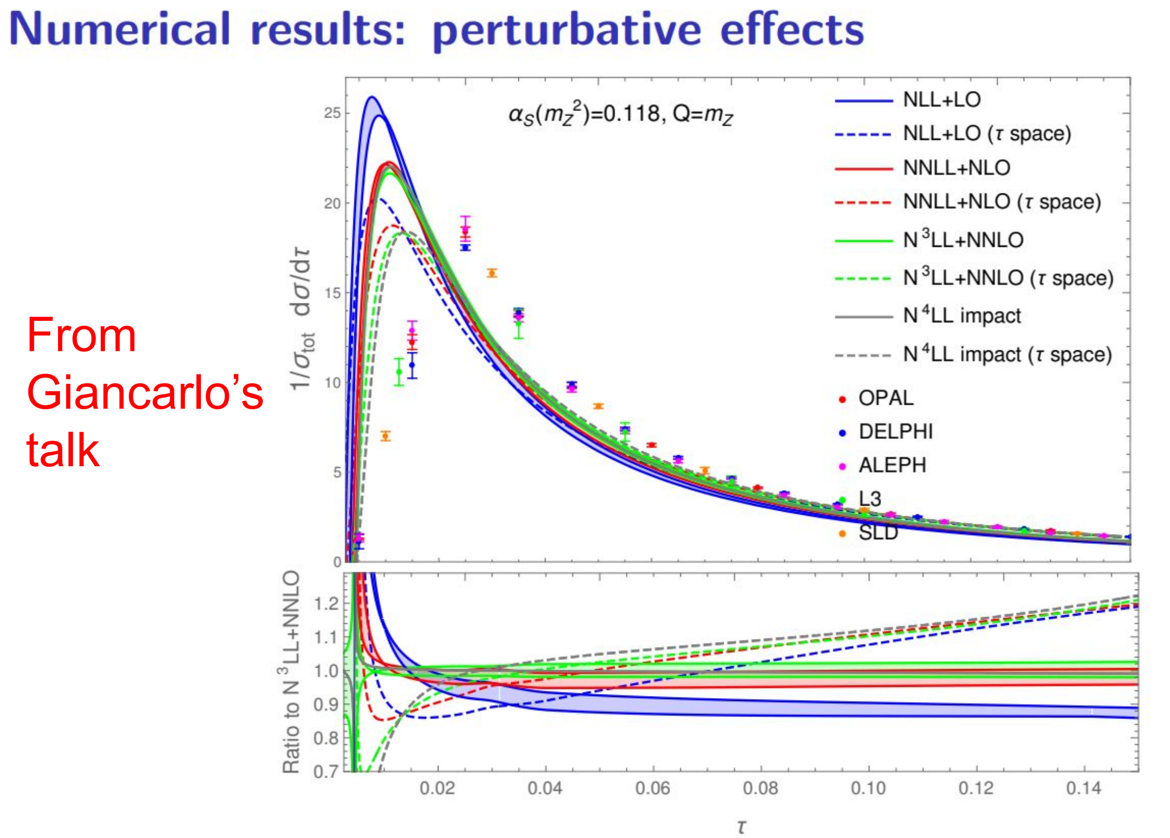
But in general:

- Important systematics to consider when fitting
- Impact of 3-jet power correction maybe quite different between different observables

TODO Dijet vs 3-jet

- Dijet vs 3-jet region:
    - Perturbative (when to turn off resummation)
    - Non-Perturbative (break down of properties of dijet non-perturbative treatment)
- Thrust fits at N3LL'+O(as^3) in tau [0.15, 0.33]
  Does the treatment of the transition region from resummation to fixed order give compatible results with the dijet fits in [0.06,0.15]?
- Non-singular partonic cross section vs total partonic cross section, order by order
  Is 10% at tau=0.1 (or 16% at tau=0.15) stable order by order or is it an accident at O(as^3)
- In general, we will need more discussion on this aspect

Resummation Space



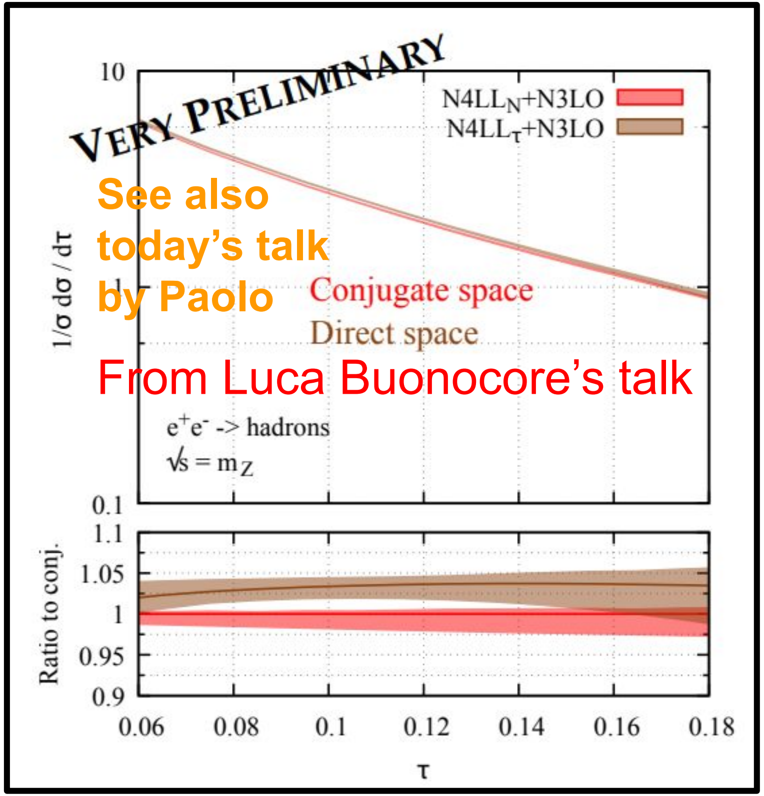
From Giancarlo's talk

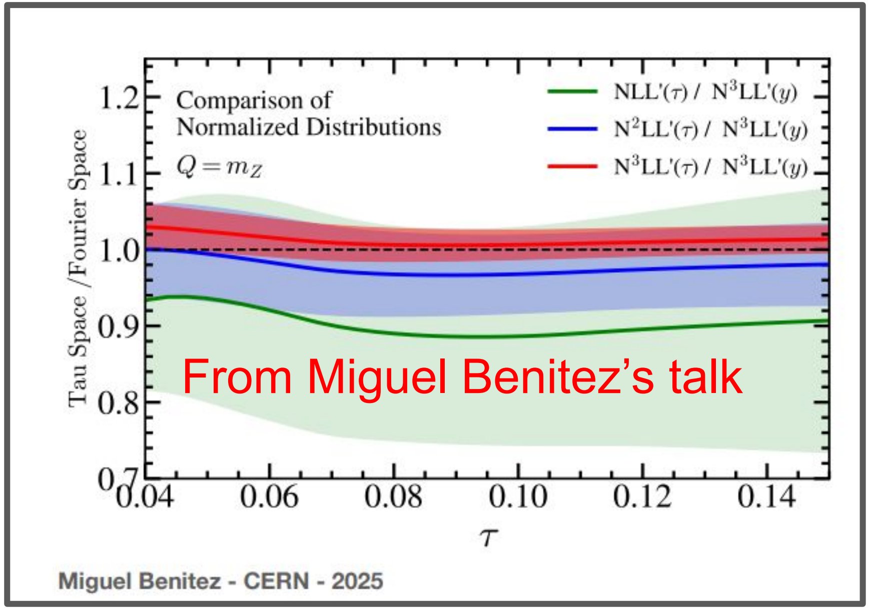
Resummation space impact

- Large effects at peak
- Up to 20% effects even at τ = 0.15
- Discrepancy doesn't decrease with resummation order, nor matching order
- Large impact on alphas fits

Resummation Space

Effect not reproduced in studies by other groups





- Mismatch reduces with perturbative order
- At highest order is O(1-2%) not 20%

Resummation Space

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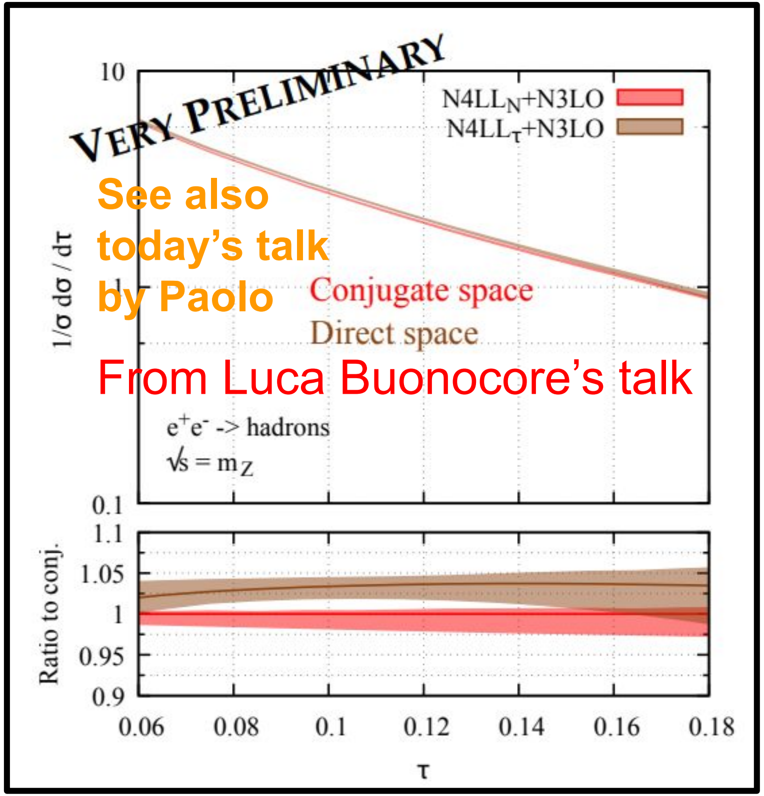

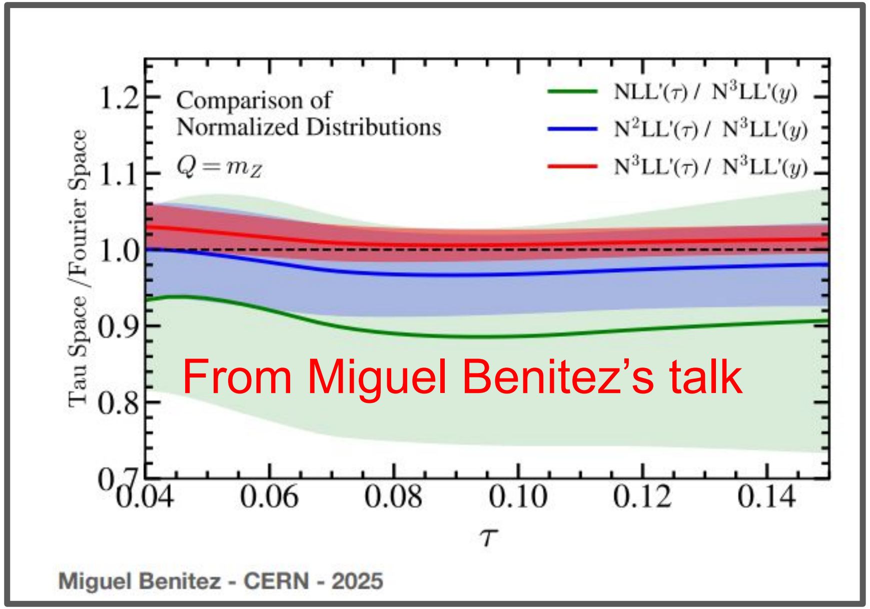

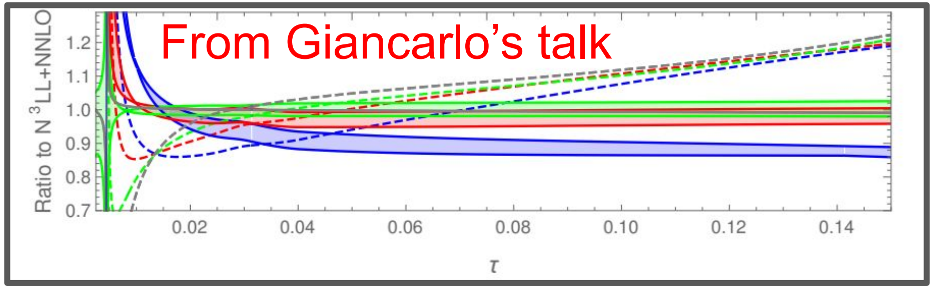

TODO resummation & matching uncertainties

- Solve discrepancy between predictions of Luca et al & Giancarlo et al. in the fit region (initially $\tau \in [0.05\text{-}0.15]$, extend later);
- Assess matching uncertainties
    - Different speed with which resummation is turned off in Log-R matching and different matching schemes
    - See impact of matching uncertainties order by order
    - Break down of impact of profile parameters on α_S fits in SCET
    - Impact of matching on alphas fits
- Note: Peak fits systematics not discussed, to be done in next meeting

Hadron Mass Effects

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From Paolo's talk

- Study impact of hadron mass effects by varying how hadron masses are treated

Call p_i the 4-momenta of the final state particles.

- *p-scheme*: the time component of the momenta p_i^0 are set to $|\vec{p}_i|$ before the computation of the shape variable.
- *E-scheme*: the space components are rescaled $\vec{p}_i \to p^0 \vec{p}_i / |\vec{p}_i|$.
- *D-scheme*: all particles are decayed isotropically into a pair of massless pseudoparticles. The shape variables are evaluated using these pseudoparticles.

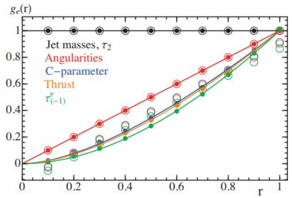
Hadron Mass Effects

- $\Omega_1(r) \equiv \langle 0 | \overline{Y}_{\bar{n}}^{\dagger} Y_n^{\dagger} \hat{\mathcal{E}}_T(r,0) Y_n \overline{Y}_{\bar{n}} | 0 \rangle$ universal 2-jet hadronization function
- Dijet event shapes $e = \sum_i \frac{m_i^{\perp}}{Q} f_e(r_i, y_i) \ll 1$

$$\Omega_1^e = c_e \int_0^1 \mathrm{d}r \, g_e(r) \, \Omega_1(r)$$

power correction

$$\{\tau, C\} \neq \{\rho, \ldots\} \neq \{\mathrm{EEC}, \ldots\}$$



From Iain's talk

For fit to single event shape (eg. thrust), if we assume that all expts. treat m_H effects with same method, then fit one parameter Ω_1^e

Fits using multiple event shapes (in different classes) should not be done with only a single hadronic parameter!

Hadron Mass Effects

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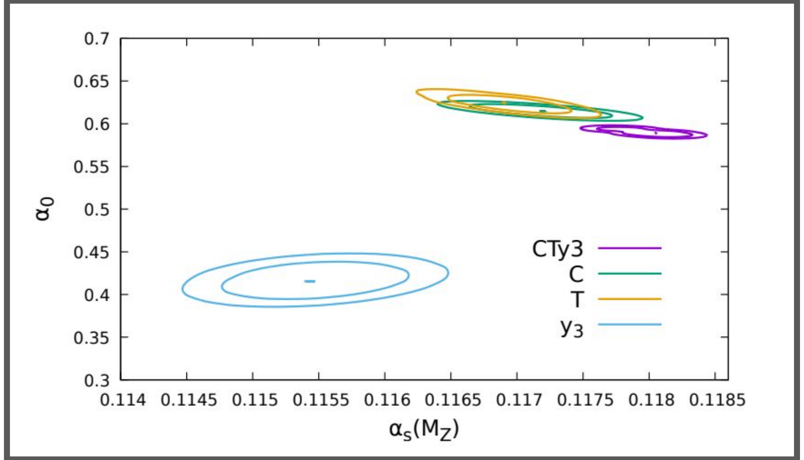

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TODO Hadron Mass Effects

- Fit with different mass schemes
  - start with E and p schemes
  - Expectation: changing mass scheme should only change value of O1 (in dijet)
  - Use deviation from it as signal of 3jet contributions/things not controlled by dijet fact
- Fits with multiple Omega parameters (one for each universality class: {T,C} & {y3})
- Fix α_S=0.118 and check consistency of fits of α_0 within universality classes

Organisation and next steps

- Created task force inside LHC Physics Centre at CERN (LPCC)
- Conveners: GV and Luca Buonocore
- Create document in CDS summarizing 27-28 November meeting
  - Reference also for reanalysis of e+e- data
- Plan for next meeting: dates, topics, participants
- In the longer term, set up an analogue of FLAG for event-shape extractions