Pino and Power Corrections: from LEP to LHC

Gavin Salam
CERN, Princeton University & LPTHE/CNRS (Paris)

Pino 2012
A special meeting in honour of Giuseppe Marchesini,
on the occasion of his 70th birthday.

Palazzone della Scuola Normale Superiore di Pisa,
Cortona, Italy, 29 May 2012

Yuri told you briefly about the "Wise Dispersive Method" (WDM): trying to quantify non-perturbative effects in QCD, using IR properties of perturbation theory.

This talk: some of the research done when I was postdoc with Pino from 1996–1999, to figure out if the idea worked.

Best place to check: event shapes

First discussion goes back to 1964. Serious work got going in late '70s. Various proposals to measure *shape* of events. Most famous example is Thrust:

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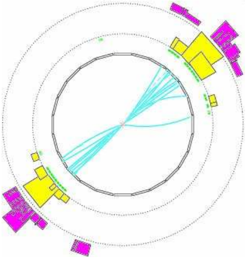
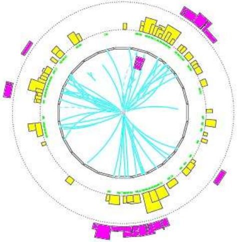


2-jet event: $T \simeq 1$



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There exist many other measures of aspects of the shape: Thrust-Major, C-parameter, broadening, heavy-jet mass, jet-resolution parameters,. . .

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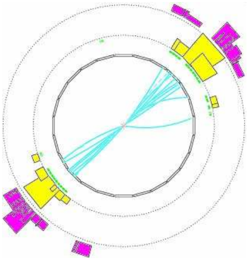

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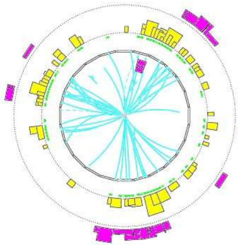

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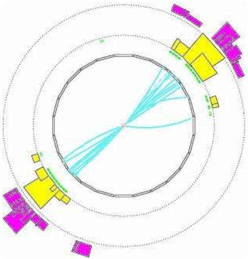

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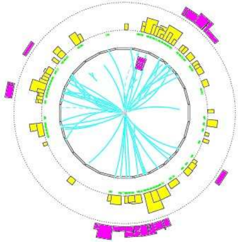

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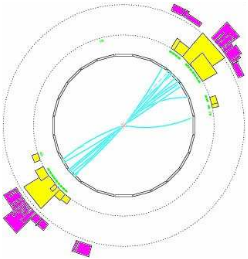

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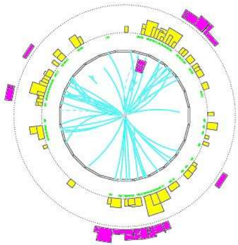

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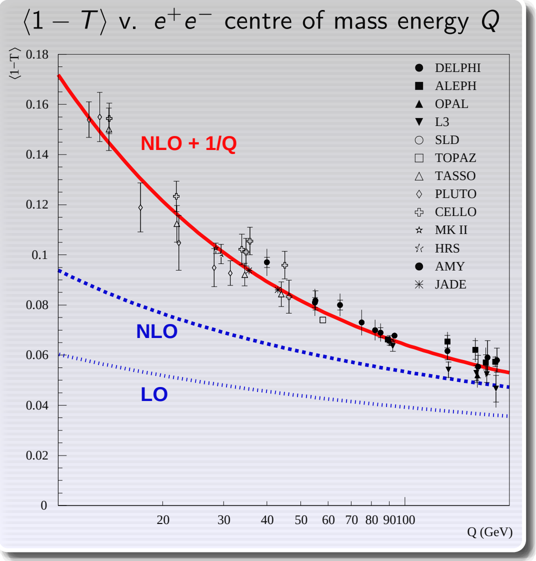
Clear need for contributions beyond perturbation theory



Schematic picture:

$$\langle 1-T \rangle \simeq \underbrace{A\alpha_s}_{LO} + \underbrace{B\alpha_s^2}_{NLO} + c_T \frac{\alpha_0}{Q}$$

several papers, notably Dokshitzer, Marchesini & Webber '95

- α_0 is non-perturbative but should be **universal**
- c_T can be **predicted** through a calculation using a single massive-gluon emission

You could legitimately ask the question:

Given the complexity of real hadronic events, could dominant non-perturbative physics truly be determined from just a single-gluon calculation?

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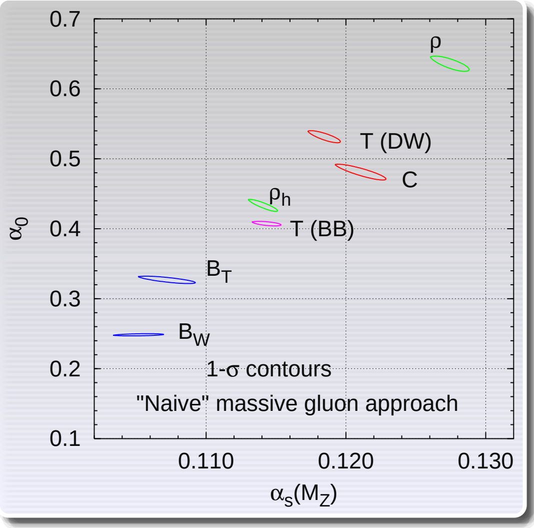

The data clearly say something is wrong with this assumption

initially, most clearly pointed out by the JADE collaboration

A first key result with Pino (+ Yuri & A. Lucenti)

Idea of "wise dispersive method": probe non-perturbative effects by integrating over virtuality of an infrared gluon.

But such a "massive" gluon will necessarily decay to two gluons or $q\bar{q}$ that go in different directions.

issue raised: Nason & Seymour '95

So: explicitly include the calculation of that splitting.
A very simple result: for thrust, non-perturbative correction simply gets rescaled by a numerical "Milan" factor

$$\mathcal{M} \simeq 1.49$$

Matrix elements from Berends and Giele '88 + Dokshitzer, Marchesini & Oriani '92

$\mathcal{M}$ first calculated for thrust: Dokshitzer, Lucenti, Marchesini & GPS '97

n_f piece for σ_L: Beneke, Braun & Magnea '97

calculation fixed: Dasgupta, Magnea & Smye '99

There are two classes of event shape

1) those that are a **linear** combination of contributions from individual emissions $i = 1 \ldots n$

$$\left(\text{e.g.} \quad 1 - T \simeq \sum_{i=1}^{n} p_{ti} e^{-|\eta_i|}\right)$$

2) those that are **non-linear**, e.g. B_W, B_T, ρ_h

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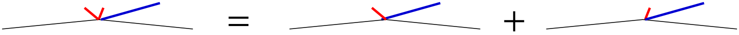
In the presence of **perturbative emissions** with $p_t \gg \Lambda_{QCD}$, then all the non-linear event shapes turn out to have an "emergent" linearity for **non-perturbative emissions** at scales $\sim \Lambda_{QCD}$



➥ non-perturbative (NP) effects can still be deduced from the effect of a single non-perturbative gluon, but its impact must be determined by averaging over perturbative configurations

$$\langle \text{NP} \rangle \simeq \int [d\Phi_{pert.}] \, |M^2(pert.)| \times \text{NP}(pert.)$$

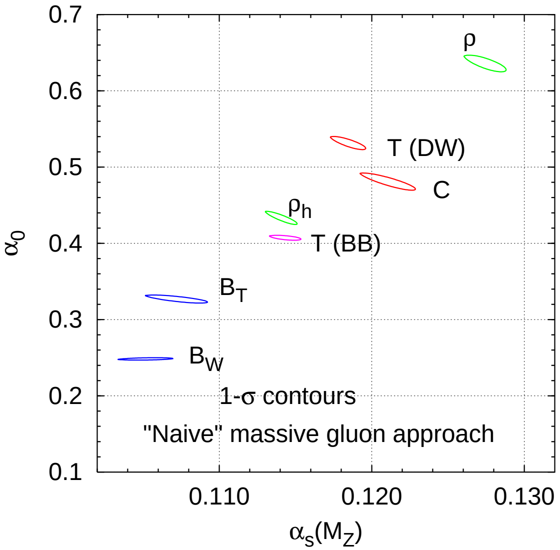
first such observation, for ρ_h: Akhoury & Zakharov '95

universality of "Milan" factor in e^+e^-: Dokshitzer, Marchesini, Lucenti & GPS '98

PT and NP effects together in jet broadenings: Dokshitzer, Marchesini & GPS '98

universality of "Milan" factor in DIS: Dasgupta & Webber '98

moderate Λ/p_t effects: Korchemsky & Tafat '00



Original results for fits of α_s and the non-perturbative parameter α_s.

↓

Including all the "DLMS" improvements

Pino et al '97-98

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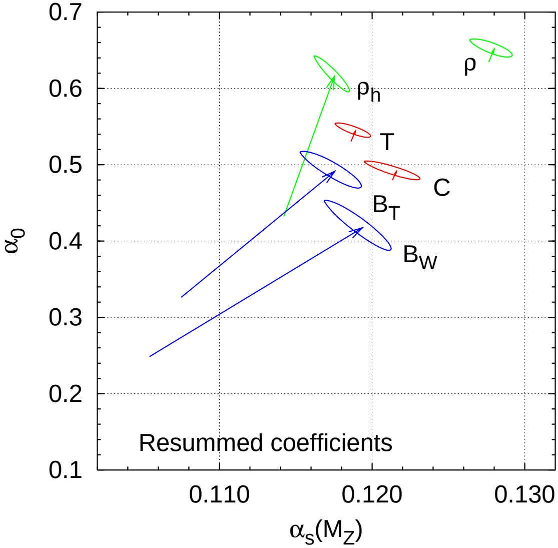
Taking care not just of gluon masses, but also hadron masses

GPS & Wicke '01



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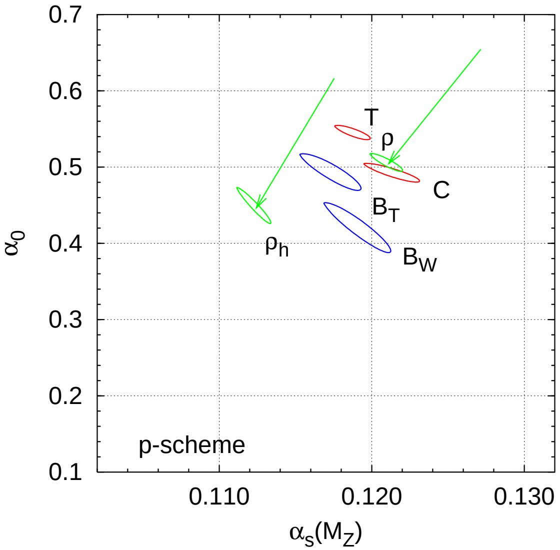

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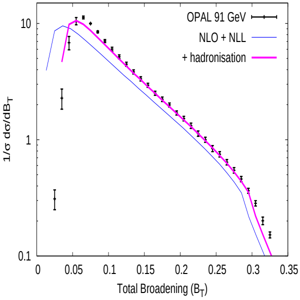
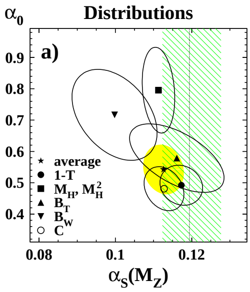
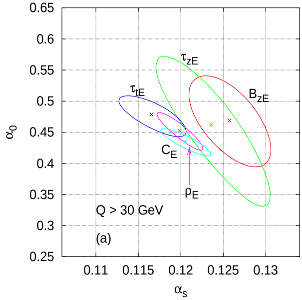
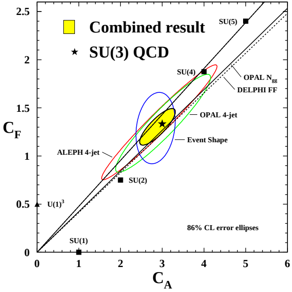
A rich field: many investigations in e^+e^- and DIS









Overall, many analyses in late '90s and early '00s paint a picture of general success of the simple physical idea of probing NP physics with perturbative tools.

Even if there are "corners" where it doesn't work as well as we'd like. . .

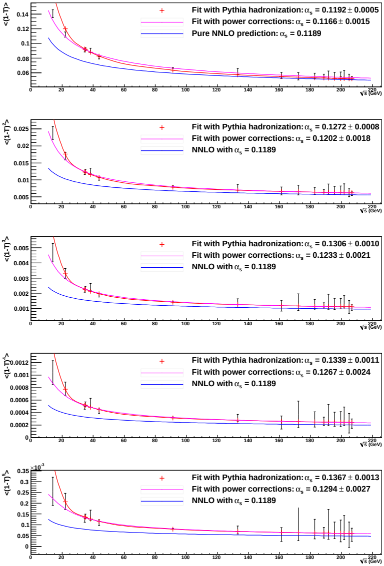
Some people had objected that combing NLO + $1/Q$ was inconsistent, because NNLO might easily account for all the discrepancy between NLO and data.

In the past few years, thanks to epic calculations, NNLO has become available.

Gehrmann-De Ridder, Gehrmann Glover & Heinrich '07 Weinzierl '09

A fit with NNLO shows clear need still for $1/Q$ component.

Gehrmann, Jacquier & Luisoni '09



Could have been deduced from old work

Korchemsky & Sterman '95
also Seymour '97

Main result

$$\langle p_{t,jet} - p_{t,parton-shower} \rangle \simeq -\frac{0.4\ \text{GeV}}{R} \times \begin{cases} C_F & quarks \\ C_A & gluons \end{cases}$$

cf. Dasgupta, Magnea & GPS '07
coefficient including $\mathcal{M} = 1.49$ holds for anti-k_t
see Dasgupta & Delenda '09 for k_t alg. — only calculated example of $\mathcal{M} \neq 1.49$

"Naive" prediction (UE $\simeq$ colour dipole between pp):

$$\Delta p_t \simeq 0.4 \text{ GeV} \times \frac{R^2}{2} \times \begin{cases} C_F & q\bar{q} \text{ dipole} \\ C_A & \text{gluon dipole} \end{cases}$$

Monte Carlo tunes tell you:

$$\Delta p_t \sim \mathbf{5 - 10\ GeV} \times \frac{R^2}{2}$$

This big coefficient motivated special effort to understand interplay between jet algorithm and UE: "jet areas"

How does coefficient depend on algorithm?

How does it depend on jet p_t? How does it fluctuate?

cf. Cacciari, GPS & Soyez '08

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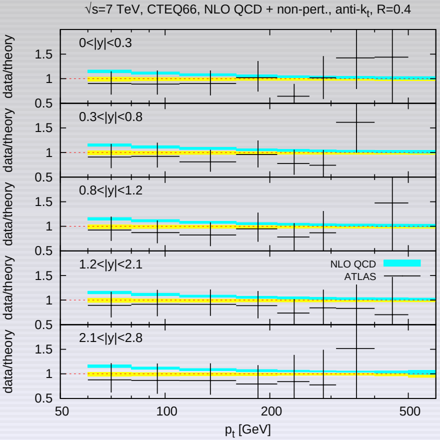
$1/Q$ corrections for hadron-collider jets v. data

(ATLAS jet data) / (NLO + $1/Q$)



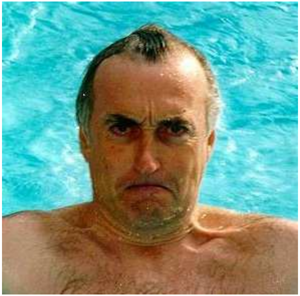
Soyez '11

This is just one of several fun physics topics that were pushed forwards in the late '90s with Pino in Milan.

small x, resummations were others

Pino wrote $\sim$ 15 articles with the students and postdocs then (including Banfi, Dasgupta, GPS, Smye, Zanderighi)

Many of the collaborations that formed between them then have continued to this day, easily having produced another $\sim$ 15 articles.



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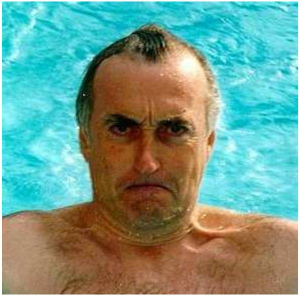

THANK YOU PINO!