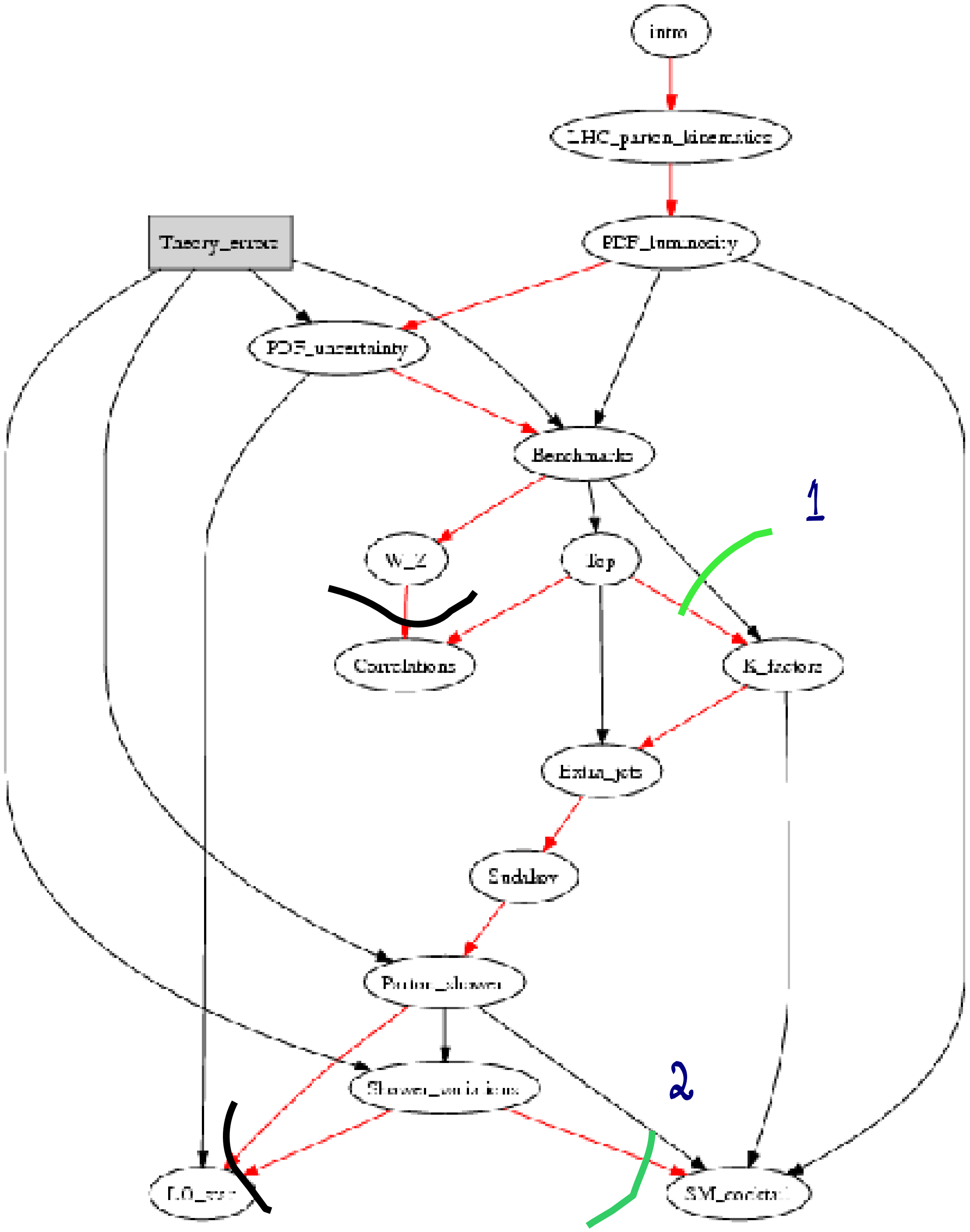
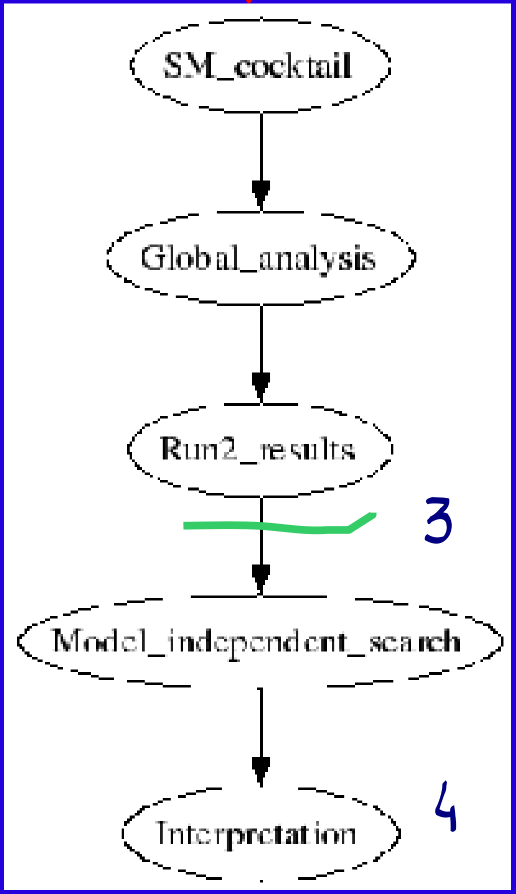
Outline


intro
LHC_parton_kinematics
Theory_errors
PDF_luminosity
PDF_uncertainty
Benchmarks
W_Z
Top
1
Correlations
K_factors
Extra_jets
Sudakov
Parton_shower
Shower_variations
2
LO_vs
SM_cocktail


SM_cocktail
Global_analysis
Run2_results
3
Model_independent_search
Interpretation
4

Why we want new PDFs for event generators

- Many kinematic effects at NLO come from just the NLO PDFs
- PDF errors only work for NLO
  - We make assumptions when calculating PDF uncertainties the standard way

$$f_{LO}(x,Q)\times\frac{f_{NLO,error}(x,Q)}{f_{NLO,central}(x,Q)}$$

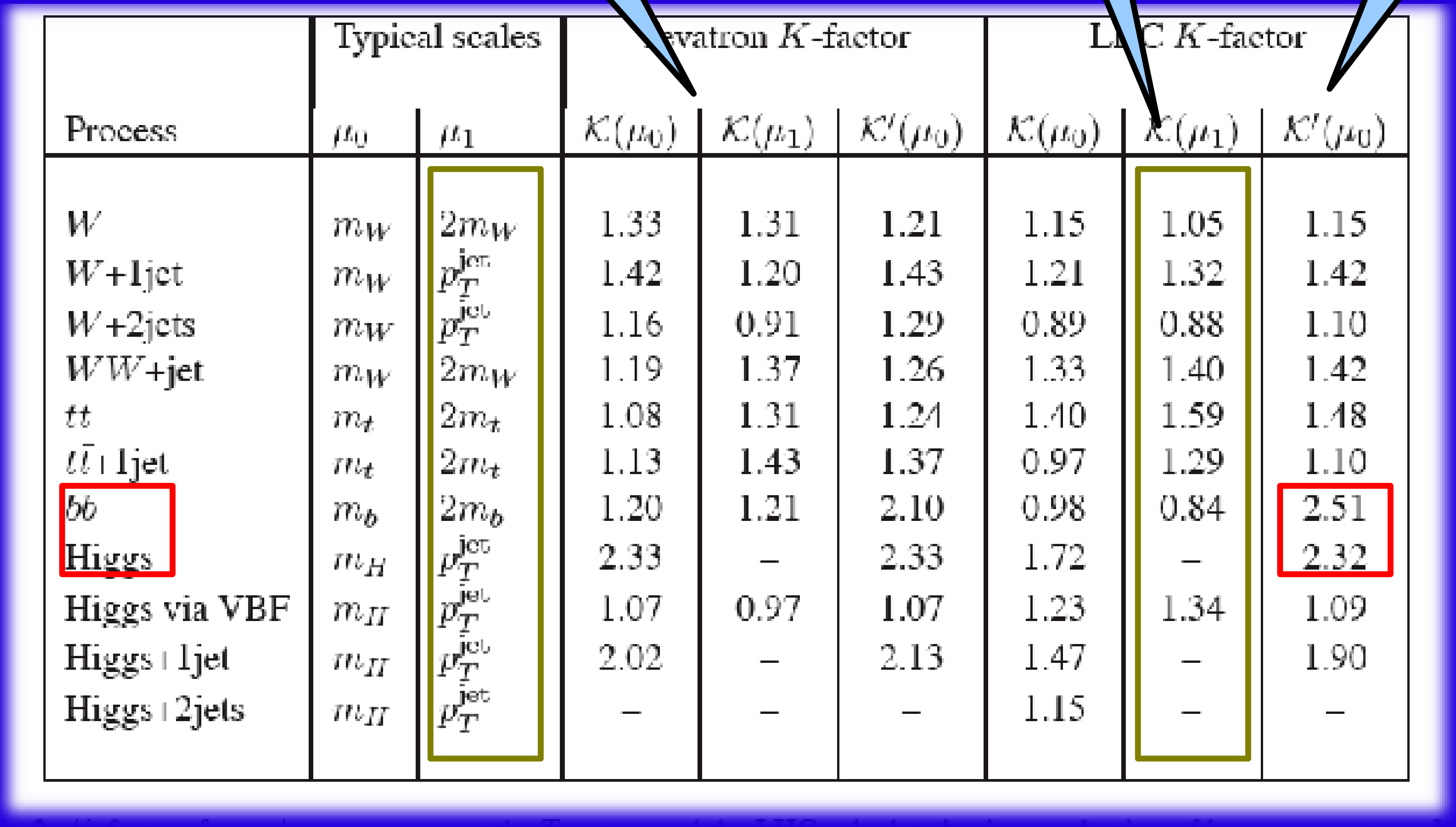
- UE models described well by LO PDF, which is very different from NLO

Some high pT processes behave poorly with ordinary NLO PDFs

K=NLO/LO

6M/6L1

6M/6M

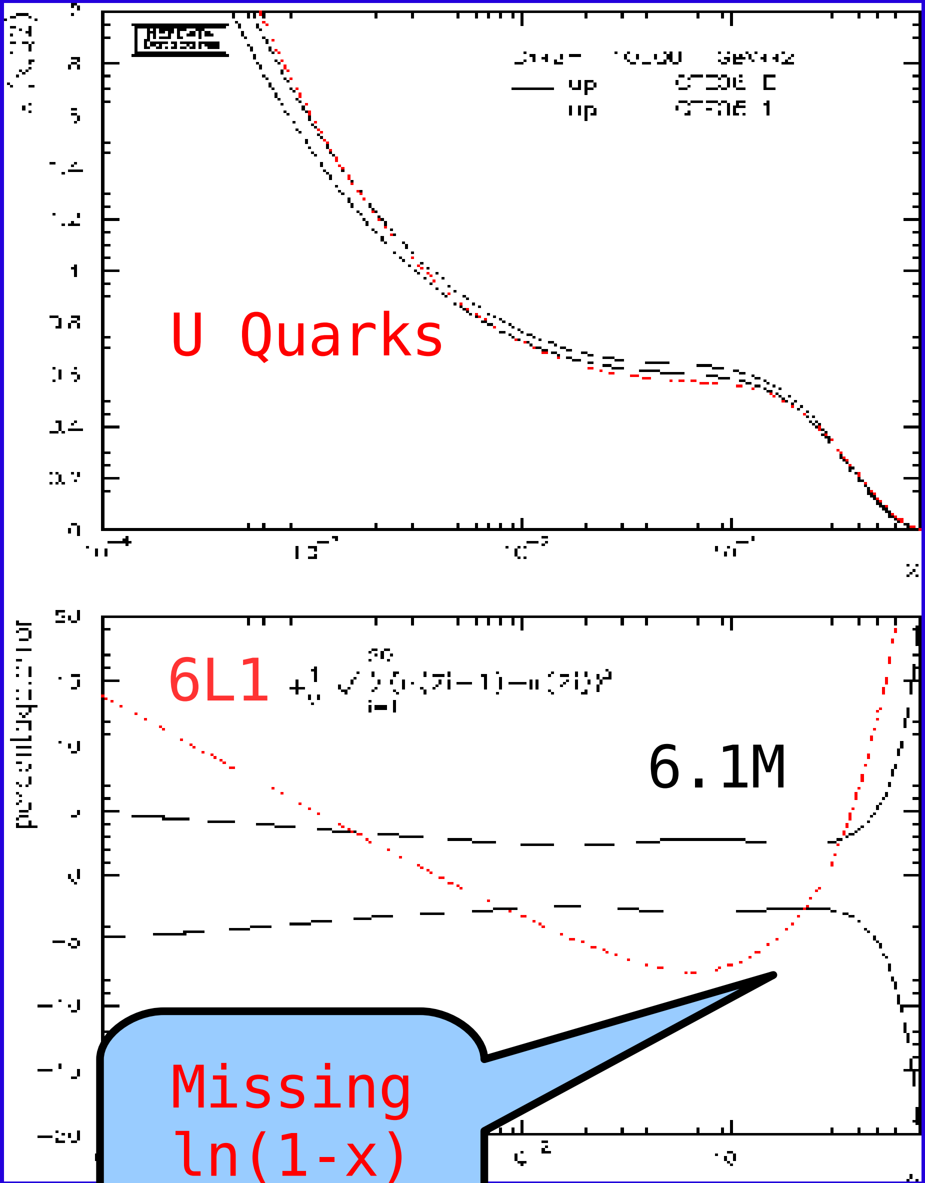


Process	Typical scales		Tevatron K-factor			LHC K-factor		
	μ_0	μ_1	$\mathcal{K}(\mu_0)$	$\mathcal{K}(\mu_1)$	$\mathcal{K}'(\mu_0)$	$\mathcal{K}(\mu_0)$	$\mathcal{K}(\mu_1)$	$\mathcal{K}'(\mu_0)$
W	m_W	$2m_W$	1.33	1.31	1.21	1.15	1.05	1.15
W+1jet	m_W	p_T^{jet}	1.42	1.20	1.43	1.21	1.32	1.42
W+2jets	m_W	p_T^{jet}	1.16	0.91	1.29	0.89	0.88	1.10
WW+jet	m_W	$2m_W$	1.19	1.37	1.26	1.33	1.40	1.42
$t\bar{t}$	m_t	$2m_t$	1.08	1.31	1.24	1.40	1.59	1.48
$t\bar{t}$+1jet	m_t	$2m_t$	1.13	1.43	1.37	0.97	1.29	1.10
$b\bar{b}$	m_b	$2m_b$	1.20	1.21	2.10	0.98	0.84	2.51
Higgs	m_H	p_T^{jet}	2.33	–	2.33	1.72	–	2.32
Higgs via VBF	m_H	p_T^{jet}	1.07	0.97	1.07	1.23	1.34	1.09
Higgs+1jet	m_H	p_T^{jet}	2.02	–	2.13	1.47	–	1.90
Higgs+2jets	m_H	p_T^{jet}	–	–	–	1.15	–	–

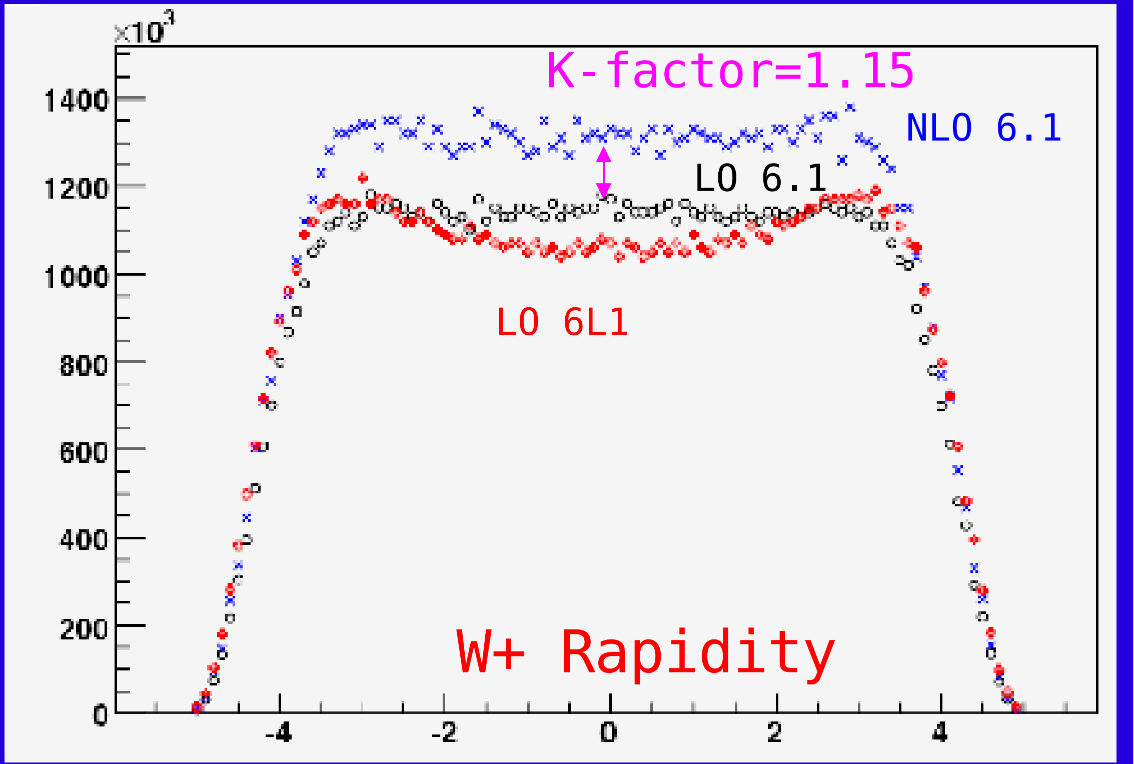
Requirements for LO* PDFs

- LO as x->0; → NLO as x->1
- universal and reasonable
- Allows for sensible error PDFs:
  - similar Sudakov form factors
  - PDF re-weighting makes sense
- describes UE @TeV with a tune similar to CTEQ6L (for convenience) and extrapolates to a *reasonable* UE at the LHC

Differences between LO and NLO partons?

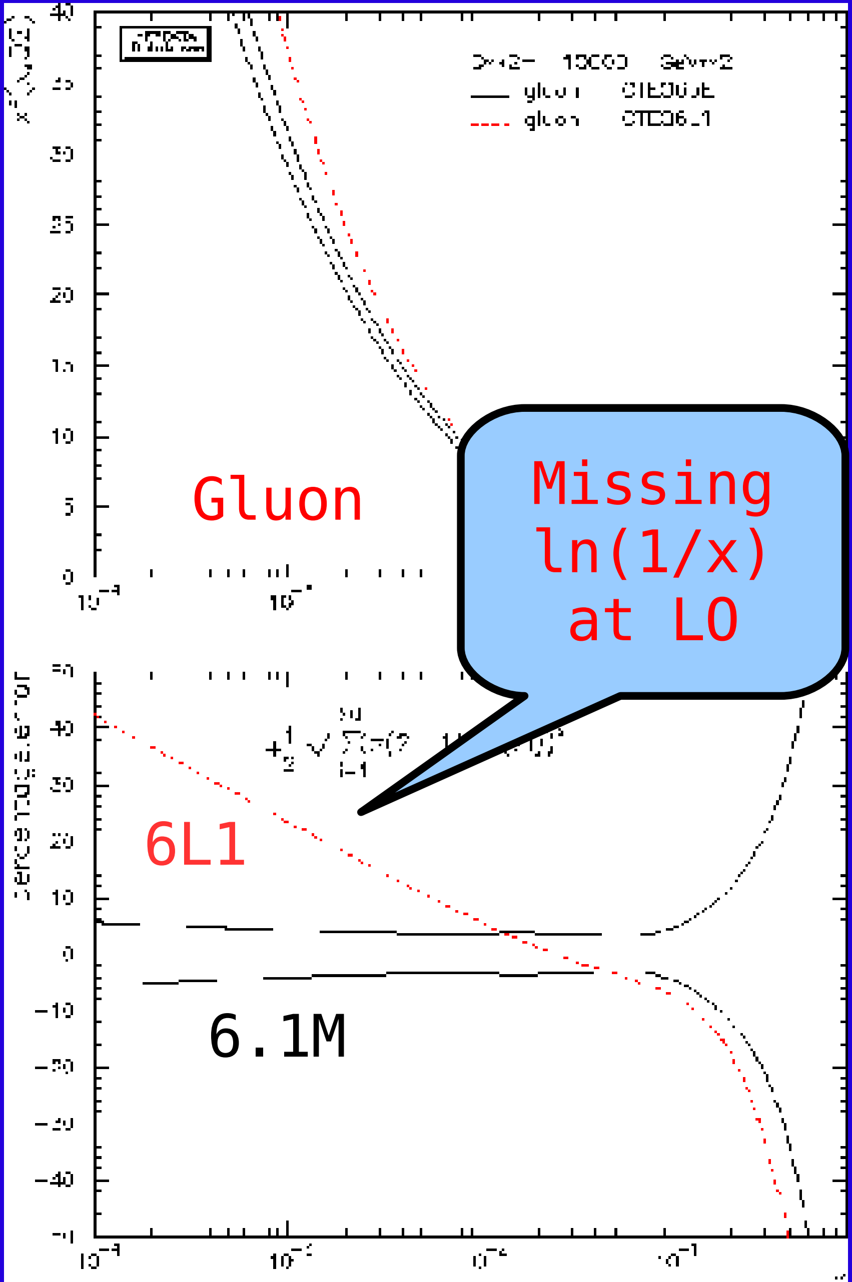


Missing ln(1-x) at LO

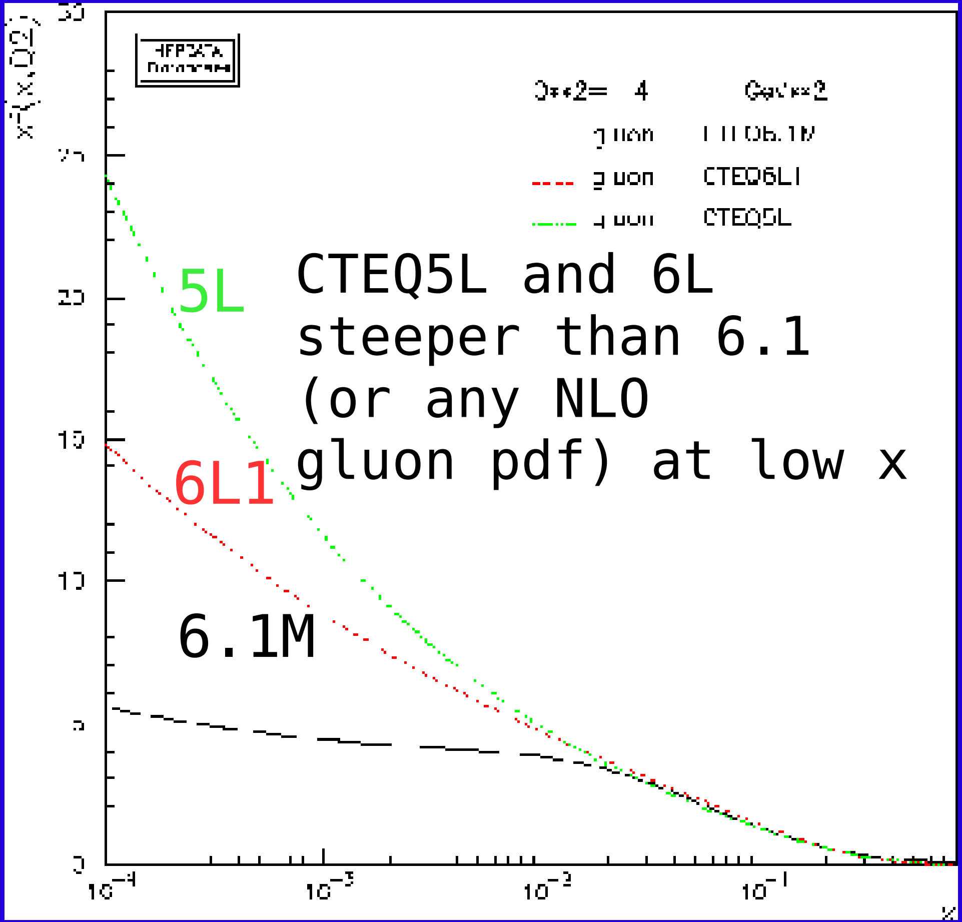


LO 6L1 == (LO ME) (LO PDF)
LO 6.1 == (LO ME) (NLO PDF)
NLO 6.1 == (NLO ME) (NLO PDF)

Where are the differences:gluons?



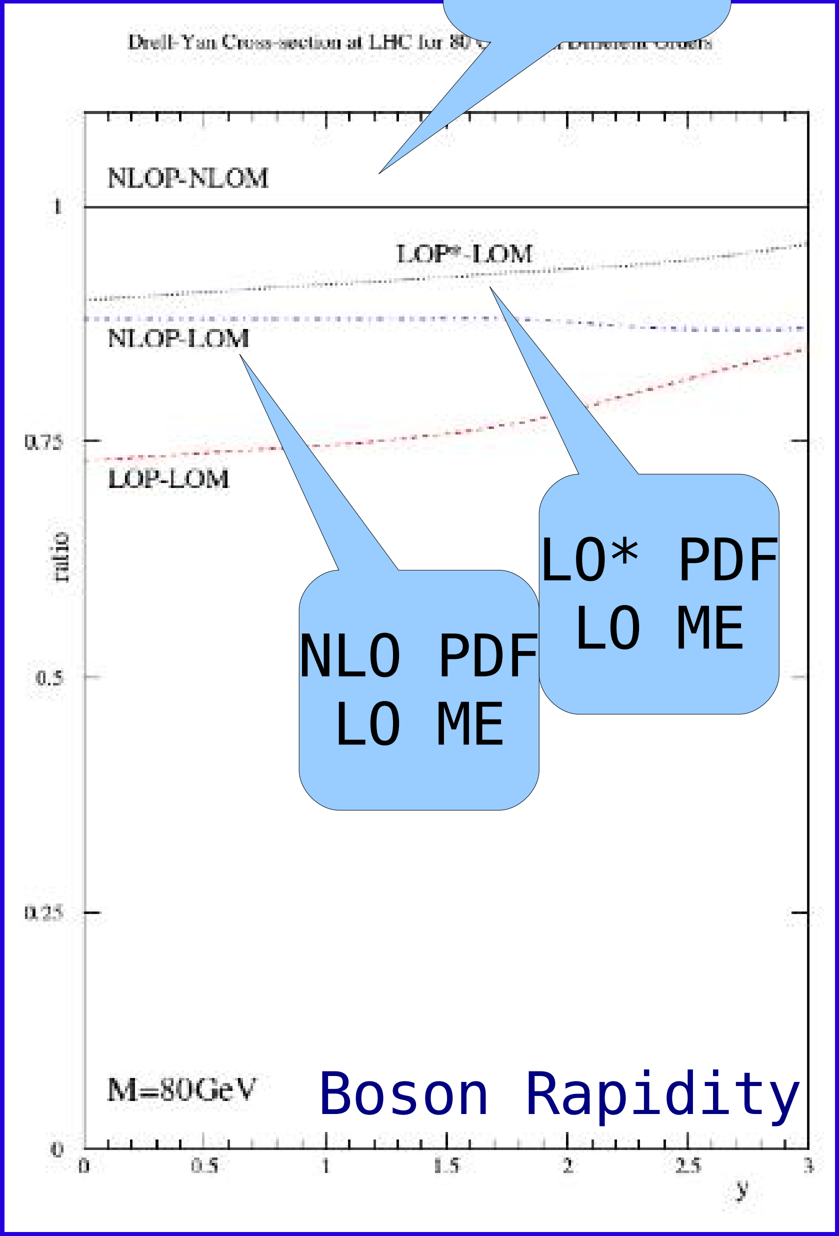
Missing ln(1/x) at LO



CTEQ5L and 6L steeper than 6.1 (or any NLO gluon pdf) at low x

MRSTLO*

- incorporate many of previous points
- relax the momentum sum rule (114%) and achieve a better agreement (than MRST LO pdf’s) with some important LHC benchmark cross sections
- Available in LHAPDF



NLO PDF
NLO ME

LO* PDF
LO ME

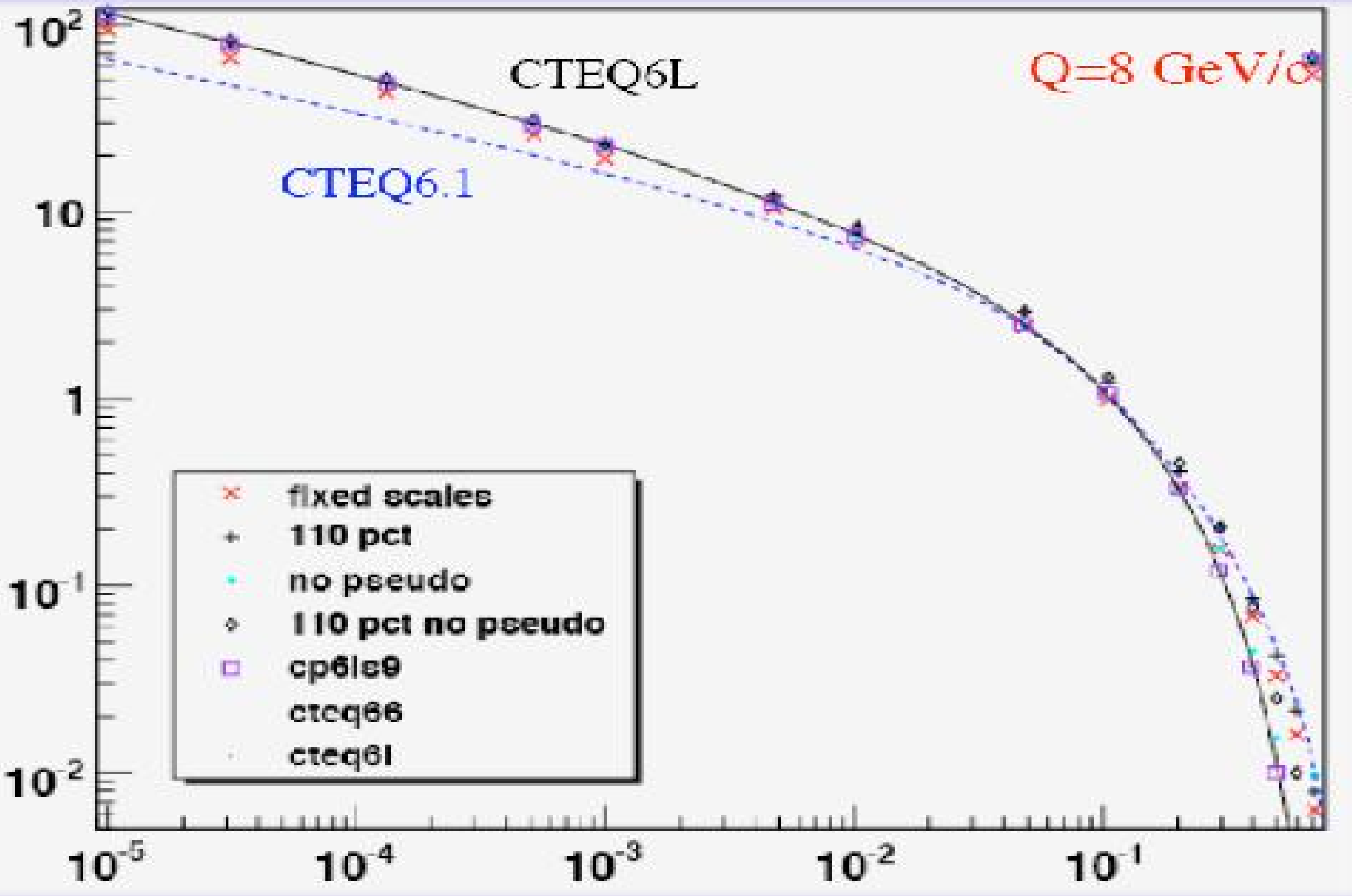
NLO PDF
LO ME

Boson Rapidity

CTEQ variations

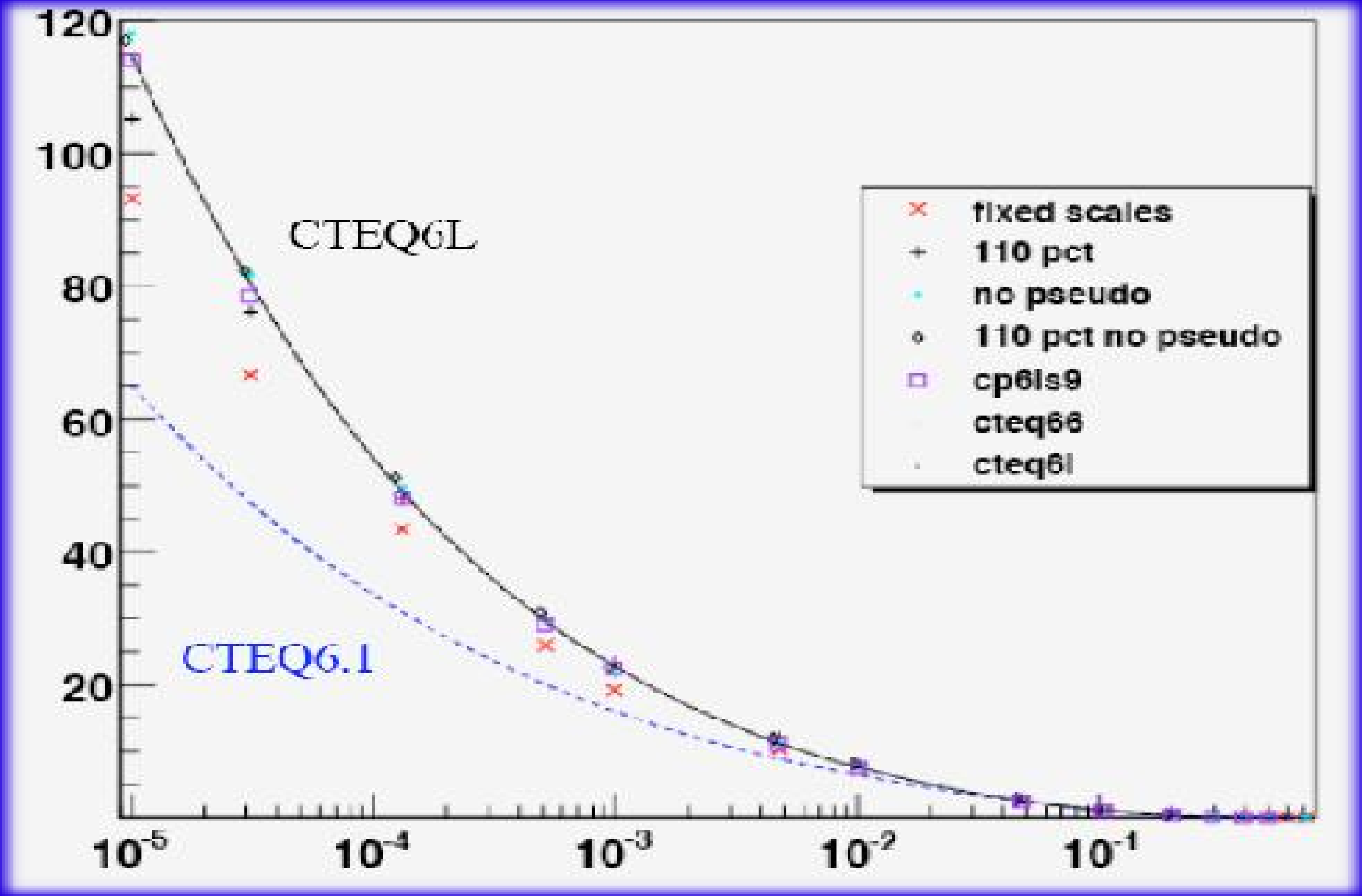
- INCLUDE IN LO* FIT (WEIGHTED) **PSEUDO-DATA** FOR CHARACTERISTIC LHC PROCESSES PRODUCED USING CTEQ6.6 NLO PDF’S WITH NLO MATRIX ELEMENTS (USING MCFM)
- Try 2-loop or 1-loop α
- Fixed momentum sum rule, or not
    - re-arrange momentum within proton and/or add extra momentum
    - extra momentum appreciated by some of pseudo-data sets but not others and may lose some useful correlations
- Fix pseudo-data normalizations to K-factors expected from higher order corrections, or let float
- Scale variation within reasonable range for fine-tuning of agreement with pseudo-data
    - vector boson scale varies from 0.5 m_B to 2.0 m_B

Results: gluon distribution



- Candidate pdf titled *fixed scales* tries to fit pseudo-data
- Larger than CTEQ6L at high x, but smaller at low x
- With *110%* momentum in proton, gluon is larger at high x
- Including the pseudo-data in the fit increases the high x gluon even more

Focus on small-x



Desired Perturbative Variations for Shower Uncertainty

- Radiation functions
- Evolution variables
- Phase space mapping
- Internal scales
- ...

Skands/Giele/Kosower VINCIA is the closest match to this

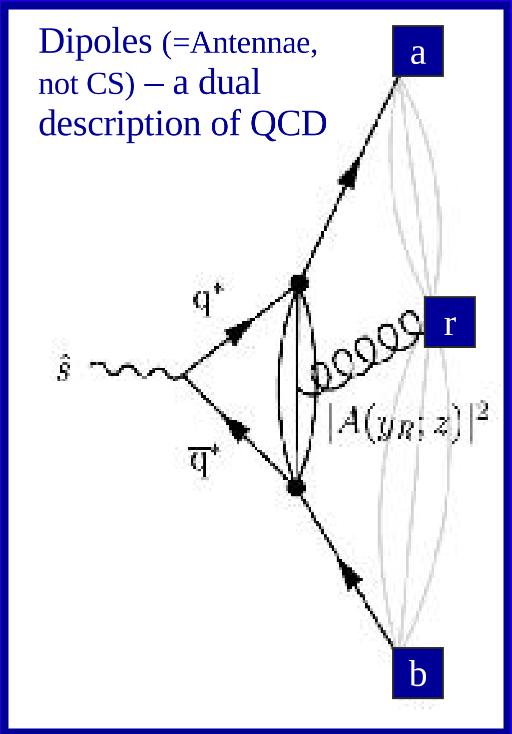
VINCIA

VIRTUAL NUMERICAL COLLIDER WITH INTERLEAVED ANTENNAE

Gustafson, PLB175(1986)453; Lönnblad (ARIADNE), CPC71(1992)15.
Azimov, Dokshitzer, Khoze, Troyan, PLB165B(1985)147
Kosower PRD57(1998)5410; Campbell,Cullen,Glover EPJC9(1999)245

- Based on Dipole-Antennae
    - Shower off color-connected pairs of partons
  - 3 different shower evolution variables:
    - pT-ordering (= ARIADNE ~ PYTHIA8)
    - Dipole-mass-ordering (~ but not = PYTHIA6)
    - Thrust-ordering (3-parton Thrust)
  - family of antenna functions
  - Shower cutoff contour: independent of evolution variable
  - Several different choices for α_s

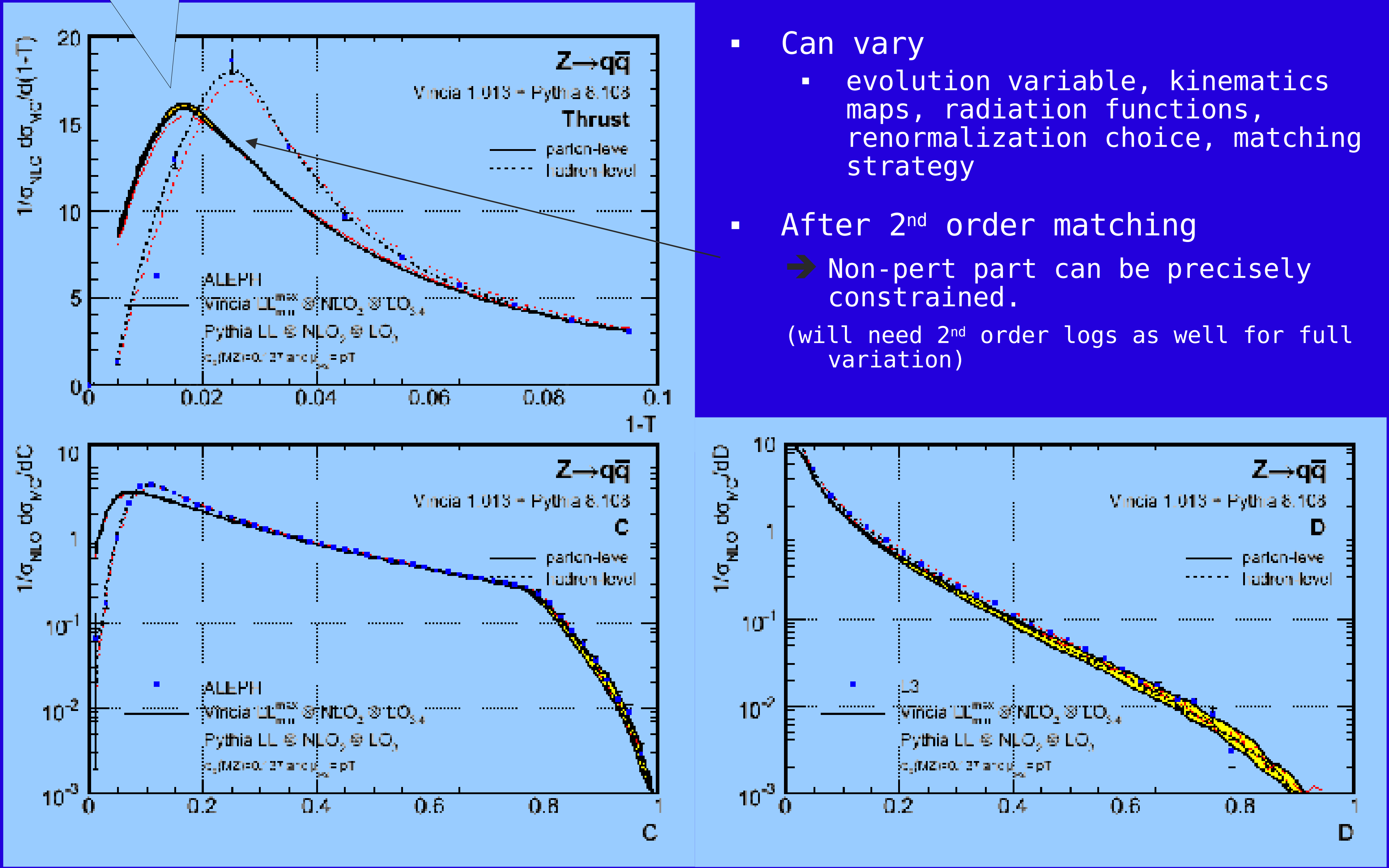
    (evolution scale, p_T, mother antenna mass, 2-loop, …)
  - Different phase space mappings:
    - Antenna-like (ARIADNE angle) or Parton-shower-like


Dipoles (=Antennae, not CS) – a dual description of QCD

Giele, Kosower, PS : hep-ph/0707.3652 + Les Houches 2007

VINCIA in Action

Different Finite pieces



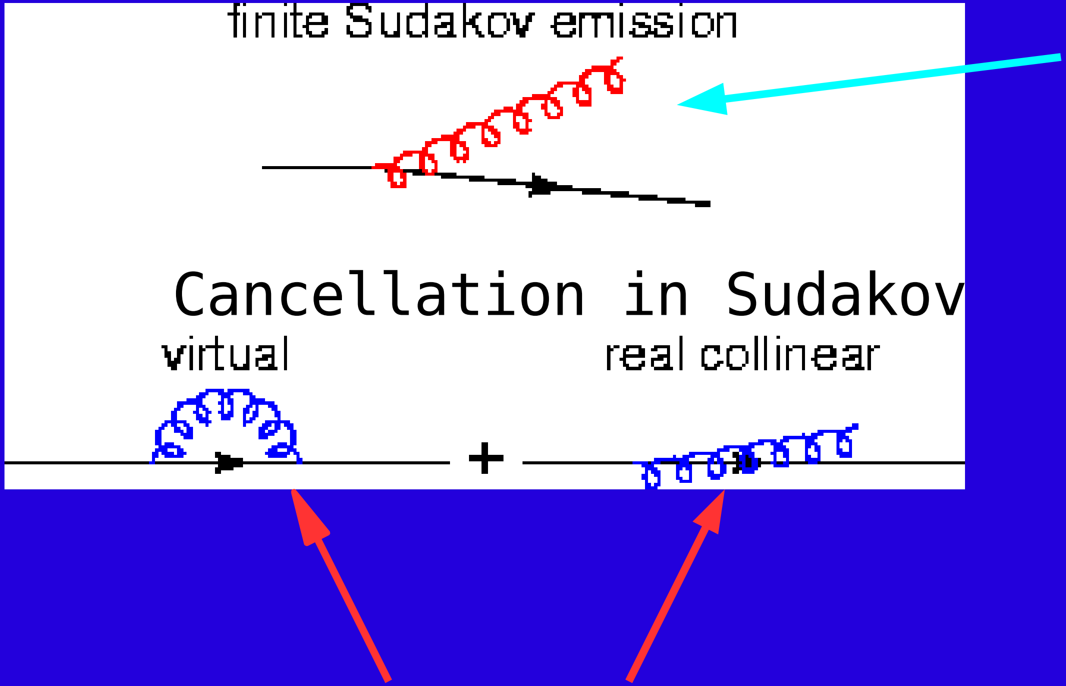
- Can vary
  - evolution variable, kinematics maps, radiation functions, renormalization choice, matching strategy
- After 2nd order matching

  ➔ Non-pert part can be precisely constrained.

  (will need 2nd order logs as well for full variation)

Giele, Kosower, PS : PRD78(2008)014026 + Les Houches ‘NLM’ 2007

NLO and Parton Showers



Piece of a parton shower prediction

Inside a NLO calculation

Methods for including PS corrections to NLO predictions must remove the overlap

Highly non-trivial: can depend on subtraction method, shower, etc.

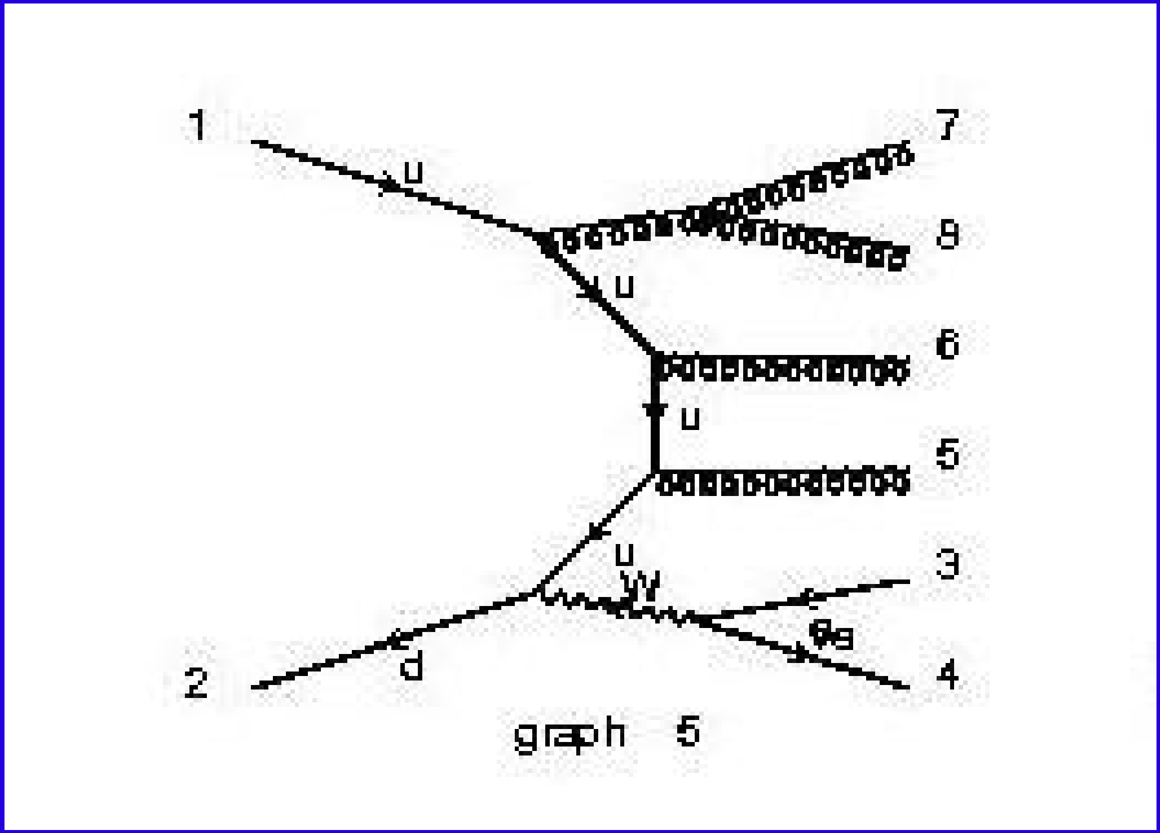
In some cases, already covered by ME corrections in showers

MC@NLO, POWHEG, NL^3(e+e-) (Vincia)

Modeling the SM in practice

- Discussed importance of PDFs, NLO …
- In practice, we try to use the data to calculate all orders, pert and non
- Data(Y) = MC(Y)/MC(X) * Data(X)
  - Other theoretical developments are used mainly for cross checks or to model signals
- Like mixing cocktails or making sausage

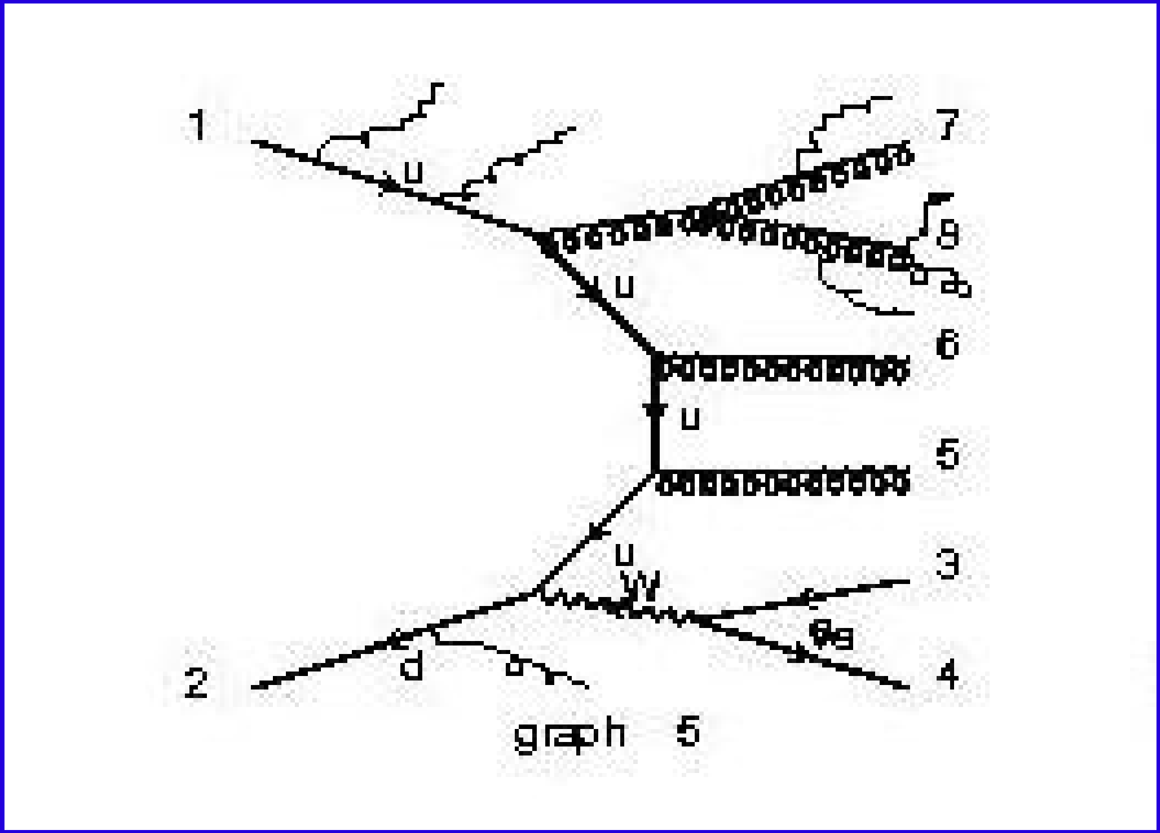
Tools: ME calculators



graph 5

$$\alpha_s^{\,4} + O(\alpha_s^{\,5}), \alpha_s \sim .12$$

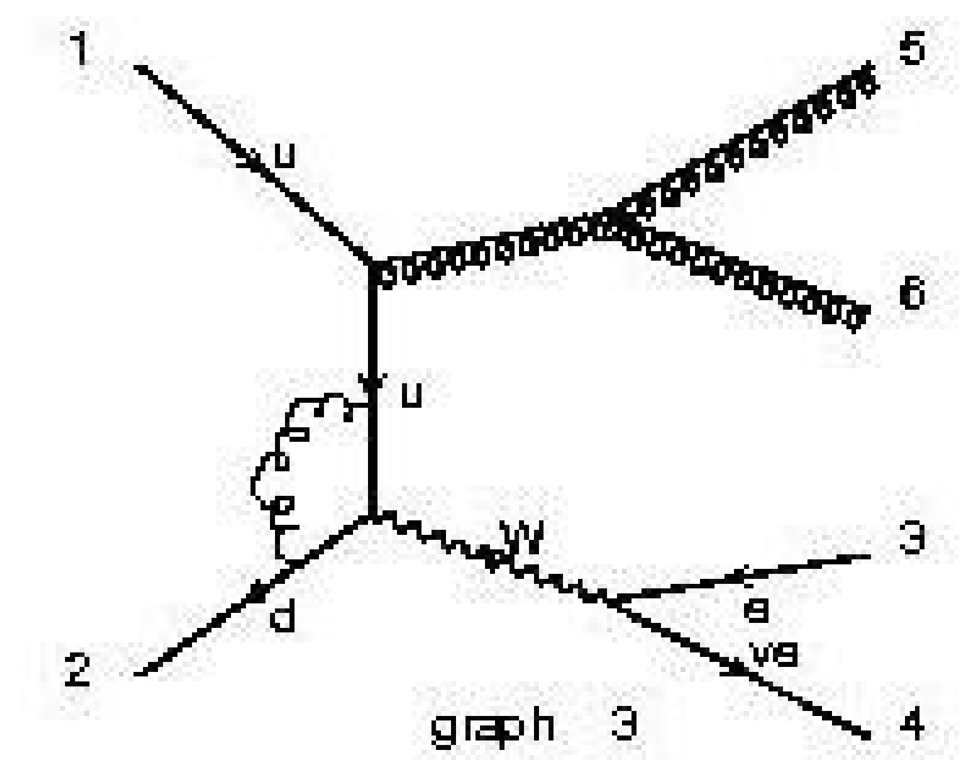
+ parton showers



$$\alpha_s \sim \frac{1}{\ln(\frac{p_T}{Q})}$$

$$\alpha_s \ln(\frac{p_T}{Q})(\ln(\frac{p_T}{Q})+1)+O(\alpha_s{}^N \ln^{2N,2N-1})$$

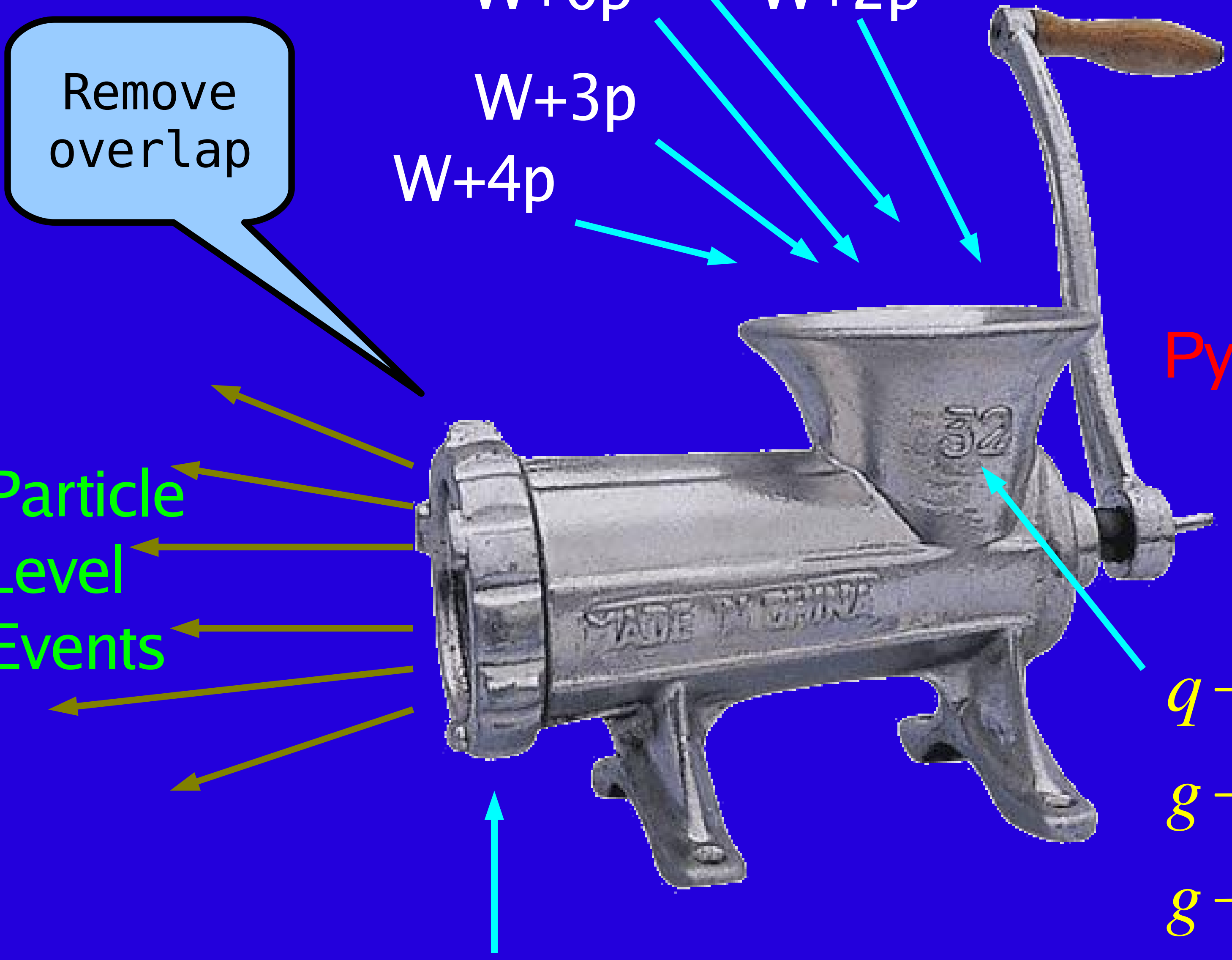
Tools: NLO



$$\alpha_s\left(\infty + O(1) - \infty + O(1)\right)$$

Alpgen/MadEvent

$p = q, \bar{q}, g$



W+0p

W+1p

W+2p

W+3p

W+4p

Remove overlap

Pythia/Herwig

Particle Level Events

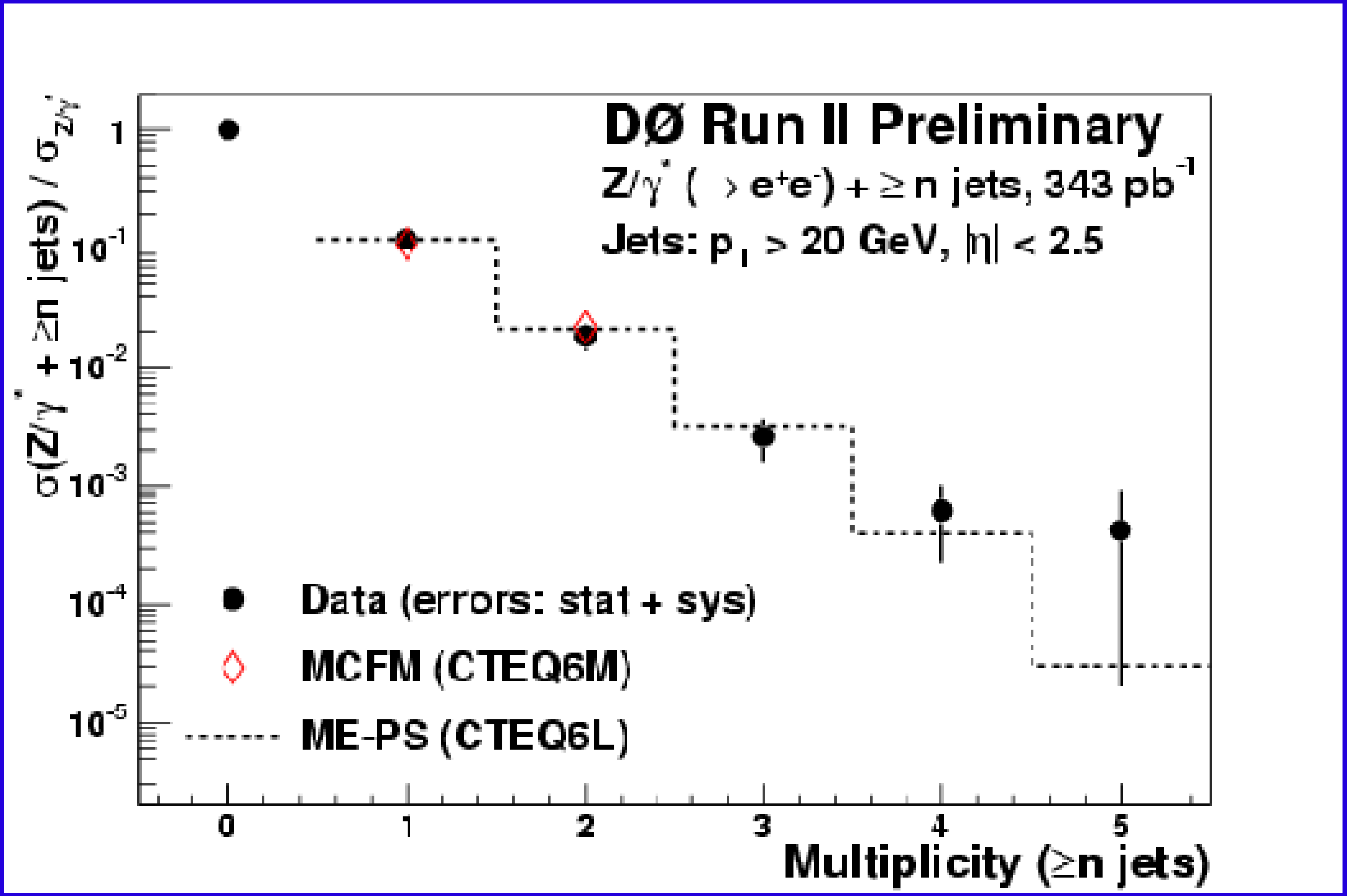
$q \rightarrow q\,g$

$g \rightarrow g\,g$

$g \rightarrow q\,\bar{q}$

$W + 4\text{p} \rightarrow W + 4\text{j} + \text{softer stuff}$

Example of a Cross Check



How well do we understand the Standard Model (@ high pT)?

Particle content is 'known' (*)

Parameters of L_{int} measured with some precision (**)

No sufficiently significant discrepancies between predictions and data

It seems to work very well ... how well?

(*) Higgs boson? (**) Neutrino masses?

Is there a Quantitative Measure?

Tells us how to view discrepancies

Directs theory/expt'l research

A benchmark for comparing to other fields

I will spend remaining part of the lecture:

Explaining a framework to answer this question

Showing the result

The Framework

Define high-p_T objects reconstructed in experiment (CDF in this case)

Generate-Simulate Monte Carlo events and reconstruct same objects

Introduce a correction model (fakes, K-factors, uncertainties) and refine

Compare counts and shapes in different final states

Event Selection

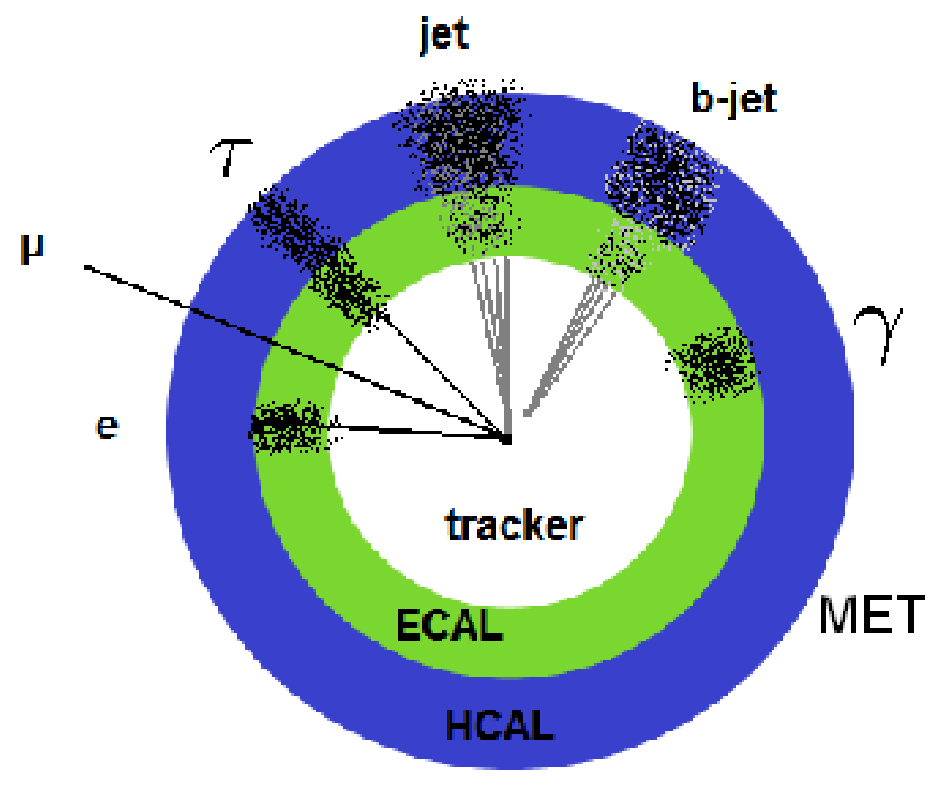
Objects identified:

- e, μ, τ, jet, b-jet, γ, Missing E_T

Consider **objects** of $p_T > 17$ GeV

Select **events** with any of the following:

- e, $p_T > 25$ GeV
- μ, $p_T > 25$ GeV
- γ, $p_T > 60$ GeV
- jet, $p_T > 40$ GeV or 200 GeV
- additional diobject triggers



Final State: 1a 1b 1pmiss

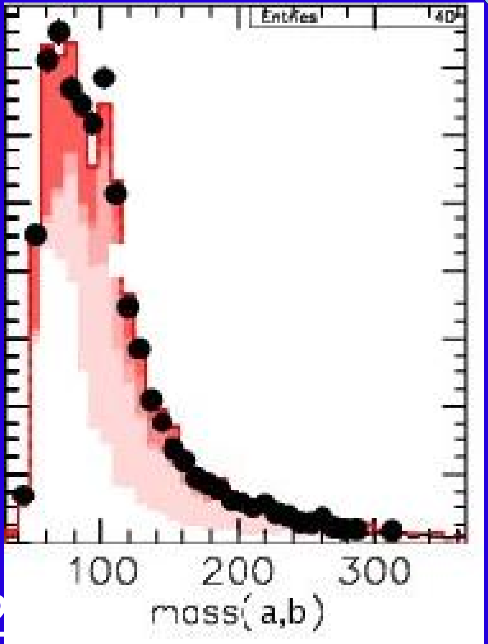
1 high-P_T object “a”+ any number low-P_T

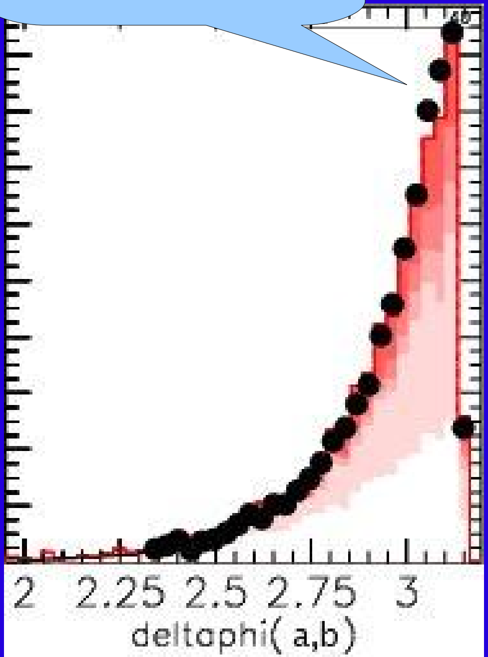
1 high-P_T object “b”+ any number low-P_T

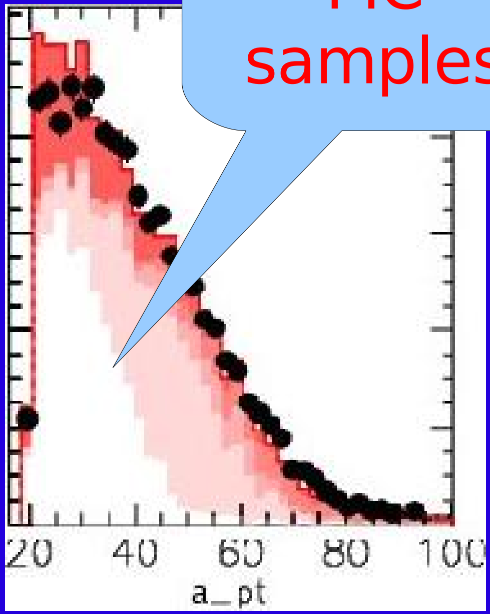
Significant missing -P_T

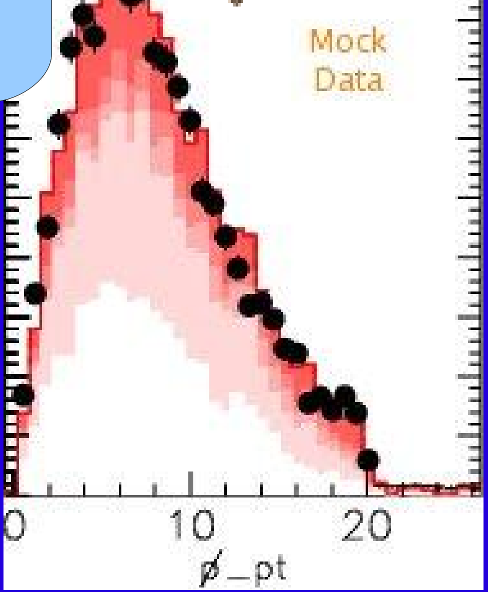
DATA

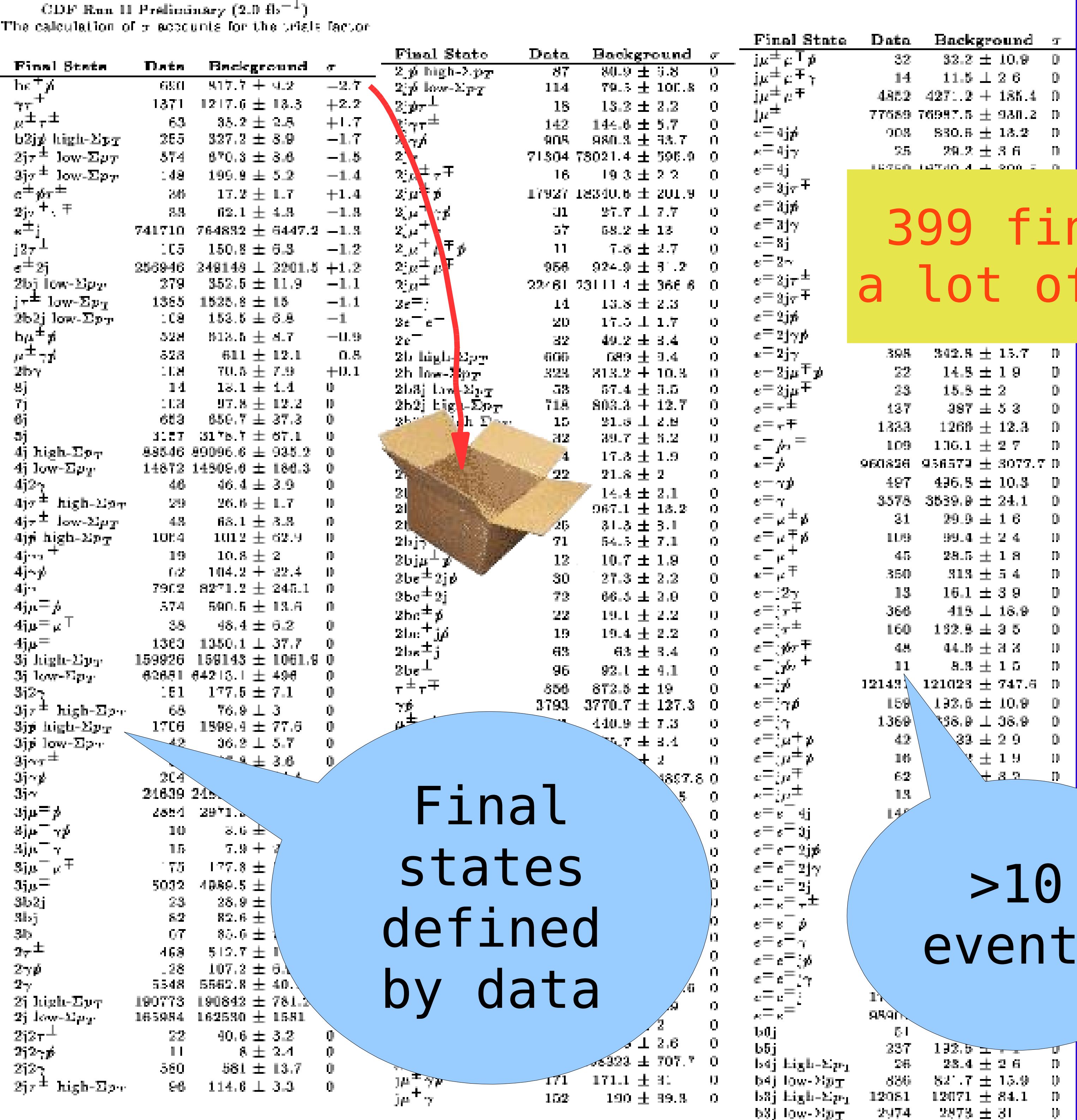
(Stacked) MC samples











CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

Final State	Data	Background	σ
$be^{\pm}\not{p}$	690	817.7 ± 9.2	−2.7
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3	+2.2
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8	+1.7
$b2j\not{p}$ high-Σp_T	255	327.2 ± 8.9	−1.7
$2j\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6	−1.5
$3j\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2	−1.4
$e^{\pm}\not{p}\tau^{\pm}$	36	17.2 ± 1.7	+1.4
$2j\tau^{\pm}\tau^{\mp}$	33	62.1 ± 4.3	−1.3
$e^{\pm}j$	741710	764832 ± 6447.2	−1.3
$j2\tau^{\pm}$	105	150.8 ± 6.3	−1.2
$e^{\pm}2j$	256946	249148 ± 2201.8	+1.2
$2bj$ low-Σp_T	279	352.5 ± 11.9	−1.1
$j\tau^{\pm}$ low-Σp_T	1365	1525.3 ± 15	−1.1
$2b2j$ low-Σp_T	108	153.6 ± 6.9	−1
$b\mu^{\pm}\not{p}$	328	412.5 ± 8.7	−0.9
$\mu^{\pm}\tau\not{p}$	528	611 ± 12.1	0.8
$2b\gamma$	108	70.5 ± 7.9	+0.1
8j	14	13.1 ± 1.4	0
7j	113	97.8 ± 12.2	0
6j	653	656.7 ± 37.3	0
5j	3157	3178.7 ± 67.1	0
4j high-Σp_T	88546	89096.6 ± 935.2	0
4j low-Σp_T	14872	14509.6 ± 186.3	0
$4j2\gamma$	46	46.4 ± 3.9	0
$4j\tau^{\pm}$ high-Σp_T	29	26.6 ± 1.7	0
$4j\tau^{\pm}$ low-Σp_T	43	63.1 ± 3.8	0
$4j\not{p}$ high-Σp_T	1064	1012 ± 62.9	0
$4j\gamma\tau^{\pm}$	19	10.8 ± 2	0
$4j\gamma\not{p}$	62	104.2 ± 22.4	0
$4j\gamma$	7902	8271.2 ± 245.1	0
$4j\mu^{\pm}\not{p}$	574	590.5 ± 13.6	0
$4j\mu^{\pm}\tau^{\mp}$	38	48.4 ± 6.2	0
$4j\mu^{\pm}$	1363	1350.1 ± 37.7	0
3j high-Σp_T	159926	158143 ± 1061.8	0
3j low-Σp_T	62681	64213.1 ± 496	0
$3j2\gamma$	151	177.5 ± 7.1	0
$3j\tau^{\pm}$ high-Σp_T	63	76.9 ± 3	0
$3j\not{p}$ high-Σp_T	1706	1599.4 ± 77.6	0
$3j\not{p}$ low-Σp_T	42	36.2 ± 5.7	0
$3j\gamma\tau^{\pm}$	[illegible]	[illegible] ± 3.6	0
$3j\gamma\not{p}$	204	[illegible]	[illegible]
$3j\gamma$	21639	[illegible]	[illegible]
$3j\mu^{\pm}\not{p}$	2854	[illegible]	[illegible]
$3j\mu^{\pm}\gamma\not{p}$	10	8.6 ± [illegible]	[illegible]
$3j\mu^{\pm}\gamma$	15	7.9 ± [illegible]	[illegible]
$3j\mu^{\pm}\mu^{\mp}$	175	177.8 ± [illegible]	[illegible]
$3j\mu^{\pm}$	5032	4989.5 ± [illegible]	[illegible]
$3b2j$	23	26.9 ± [illegible]	[illegible]
$3bj$	82	82.6 ± [illegible]	[illegible]
$3b$	67	85.6 ± [illegible]	[illegible]
$2\tau^{\pm}$	468	512.7 ± [illegible]	[illegible]
$2\gamma\not{p}$	128	107.2 ± [illegible]	[illegible]
2γ	5548	5562.8 ± [illegible]	[illegible]
2j high-Σp_T	190773	190842 ± [illegible]	[illegible]
2j low-Σp_T	165984	162530 ± 1581	[illegible]
$2j2\tau^{\pm}$	22	40.6 ± 3.2	0
$2j2\gamma\not{p}$	11	8 ± 2.4	0
$2j2\gamma$	560	581 ± 13.7	0
$2j\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3	0

Final State	Data	Background	σ
$2j\not{p}$ high-Σp_T	87	80.9 ± 5.8	0
$2j\not{p}$ low-Σp_T	114	79.5 ± 100.8	0
$2j\not{p}\tau^{\pm}$	18	13.2 ± 2.2	0
$2j\gamma\tau^{\pm}$	142	144.6 ± 5.7	0
$2j\gamma\not{p}$	908	980.3 ± 33.7	0
$2j\gamma$	71504	78021.4 ± 596.9	0
$2j\mu^{\pm}\tau^{\mp}$	16	19.3 ± 2.2	0
$2j\mu^{\pm}\not{p}$	17927	18340.6 ± 201.9	0
$2j\mu^{\pm}\gamma\not{p}$	31	27.7 ± 7.7	0
$2j\mu^{\pm}\gamma$	57	58.2 ± 13	0
$2j\mu^{\pm}\mu^{\mp}\not{p}$	11	7.6 ± 2.7	0
$2j\mu^{\pm}\mu^{\mp}$	958	924.9 ± 31.2	0
$2j\mu^{\pm}$	22761	23111.4 ± 366.6	0
$2e^{\pm}j$	14	13.8 ± 2.3	0
$2e^{\pm}e^{\mp}$	20	17.5 ± 1.7	0
$2e^{\pm}$	32	40.2 ± 3.4	0
2b high-Σp_T	606	629 ± 9.4	0
2b low-Σp_T	323	313.2 ± 10.3	0
2b3j low-Σp_T	38	57.4 ± 3.5	0
2b2j high-Σp_T	718	803.3 ± 12.7	0
2b[illegible] high-Σp_T	15	21.6 ± 2.8	0
[illegible]	32	39.7 ± 5.2	0
[illegible]	[illegible]	17.3 ± 1.9	0
[illegible]	22	21.8 ± 2	0
[illegible]	[illegible]	14.4 ± 2.1	0
[illegible]	[illegible]	967.1 ± 13.2	0
[illegible]	26	31.3 ± 3.1	0
$2bj\gamma$	71	54.5 ± 7.1	0
$2bj\mu^{\pm}\not{p}$	12	10.7 ± 1.9	0
$2be^{\pm}2j\not{p}$	30	27.3 ± 2.2	0
$2be^{\pm}2j$	73	66.5 ± 3.0	0
$2be^{\pm}\not{p}$	22	19.1 ± 2.2	0
$2be^{\pm}j\not{p}$	19	19.4 ± 2.2	0
$2be^{\pm}j$	63	63 ± 3.4	0
$2be^{\pm}$	96	92.1 ± 4.1	0
$\tau^{\pm}\tau^{\mp}$	856	872.5 ± 19	0
$\gamma\not{p}$	3793	3770.7 ± 127.3	0
$\mu^{\pm}$[illegible]	[illegible]	440.9 ± 7.3	0
[illegible]	[illegible]	[illegible] ± 3.4	0
[illegible]	[illegible]	[illegible] ± 2	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible] ± 2	0
[illegible]	[illegible]	[illegible] ± 2.6	0
[illegible]	[illegible]	[illegible]58323 ± 707.7	0
$j\mu^{\pm}\gamma\not{p}$	171	171.1 ± 31	0
$j\mu^{\pm}\gamma$	152	190 ± 39.3	0

Final State	Data	Background	σ
$j\mu^{\pm}\mu^{\mp}\not{p}$	32	32.2 ± 10.9	0
$j\mu^{\pm}\mu^{\mp}\gamma$	14	11.5 ± 2.6	0
$j\mu^{\pm}\mu^{\mp}$	4352	4271.2 ± 185.4	0
$j\mu^{\pm}$	77589	76987.5 ± 938.2	0
$e^{\pm}4j\not{p}$	908	830.6 ± 18.2	0
$e^{\pm}4j\gamma$	25	29.2 ± 3.6	0
$e^{\pm}4j$	[illegible]	[illegible]	[illegible]
$e^{\pm}3j\tau^{\mp}$	[illegible]	[illegible]	[illegible]
$e^{\pm}3j\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}3j\gamma$	[illegible]	[illegible]	[illegible]
$e^{\pm}3j$	[illegible]	[illegible]	[illegible]
$e^{\pm}2\gamma$	[illegible]	[illegible]	[illegible]
$e^{\pm}2j\tau^{\pm}$	[illegible]	[illegible]	[illegible]
$e^{\pm}2j\tau^{\mp}$	[illegible]	[illegible]	[illegible]
$e^{\pm}2j\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}2j\gamma\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}2j\gamma$	398	342.8 ± 15.7	0
$e^{\pm}2j\mu^{\mp}\not{p}$	22	14.8 ± 1.9	0
$e^{\pm}2j\mu^{\mp}$	23	15.8 ± 2	0
$e^{\pm}\tau^{\pm}$	137	137 ± 5.3	0
$e^{\pm}\tau^{\mp}$	1333	1268 ± 12.3	0
$e^{\pm}\not{p}\tau^{\pm}$	109	136.1 ± 2.7	0
$e^{\pm}\not{p}$	960826	956573 ± 3077.7	0
$e^{\pm}\gamma\not{p}$	497	436.5 ± 10.3	0
$e^{\pm}\gamma$	3578	3639.9 ± 24.1	0
$e^{\pm}\mu^{\pm}\not{p}$	31	29.9 ± 1.6	0
$e^{\pm}\mu^{\mp}\not{p}$	109	99.4 ± 2.4	0
$e^{\pm}\mu^{\pm}$	45	28.5 ± 1.8	0
$e^{\pm}\mu^{\mp}$	350	313 ± 5.4	0
$e^{\pm}j2\gamma$	13	16.1 ± 3.9	0
$e^{\pm}j\tau^{\mp}$	366	415 ± 16.9	0
$e^{\pm}j\tau^{\pm}$	160	132.9 ± 3.5	0
$e^{\pm}j\not{p}\tau^{\mp}$	48	44.6 ± 3.3	0
$e^{\pm}j\not{p}\tau^{\pm}$	11	8.8 ± 1.5	0
$e^{\pm}j\not{p}$	121431	121023 ± 747.6	0
$e^{\pm}j\gamma\not{p}$	159	132.6 ± 10.9	0
$e^{\pm}j\gamma$	1369	[illegible]336.9 ± 36.9	0
$e^{\pm}j\mu^{\pm}\not{p}$	42	33 ± 2.9	0
$e^{\pm}j\mu^{\mp}\not{p}$	16	[illegible] ± 1.9	0
$e^{\pm}j\mu^{\mp}$	62	[illegible]	0
$e^{\pm}j\mu^{\pm}$	13	[illegible]	[illegible]
$e^{\pm}e^{\mp}4j$	14[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}3j$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}2j\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}2j\gamma$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}2j$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}\tau^{\pm}$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}\gamma$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}j\not{p}$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}j\gamma$	[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}j$	1[illegible]	[illegible]	[illegible]
$e^{\pm}e^{\mp}$	984[illegible]	[illegible]	[illegible]
b6j	51	[illegible]	[illegible]
b5j	237	132.5 ± [illegible]	[illegible]
b4j high-Σp_T	26	23.4 ± 2.6	0
b4j low-Σp_T	836	827.7 ± 13.9	0
b3j high-Σp_T	12061	12071 ± 84.1	0
b3j low-Σp_T	2974	2873 ± 31	0

399 final states:
a lot of information

$2\,fb^{-1}$

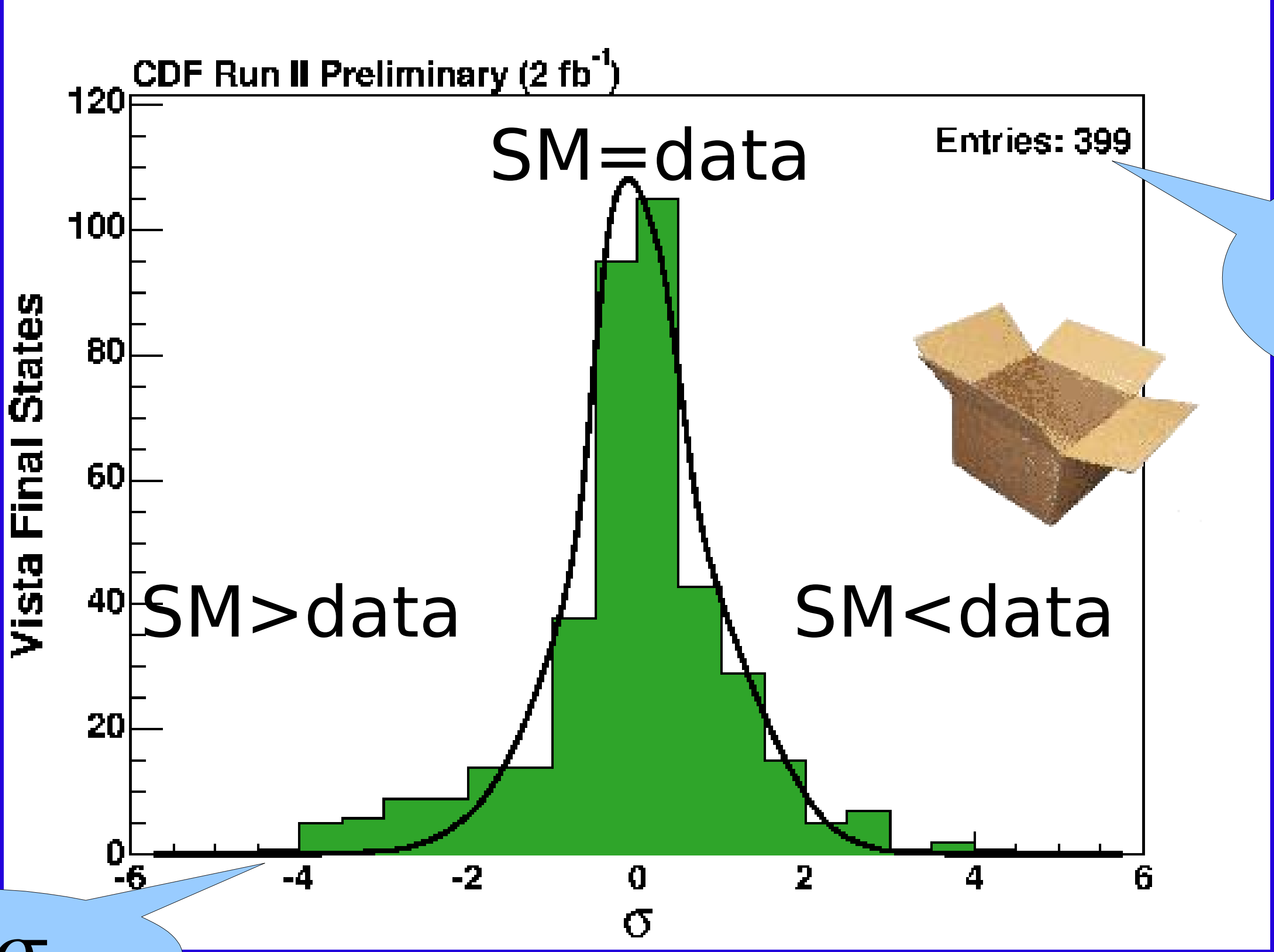
Final states defined by data

>10 events

ArXiv:0712.1311 CDF+...SM, GC, RC, CH, BK, SX

Vista final state normalizations

CDF RunII 2 fb^{-1}

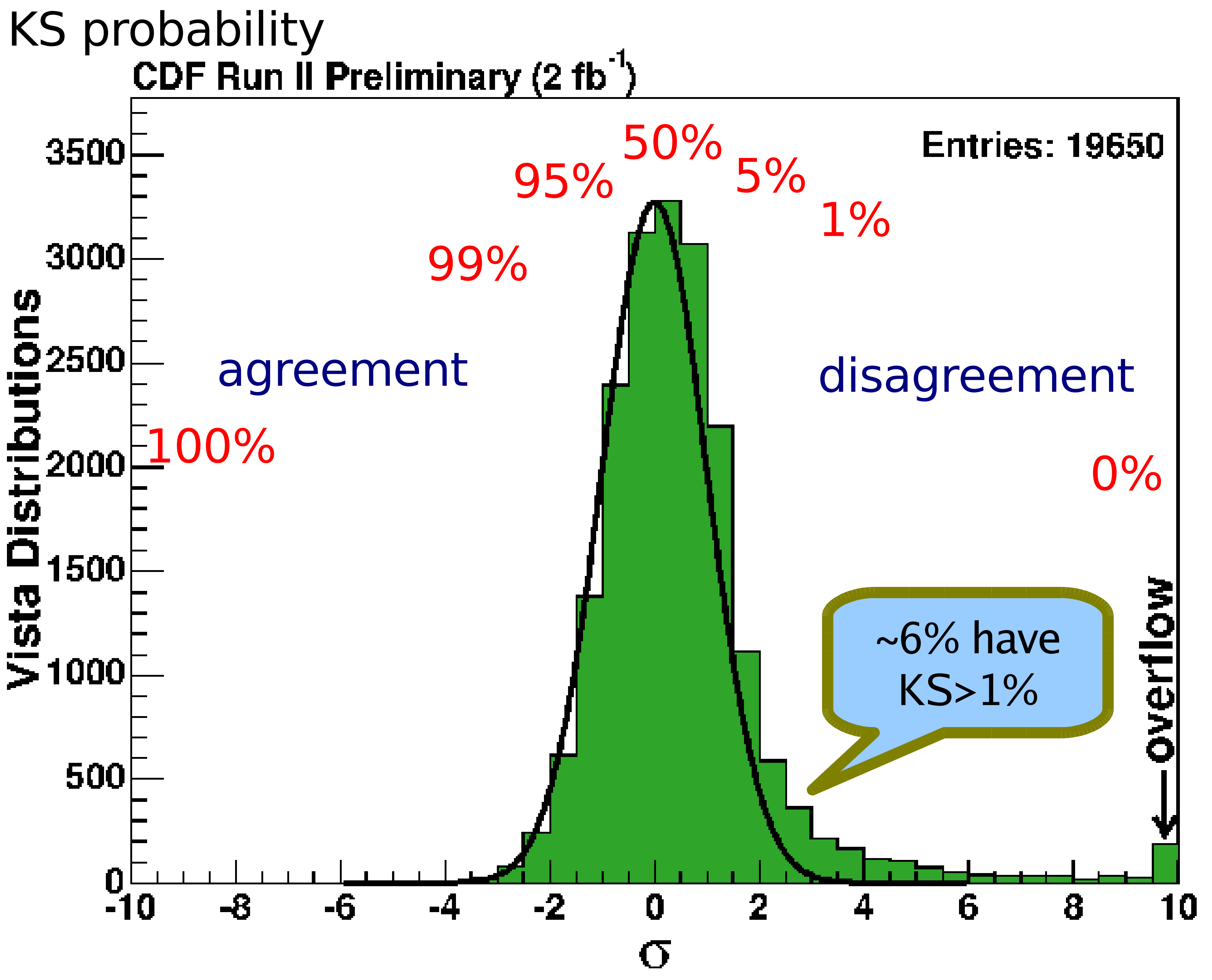


Trials factor

$2.7\,\sigma$

G. Choudalakis, R. Culbertson, C. Henderson, B, Knuteson, Si Xie

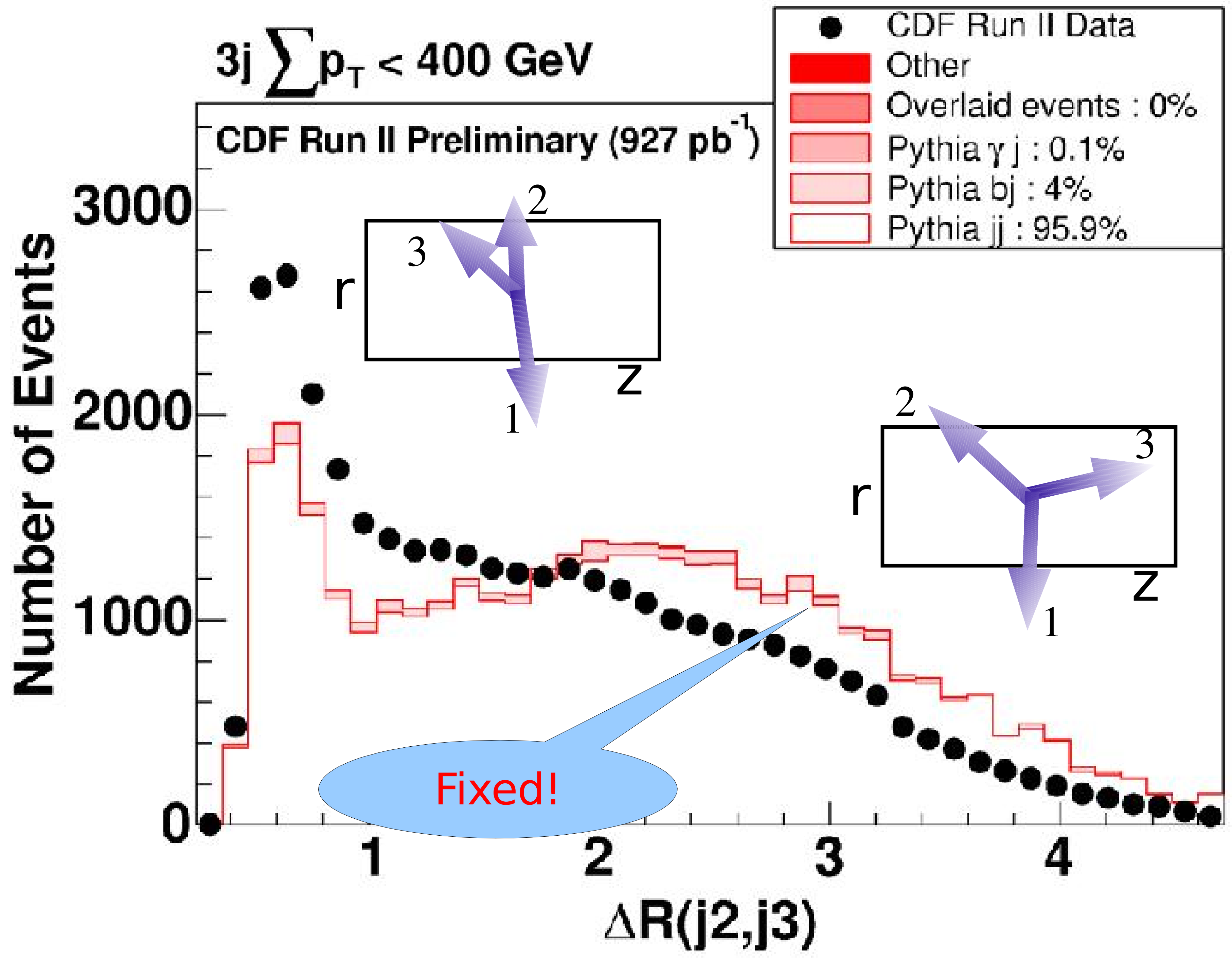
Vista kinematic shapes



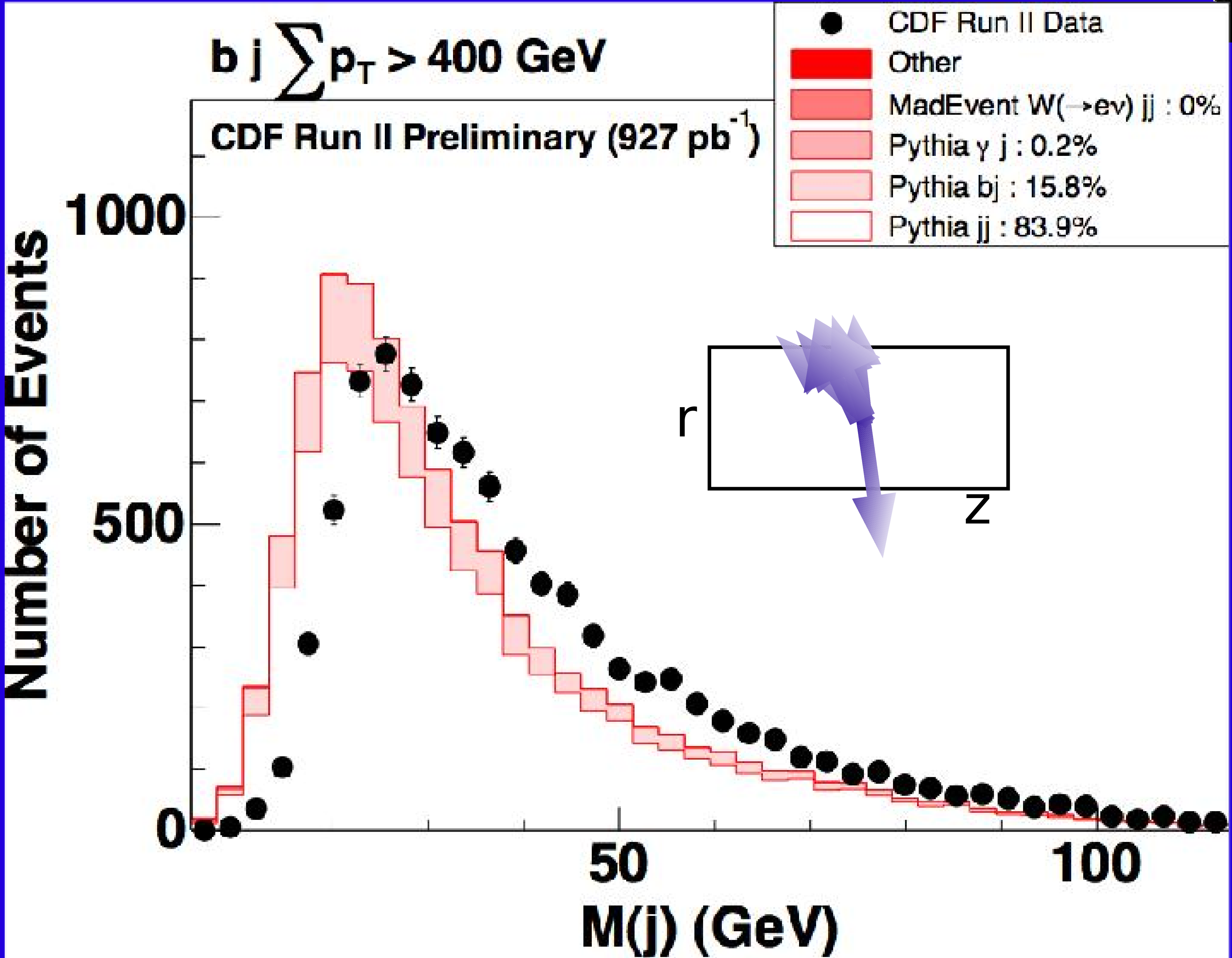
Quantitative Results

- Event counts are distributed as you expect when you look at 399 final states
    - Largest discrepancy is a 2.7sigma deficit
- Several % of all distributions disagree at the 1% level or higher
    - 1% is typical of the systematic expected in event generators
    - about 6% of distributions have KS>1%, but there are many commonalities

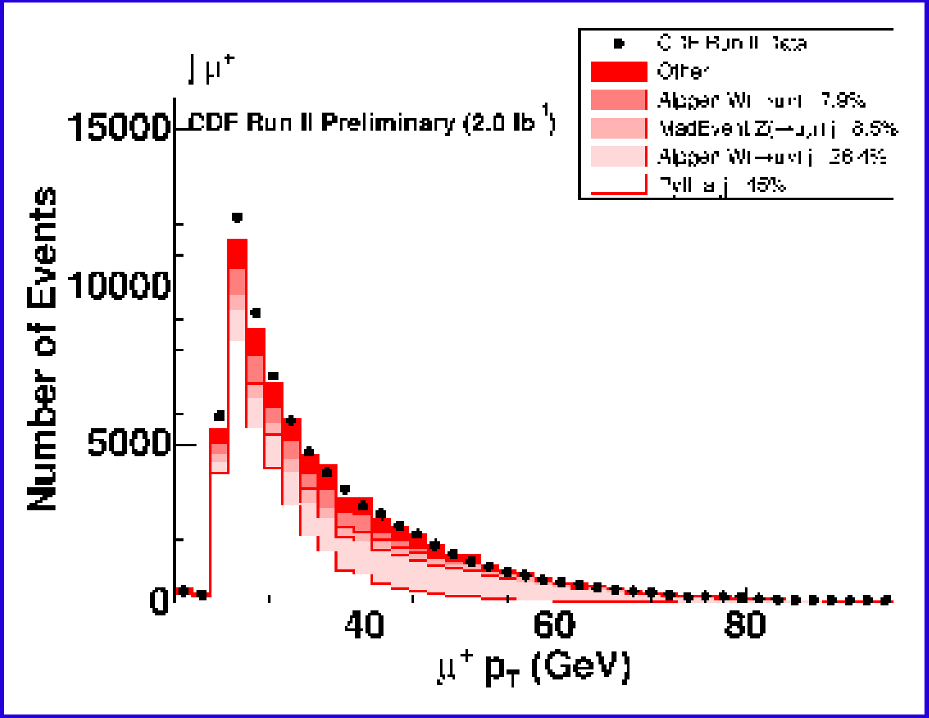
Sample discrepant distribution

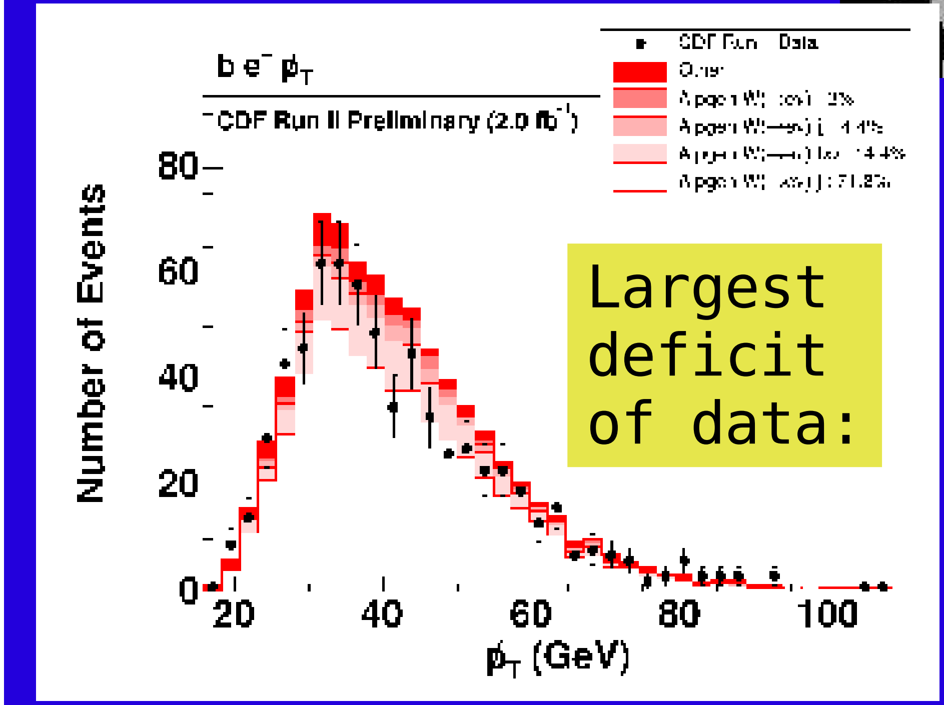


Related discrepant distribution

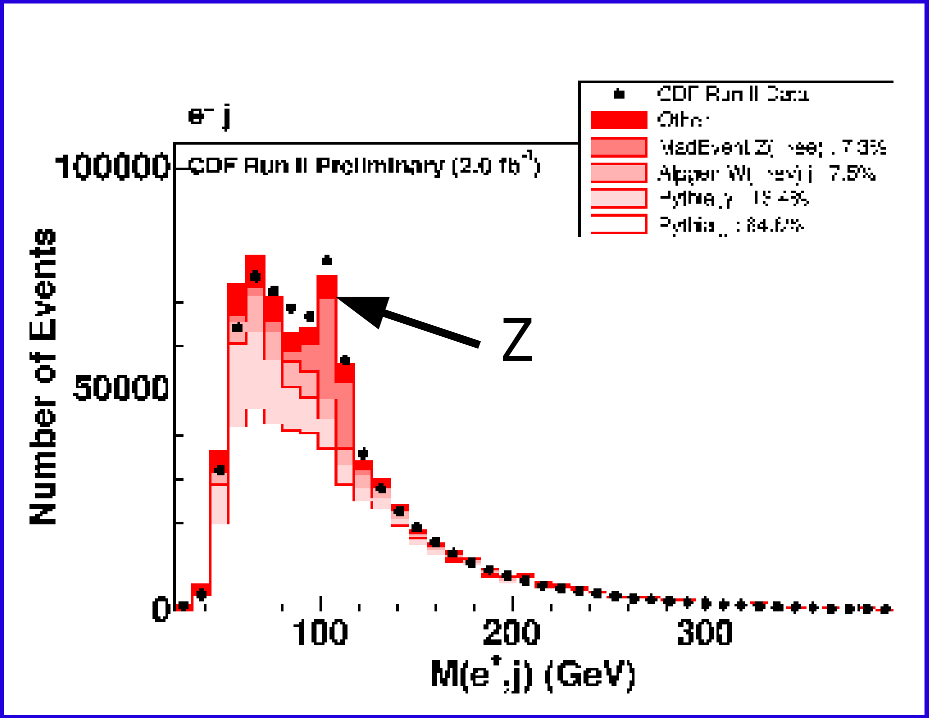


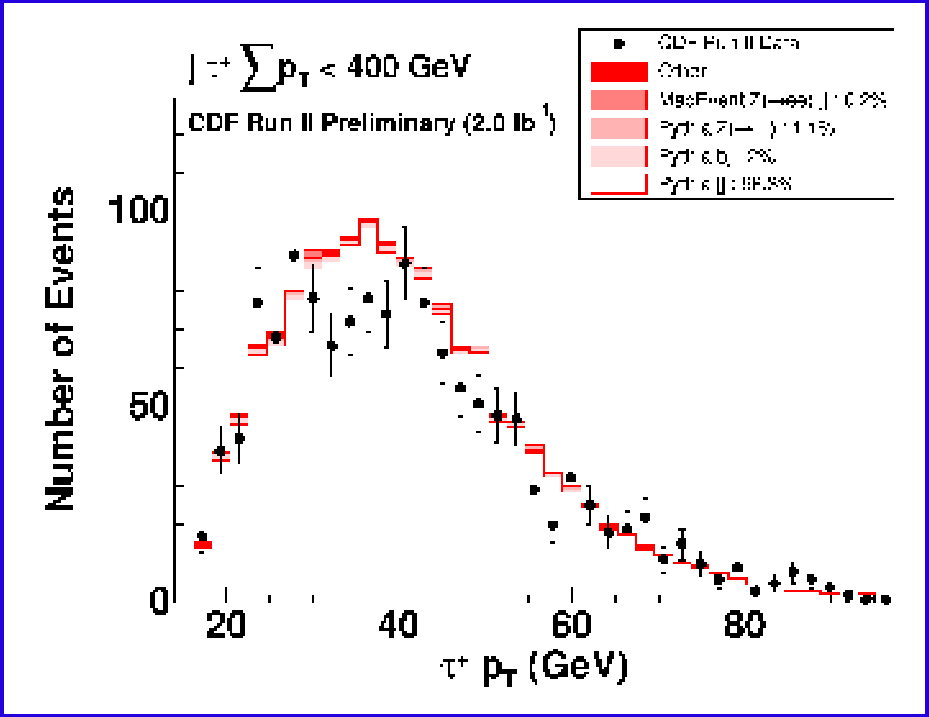
Many things described well!





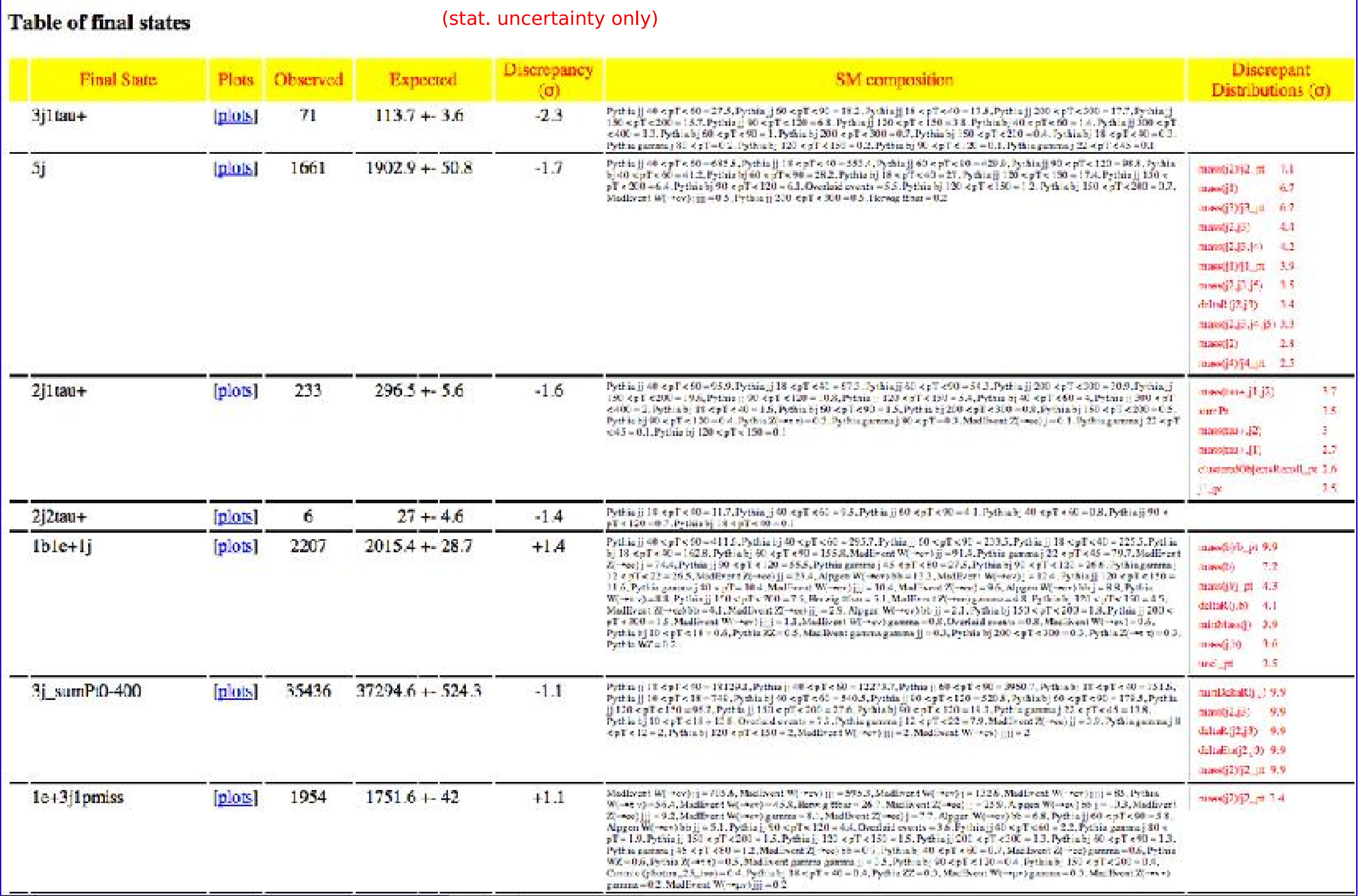
Largest deficit of data:





Vista output

CDF Run II preliminary (927 pb^{-1})



(stat. uncertainty only)

Table of final states

Final State	Plots	Observed	Expected	Discrepancy (σ)	SM composition	Discrepant Distributions (σ)
3j1tau+	[plots]	71	113.7 +- 3.6	-2.3	Pythia jj 40<pT<60 = 27.5,Pythia jj 60<pT<90 = 18.2,Pythia jj 18<pT<40 = 17.8,Pythia jj 200<pT<300 = 17.7,Pythia jj 150<pT<200 = 13.7,Pythia jj 90<pT<120 = 6.8,Pythia jj 120<pT<150 = 3.8,Pythia bj 40<pT<60 = 1.4,Pythia jj 300<pT<400 = 1.3,Pythia bj 60<pT<90 = 1,Pythia bj 200<pT<300 = 0.7,Pythia bj 150<pT<200 = 0.4,Pythia bj 18<pT<40 = 0.2,Pythia gamma j 80<pT = 0.2,Pythia bj 120<pT<150 = 0.2,Pythia bj 90<pT<120 = 0.1,Pythia gamma j 22<pT<45 = 0.1	
5j	[plots]	1661	1902.9 +- 50.8	-1.7	Pythia jj 40<pT<60 = 685.8,Pythia jj 18<pT<40 = 583.4,Pythia jj 60<pT<90 = 420.0,Pythia jj 90<pT<120 = 98.8,Pythia bj 40<pT<60 = 41.2,Pythia bj 60<pT<90 = 28.2,Pythia bj 18<pT<40 = 27,Pythia jj 120<pT<150 = 17.6,Pythia jj 150<pT<200 = 6.4,Pythia bj 90<pT<120 = 6.1,Overlaid events = 5.5,Pythia bj 120<pT<150 = 1.2,Pythia bj 150<pT<200 = 1.7,MadEvent W(→eν)jjj = 0.5,Pythia jj 200<pT<300 = 0.5,Herwig ttbar = 0.2	mass(j2)/j2_pt 7.1 mass(j1) 6.7 mass(j3)/j3_pt 6.7 mass(j2,j3) 4.3 mass(j2,j3,j4) 4.2 mass(j1)/j1_pt 3.9 mass(j2,j3,j5) 3.5 deltaR(j2,j3) 3.4 mass(j2,j3,j4,j5) 3.3 mass(j2) 2.8 mass(j4)/j4_pt 2.5
2j1tau+	[plots]	233	296.5 +- 5.6	-1.6	Pythia jj 40<pT<60 = 95.9,Pythia jj 18<pT<40 = 57.3,Pythia jj 60<pT<90 = 54.2,Pythia jj 200<pT<300 = 20.9,Pythia jj 150<pT<200 = 19.6,Pythia jj 90<pT<120 = 10.8,Pythia jj 120<pT<150 = 5.4,Pythia bj 40<pT<60 = 4,Pythia jj 300<pT<400 = 2,Pythia bj 18<pT<40 = 1.6,Pythia bj 60<pT<90 = 1.5,Pythia bj 200<pT<300 = 0.8,Pythia bj 150<pT<200 = 0.5,Pythia bj 90<pT<120 = 0.4,Pythia Z(→ee) = 0.3,Pythia gamma j 80<pT = 0.3,MadEvent Z(→ee)j = 0.1,Pythia gamma j 22<pT<45 = 0.1,Pythia bj 120<pT<150 = 0.1	mass(tau+,j1,j2) 3.7 sumPt 3.5 mass(tau+,j2) 3 mass(tau+,j1) 2.7 clusteredObjectsRecoil_pt 2.6 j1_pt 2.5
2j2tau+	[plots]	6	27 +- 4.6	-1.4	Pythia jj 18<pT<40 = 11.7,Pythia jj 40<pT<60 = 9.5,Pythia jj 60<pT<90 = 4.1,Pythia bj 40<pT<60 = 0.8,Pythia jj 90<pT<120 = 0.7,Pythia bj 18<pT<40 = 0.1	
1b1e+1j	[plots]	2207	2015.4 +- 28.7	+1.4	Pythia jj 40<pT<60 = 411.6,Pythia bj 40<pT<60 = 295.7,Pythia jj 60<pT<90 = 233.5,Pythia jj 18<pT<40 = 225.5,Pythia bj 18<pT<40 = 162.8,Pythia bj 60<pT<90 = 155.8,MadEvent W(→eν)jj = 91.4,Pythia gamma j 22<pT<45 = 79.7,MadEvent Z(→ee)j = 74.4,Pythia jj 90<pT<120 = 55.5,Pythia gamma j 45<pT<80 = 27.6,Pythia bj 90<pT<120 = 26.6,Pythia gamma j 12<pT<22 = 26.5,MadEvent Z(→ee)jj = 23.4,Alpgen W(→eν)bb = 17.3,MadEvent W(→eν)j = 12.6,Pythia jj 120<pT<150 = 11.6,Pythia gamma j 80<pT = 10.4,MadEvent W(→eν)jjj = 10.4,MadEvent Z(→ee) = 9.6,Alpgen W(→eν)bbj = 8.8,Pythia W(→eν) = 8.8,Pythia jj 150<pT<200 = 7.6,Herwig ttbar = 5.1,MadEvent Z(→ee)gamma = 4.8,Pythia bj 120<pT<150 = 4.5,MadEvent Z(→ee)bb = 4.1,MadEvent Z(→ee)jjj = 2.5,Alpgen W(→eν)bbjj = 2.1,Pythia bj 150<pT<200 = 1.8,Pythia jj 200<pT<300 = 1.5,MadEvent W(→eν)jjjj = 1.3,MadEvent W(→eν)gamma = 0.8,Overlaid events = 0.8,MadEvent W(→eν) = 0.6,Pythia bj 10<pT<18 = 0.6,Pythia ZZ = 0.5,MadEvent gamma gamma jj = 0.3,Pythia bj 200<pT<300 = 0.3,Pythia Z(→ττ) = 0.3,Pythia WZ = 0.2	mass(b)/b_pt 9.9 mass(b) 7.2 mass(j)/j_pt 4.3 deltaR(j,b) 4.1 minMass(j) 3.9 mass(j,b) 3.6 uncl_pt 3.5
3j_sumPt0-400	[plots]	35436	37294.6 +- 524.3	-1.1	Pythia jj 18<pT<40 = 18129.1,Pythia jj 40<pT<60 = 12273.7,Pythia jj 60<pT<90 = 2950.7,Pythia bj 18<pT<40 = 1531.6,Pythia jj 10<pT<18 = 746,Pythia bj 40<pT<60 = 540.5,Pythia jj 90<pT<120 = 520.8,Pythia bj 60<pT<90 = 179.5,Pythia jj 120<pT<150 = 95.7,Pythia jj 150<pT<200 = 27.6,Pythia bj 90<pT<120 = 14.3,Pythia gamma j 22<pT<45 = 13.8,Pythia bj 10<pT<18 = 12.8,Overlaid events = 7.5,Pythia gamma j 12<pT<22 = 7.0,MadEvent Z(→ee)jj = 3.0,Pythia gamma j 8<pT<12 = 2,Pythia bj 120<pT<150 = 2,MadEvent W(→eν)jjj = 2,MadEvent W(→eν)jjjj = 2	minDeltaR(j,j) 9.9 mass(j2,j3) 9.9 deltaR(j2,j3) 9.9 deltaEta(j2,j3) 9.9 mass(j2)/j2_pt 9.9
1e+3j1pmiss	[plots]	1954	1751.6 +- 42	+1.1	MadEvent W(→eν)jj = 703.6,MadEvent W(→eν)jjj = 595.3,MadEvent W(→eν)j = 132.6,MadEvent W(→eν)jjjj = 83,Pythia W(→eν) = 56.4,MadEvent W(→eν) = 45.8,Herwig ttbar = 26.7,MadEvent Z(→ee)jj = 23.9,Alpgen W(→eν)bbj = 13.3,MadEvent Z(→ee)jjj = 9.2,MadEvent W(→eν)gamma = 8.1,MadEvent Z(→ee)j = 7.7,Alpgen W(→eν)bb = 6.8,Pythia jj 60<pT<90 = 5.8,Alpgen W(→eν)bbjj = 5.1,Pythia jj 90<pT<120 = 4.4,Overlaid events = 3.6,Pythia jj 40<pT<60 = 2.2,Pythia gamma j 80<pT = 1.9,Pythia jj 150<pT<200 = 1.5,Pythia jj 120<pT<150 = 1.5,Pythia jj 200<pT<300 = 1.3,Pythia bj 60<pT<90 = 1.3,Pythia gamma j 45<pT<80 = 1.2,MadEvent Z(→ee)bb = [illegible],Pythia bj 40<pT<60 = 0.7,MadEvent Z(→ee)gamma = 0.6,Pythia WZ = 0.6,Pythia Z(→ττ) = 0.5,MadEvent gamma gamma jj = 0.5,Pythia bj 90<pT<120 = 0.4,Pythia bj 150<pT<200 = 0.4,Cosmic (photon_25_iso) = 0.4,Pythia bj 18<pT<40 = 0.4,Pythia ZZ = 0.3,MadEvent W(→μν)gamma = 0.3,MadEvent Z(→ee)gamma = 0.2,MadEvent W(→μν)jjj = 0.2	mass(j2)/j2_pt 7.4

Dissecting the SM cocktail

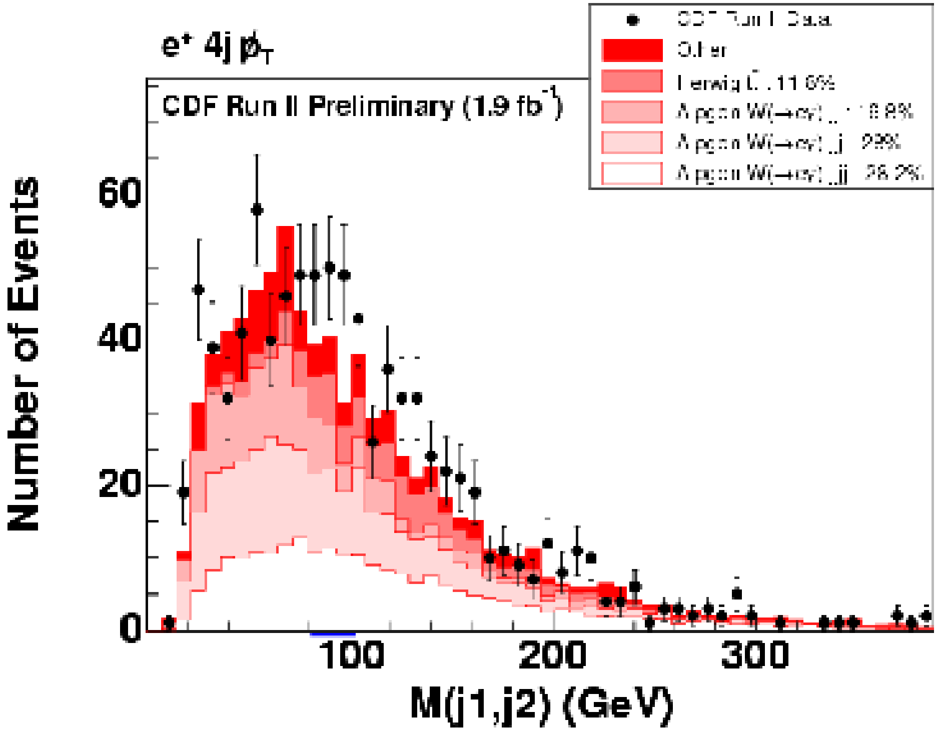
Much of the Monte Carlo is default Pythia/Herwig (simple processes + parton showers)

Some processes like W/Z/ɣ+jets combine Matrix Elements with parton showers

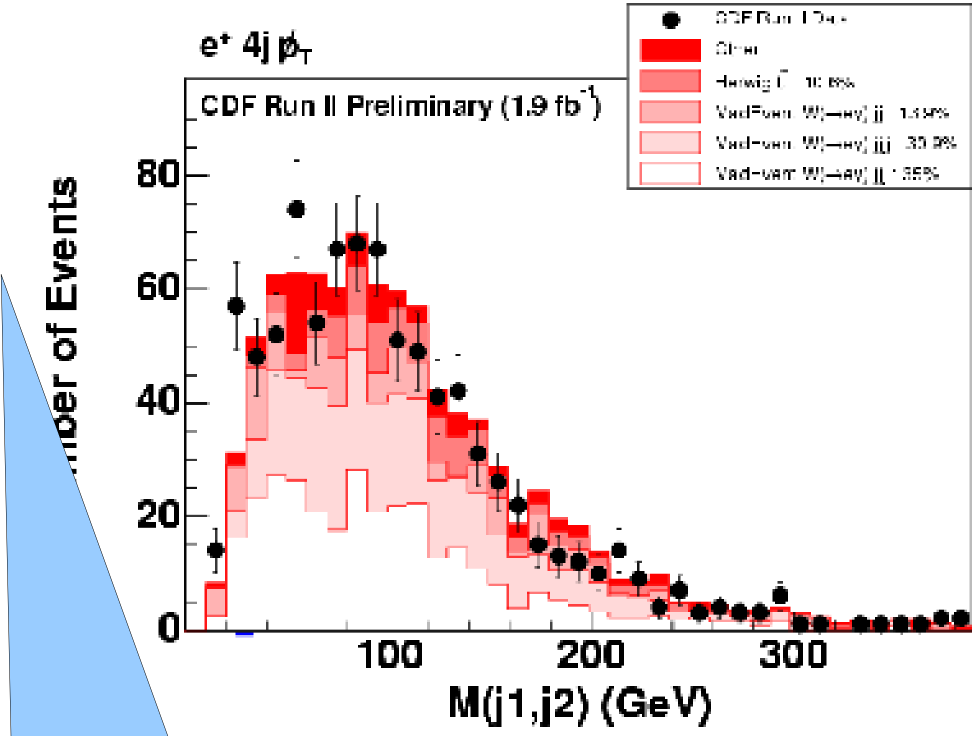
Such calculations are necessary for the LHC

We can remix our cocktail with different implementations of the Standard Model theory

Change W+4j model:Goodness of fit unchanged



MLM matching



SM matching

		Alpgen	SM
k-factor	W0j	1.379	1.452
k-factor	W1j	1.329	1.20
k-factor	W2j	2.007	1.23
k-factor	W3j	2.109	1.18

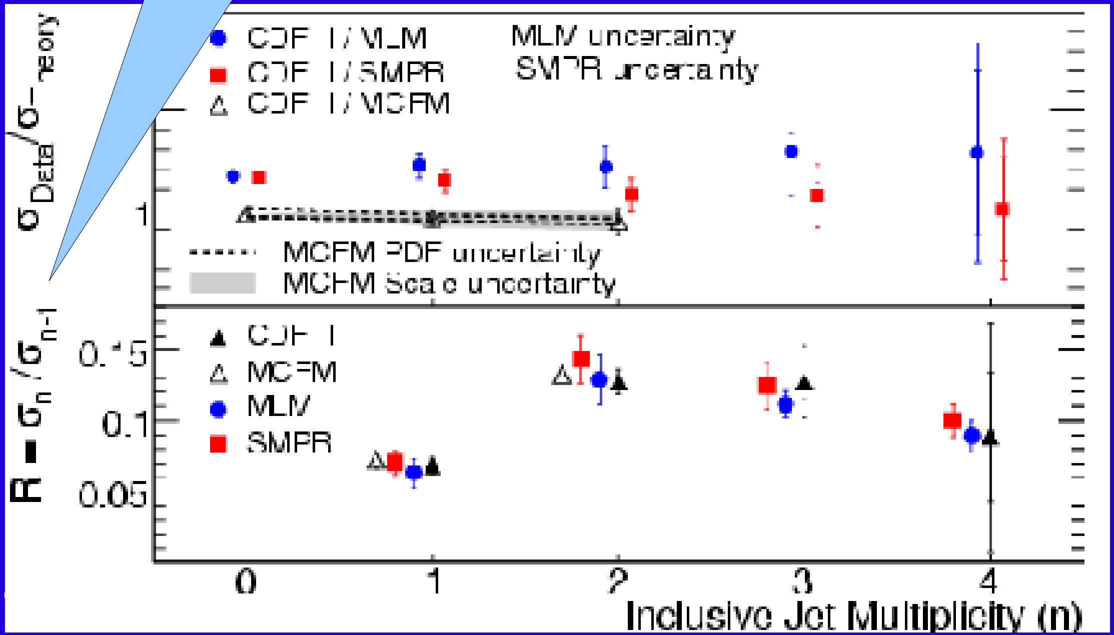
ArXiv:0711.4044 CDF...(SM)

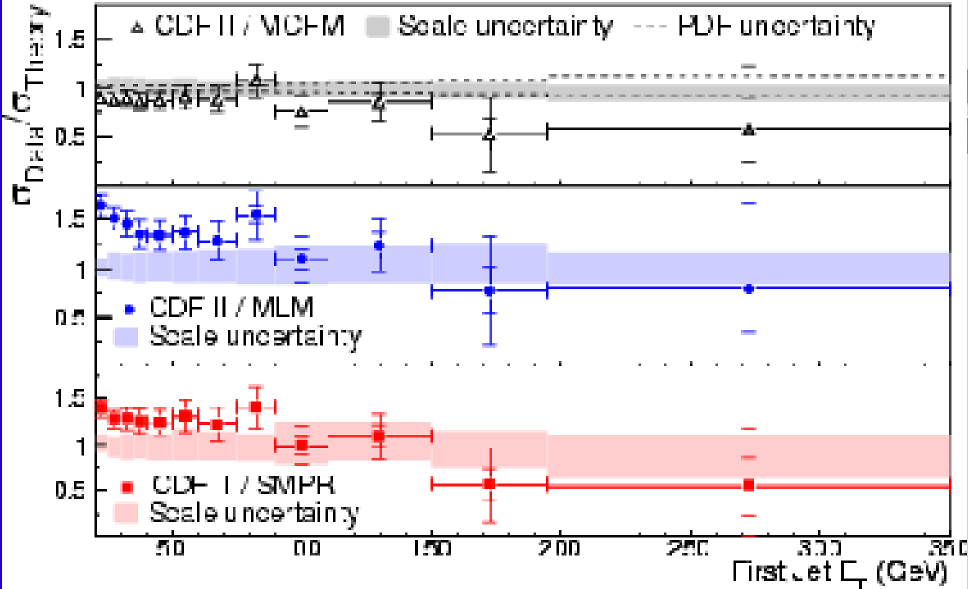
Traditional Analysis

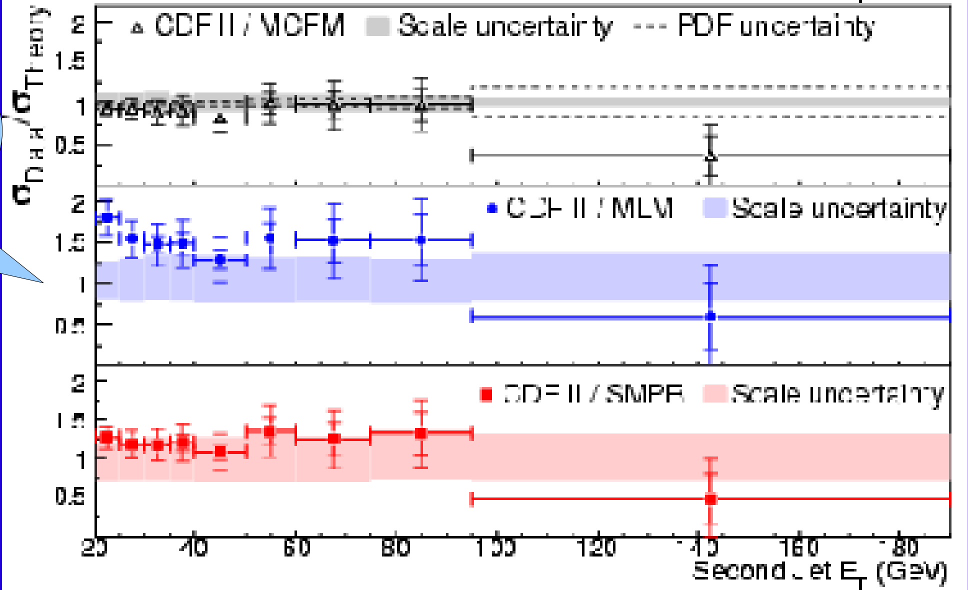
Data corrected (unfolded)
back to the particles
(this it the output of Pythia)

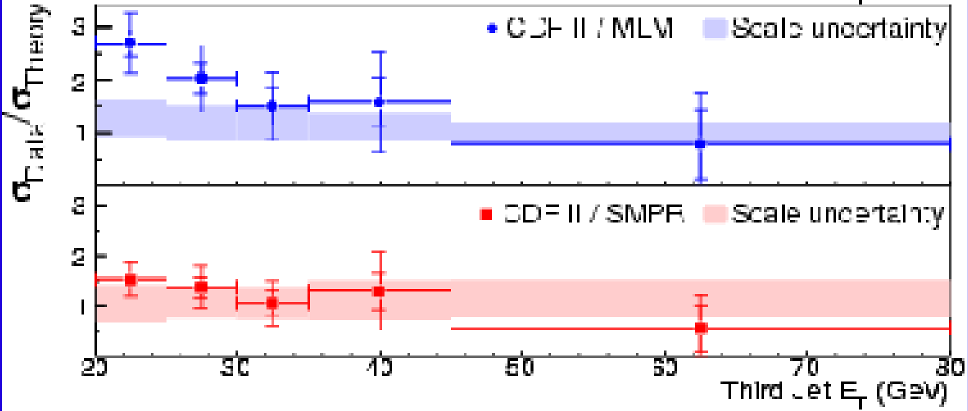
Comparison
of relative
event
counts

Comparison
of relative
shapes









“... All distributions show good agreement with the data ...”

What Next?

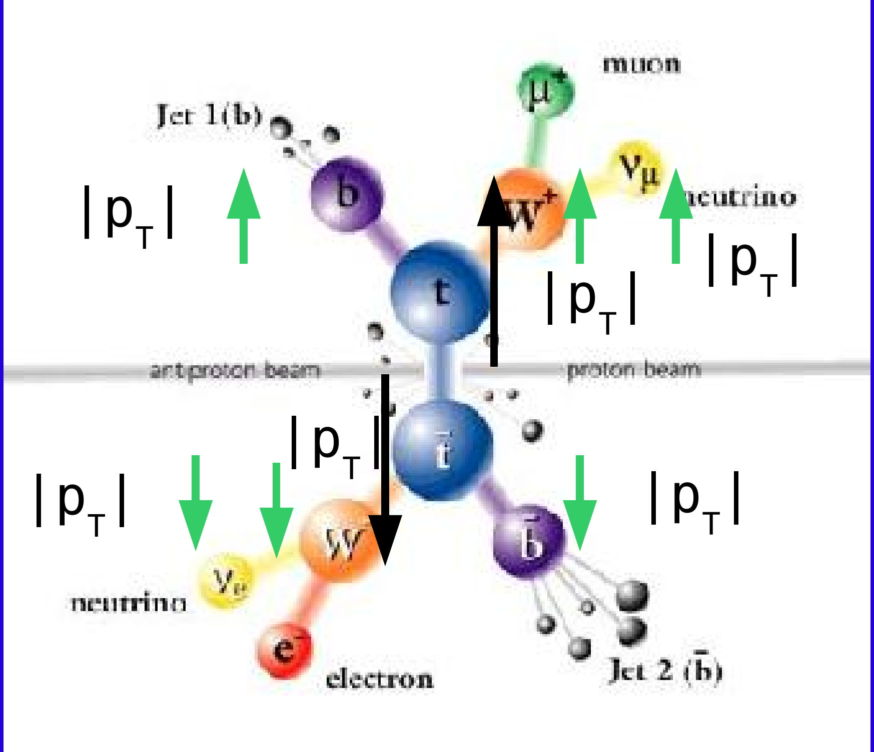
- Vista can be used as a “tuning” tool
  - This is not why we entered this game
  - Can we use this approach to probe beyond the Standard Model?
- We have a model of the Standard Model “cocktail” that is “okay”
  - Discrepancies are in a “boring” kinematic region
  - We are actively trying to understand these

Sleuth: a *quasi*-model independent search strategy for new physics

Exclusive final states

Large $\sum|p_T|$

An excess

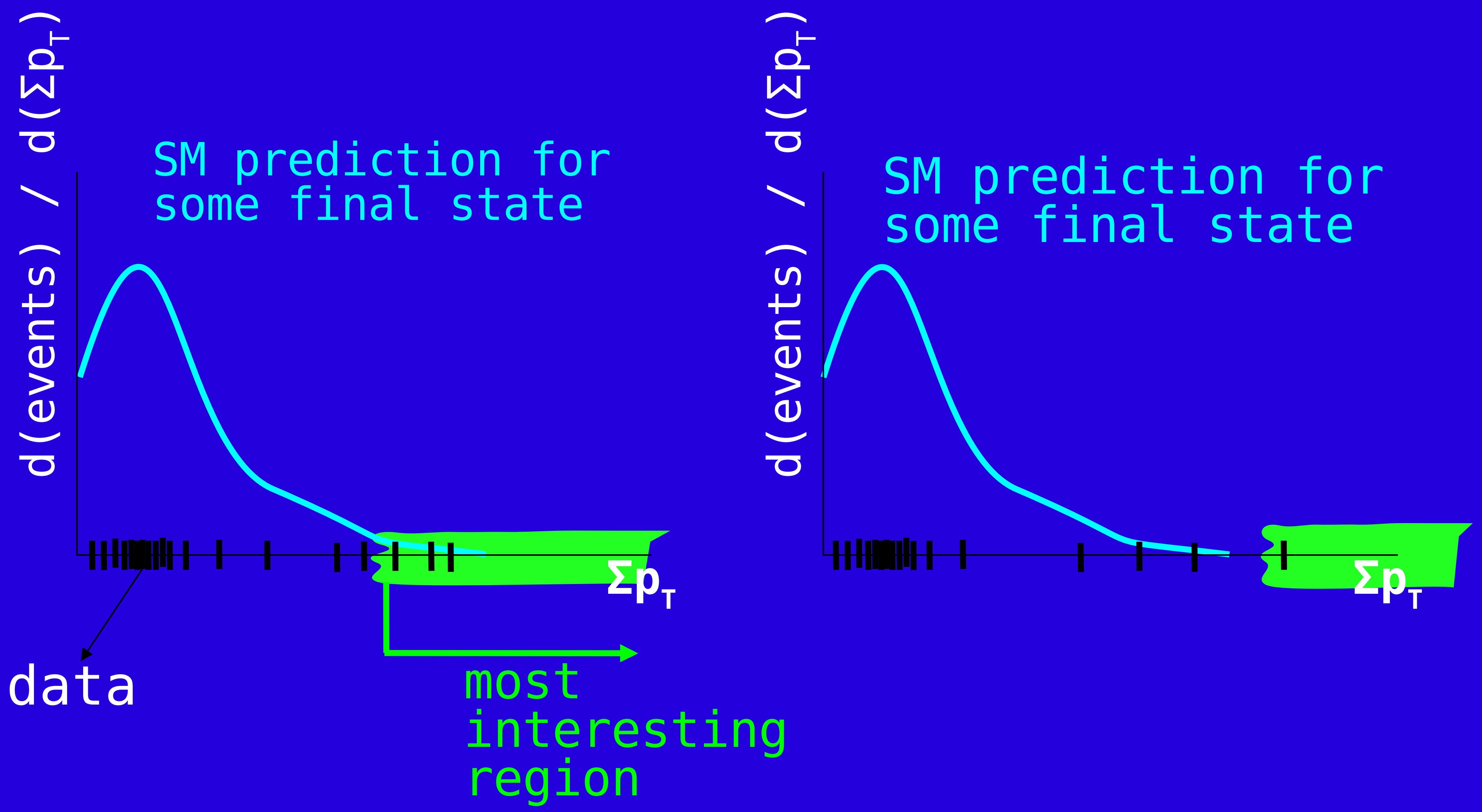


Rigorously compute the trials factor associated with looking everywhere

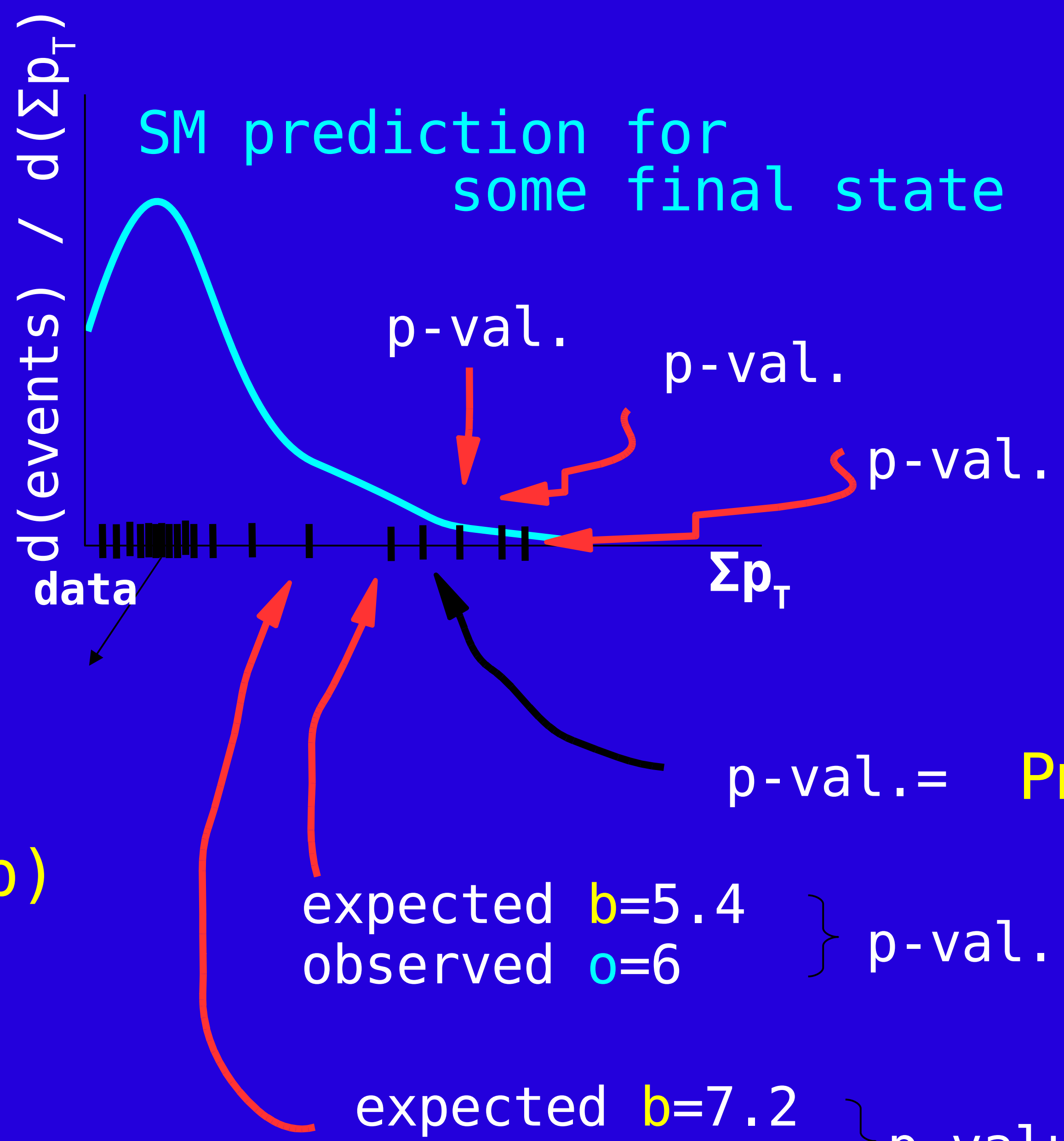
$$\int_{0001001}^{today} d(hep-ph)(prediction)$$

Goal of Sleuth

Identify statistically significant excess of data in the high-Σp_T tails.



p-value and Pmin



p-val.= Pmin

P-value ==

Prob(>=o|b)

expected b=5.4
observed o=6 } p-val.

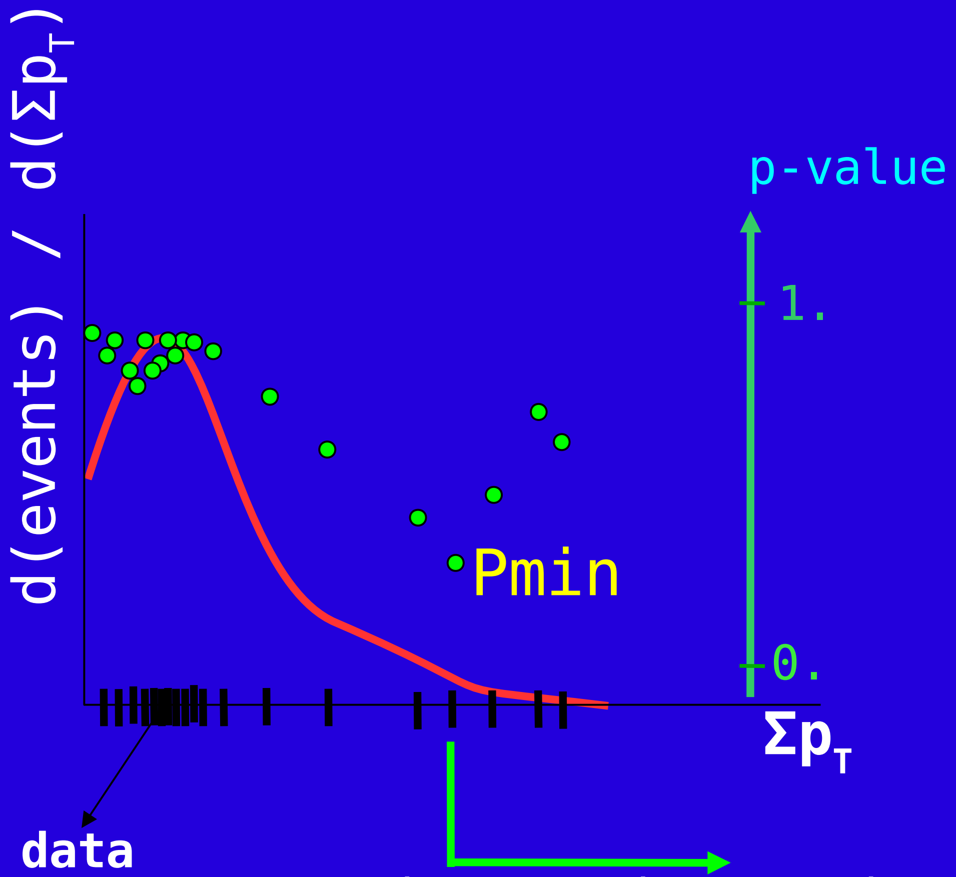
$$\sum_{\nu=d}^{\infty}\frac{b^{\nu}}{\nu!}\exp(-b)$$

expected b=7.2
observed o=7 } p-value

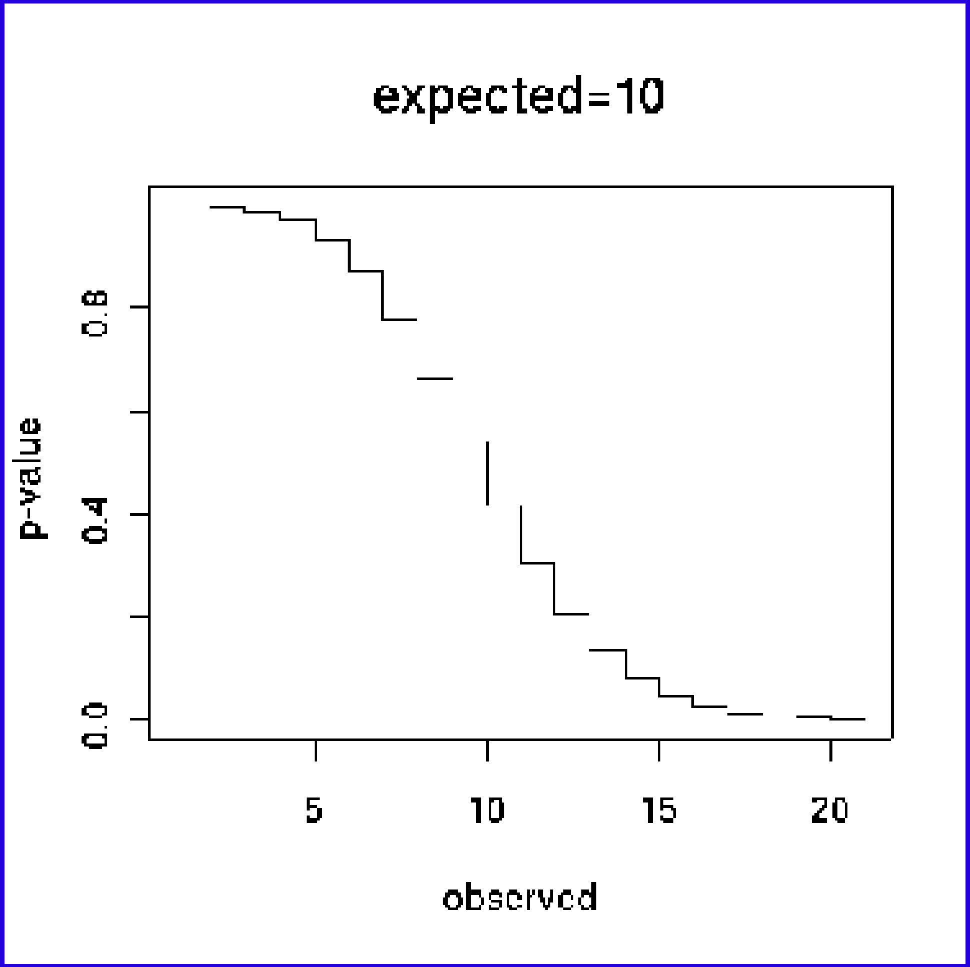
Pmin calculation

● : p-value

$$\sum_{\nu=d}^{\infty} \frac{b^{\nu}}{\nu!}\exp(-b)$$



The most interesting region, characterized by Pmin.



Pmin → scriptP

- How unusual is this Pmin?
- Generate pseudo-data to see how often this (or something more interesting) would happen.
  - Fraction == scriptP
- Smaller scriptP → more interesting

Trials Factor

Each final state → scriptP

N final states:

tildeScriptP = 1 – (1-min{scriptP})^N

Prob. fluctuation in *any region in any final state* is as or more interesting

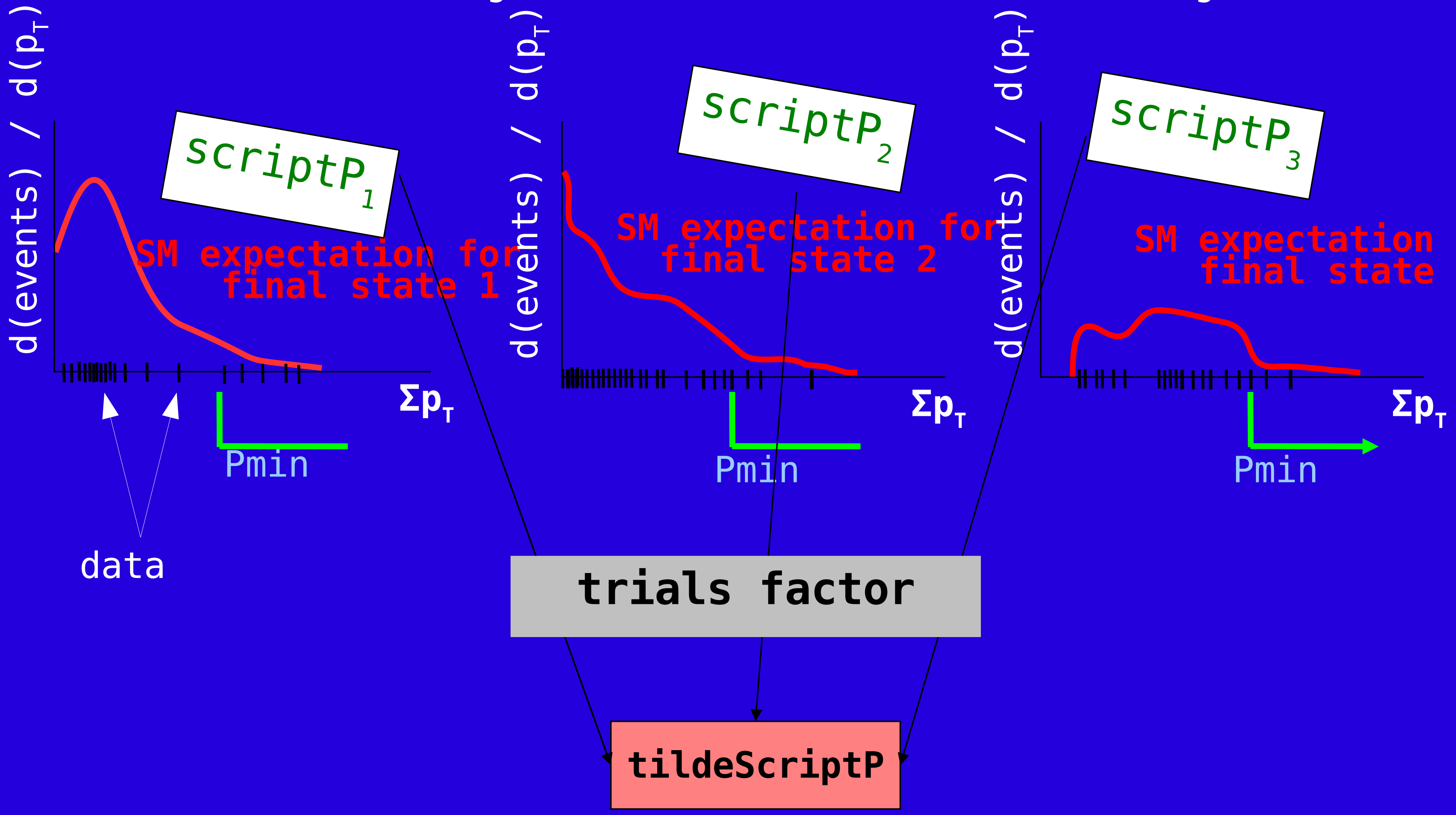
scriptP → all regions

tildeScriptP → all final states

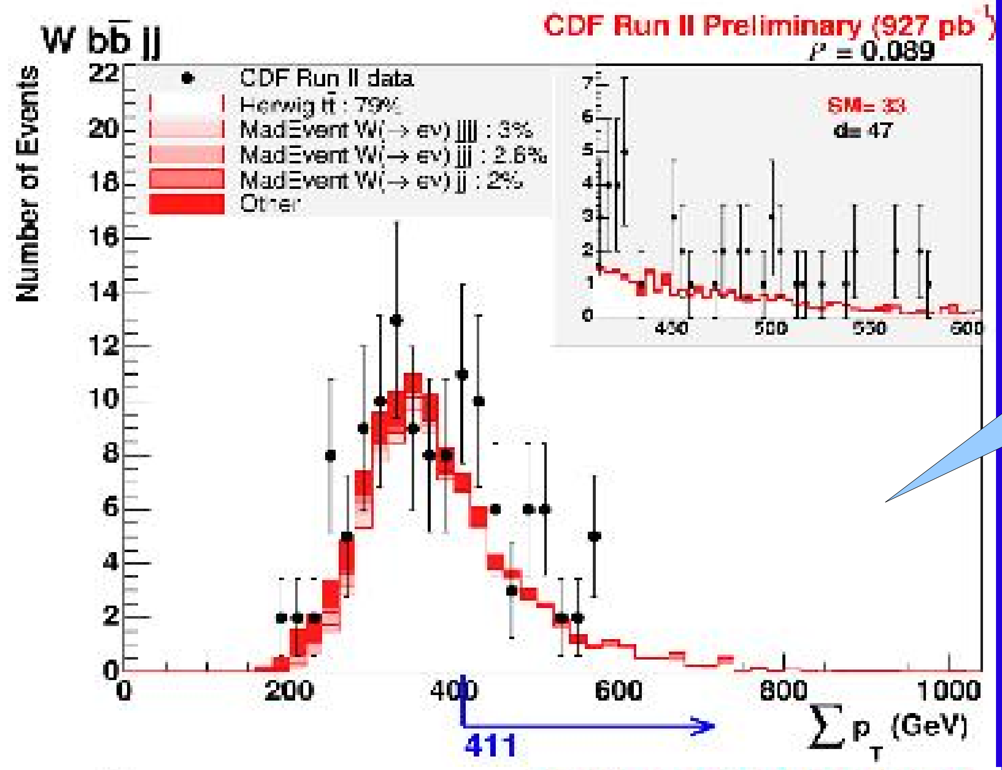
tildeScriptP < 0.001 → >3 sigma effect

Recap: Sleuth Algorithm

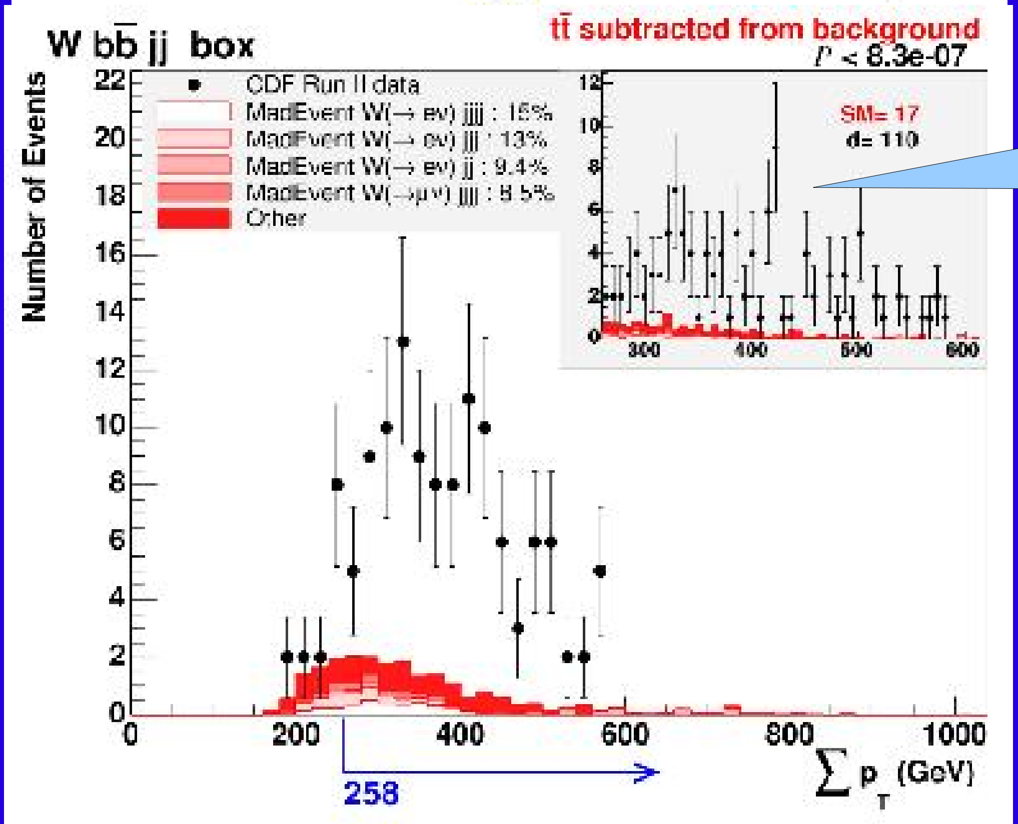
ScriptP = % of pseudo-experiments where this final state has any tail more interesting than the actual most interesting one.



TildeScriptP = % of pseudo-experiments that would produce any tail in any final state, that would be more interesting than *the* most interesting tail actually observed.

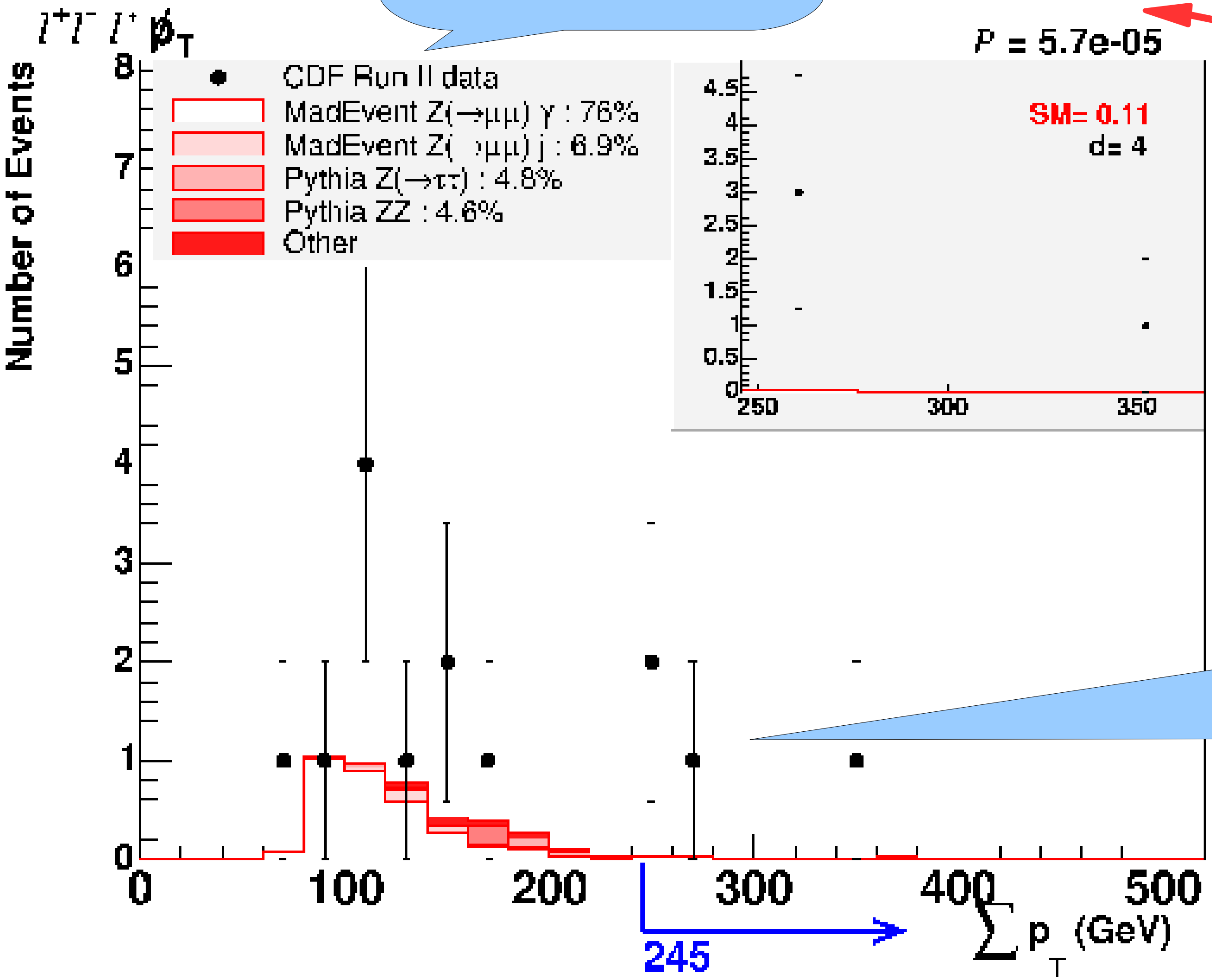


Would Sleuth find the top quark?



Yes in 80 pb-1
vs Run1: 67 pb-1

W+Z
removed



ScriptTildeP
=.01
=2.6sigma

Vista
“discovery”
of W+Z

Sleuth @CDFII result

$$\tilde{\mathcal{P}} = 0.08$$

8% of pseudo-
Experiments should
Be as interesting

(top 5)

CDF Run II Preliminary (2.0 fb^{-1})

SLEUTH Final State	$\mathcal{P}$
$\ell^+\ell'^+$	0.00055
$\ell^+\ell'^+\not{p}jj$	0.0021
$\ell^+\ell'^+\not{p}$	0.0042
$\ell^+\ell^-\ell'\not{p}$	0.0047
$\ell^+\tau^+\not{p}$	0.0065

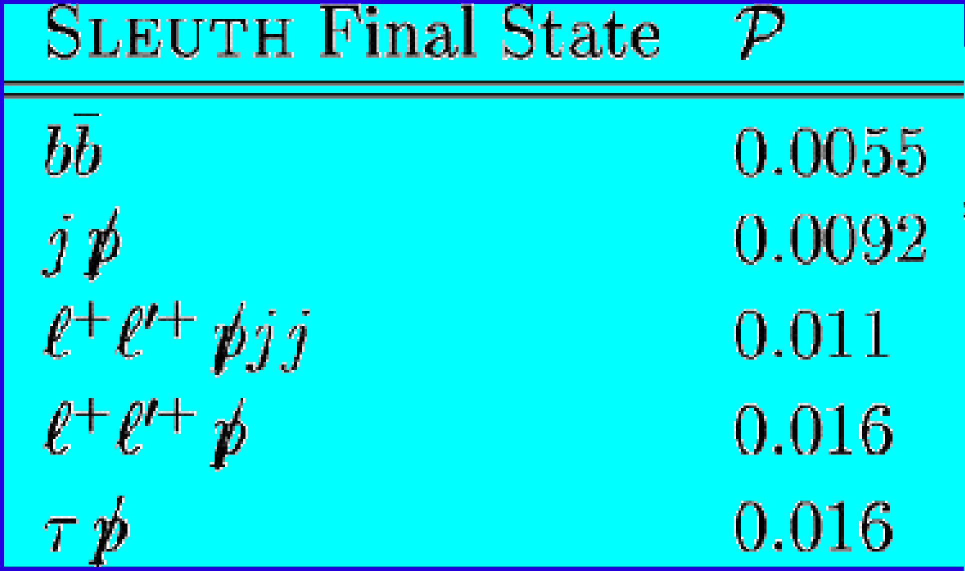
No significant excess

This does not prove
no new physics!

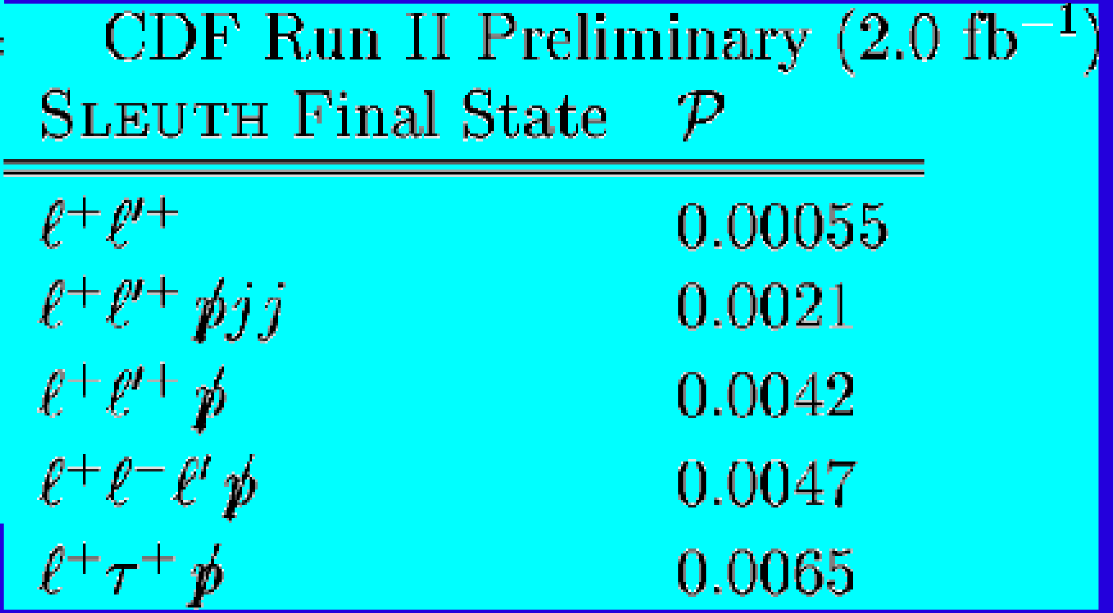
CDF Run II (1 fb^{-1})

Sleuth @CDFIIa result

$$\tilde{\mathcal{P}} = 0.46$$



Sleuth Final State	$\mathcal{P}$
$b\bar{b}$	0.0055
$j \not{p}$	0.0092
$\ell^+ \ell'^+ \not{p} j j$	0.011
$\ell^+ \ell'^+ \not{p}$	0.016
$\tau \not{p}$	0.016



CDF Run II Preliminary (2.0 fb^{-1})

Sleuth Final State	$\mathcal{P}$
$\ell^+ \ell'^+$	0.00055
$\ell^+ \ell'^+ \not{p} j j$	0.0021
$\ell^+ \ell'^+ \not{p}$	0.0042
$\ell^+ \ell^- \ell' \not{p}$	0.0047
$\ell^+ \tau^+ \not{p}$	0.0065

Summary

A global analysis of 2 fb^{-1} of CDF Run II data was performed

Vista

model-independent
searches the bulk of distributions

Sleuth

quasi-model-independent
searches the high-Σp_T tails

No significant excesses in 2 fb^{-1}
Run II can provide 5x more data yet to be searched

The greatest limitation to this blind new physics search is mis-modeling of backgrounds

Note: this analysis does NOT incorporate PDF, showering uncertainties:

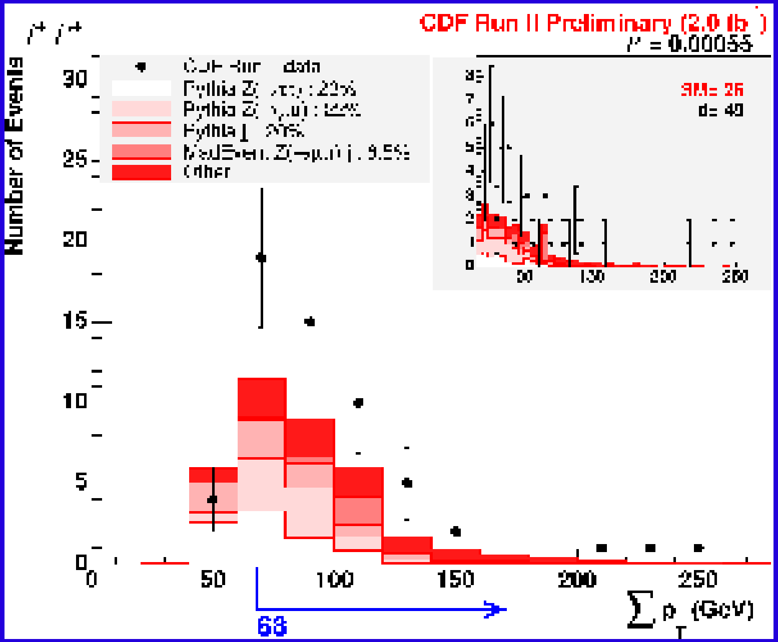
these are “fit” using correlations between different final states (e.g. K-factors from data)

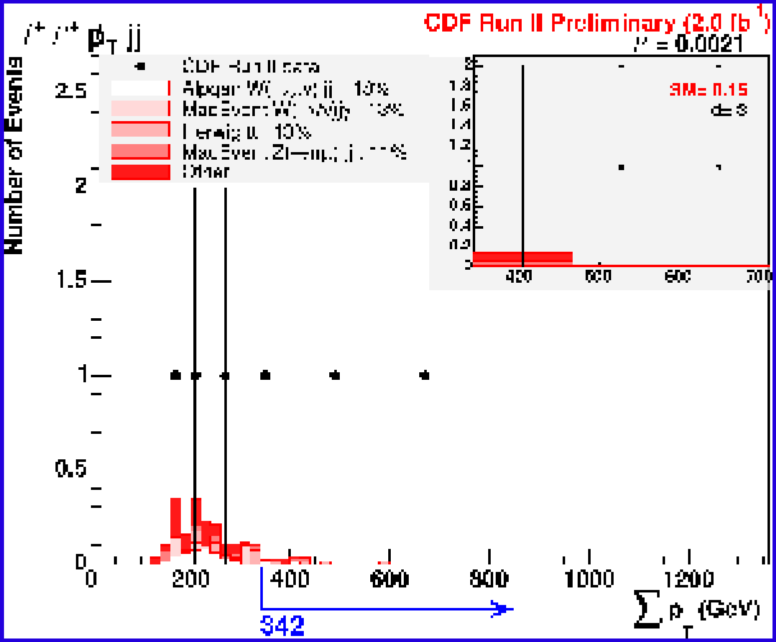
Here is something that is not yet statistically significant, but is nonetheless suggestive.

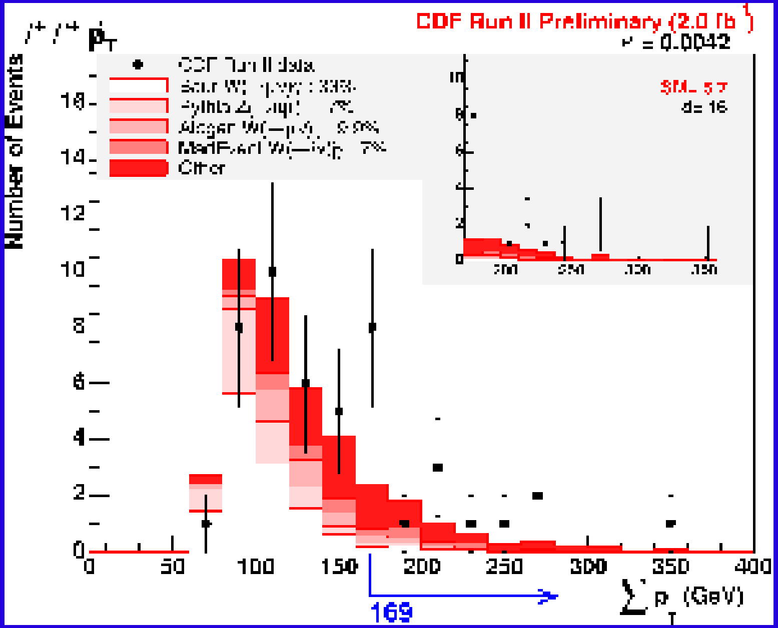
If it is real, D0 should be able to confirm it, and push it over the discovery threshold.

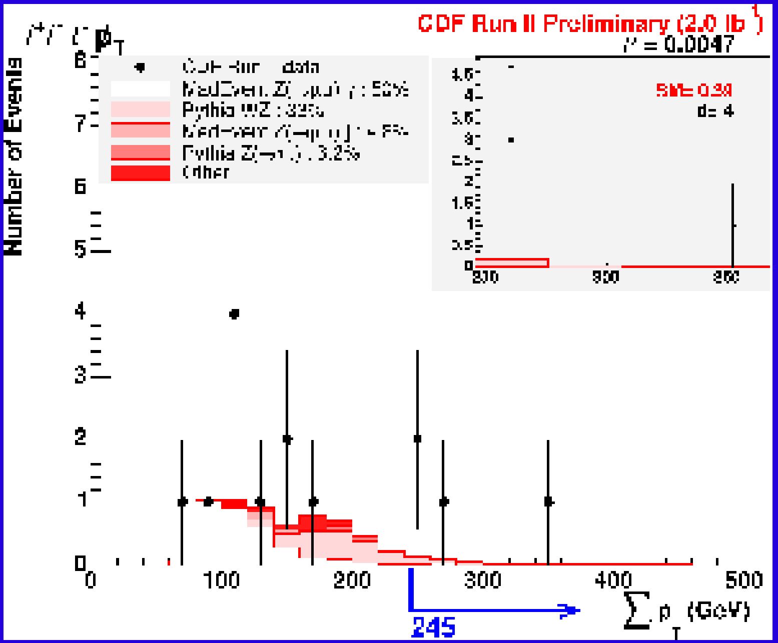
Until that happens (or doesn't), this is an interesting case to consider as something possibly real.

http://www-cdf.fnal.gov/physics/exotic/r2a/20080228.vista_sleuth/publicPage.html





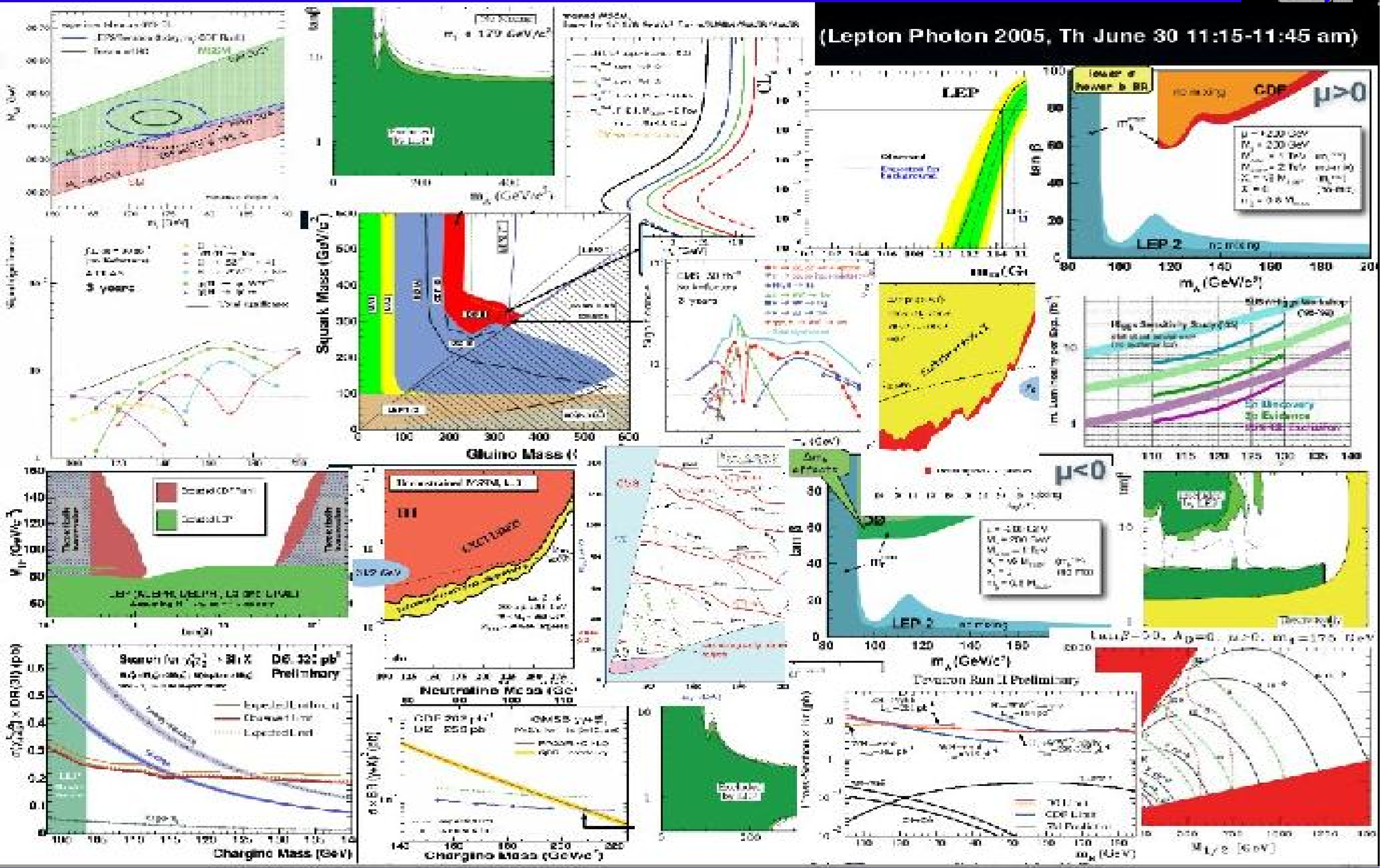




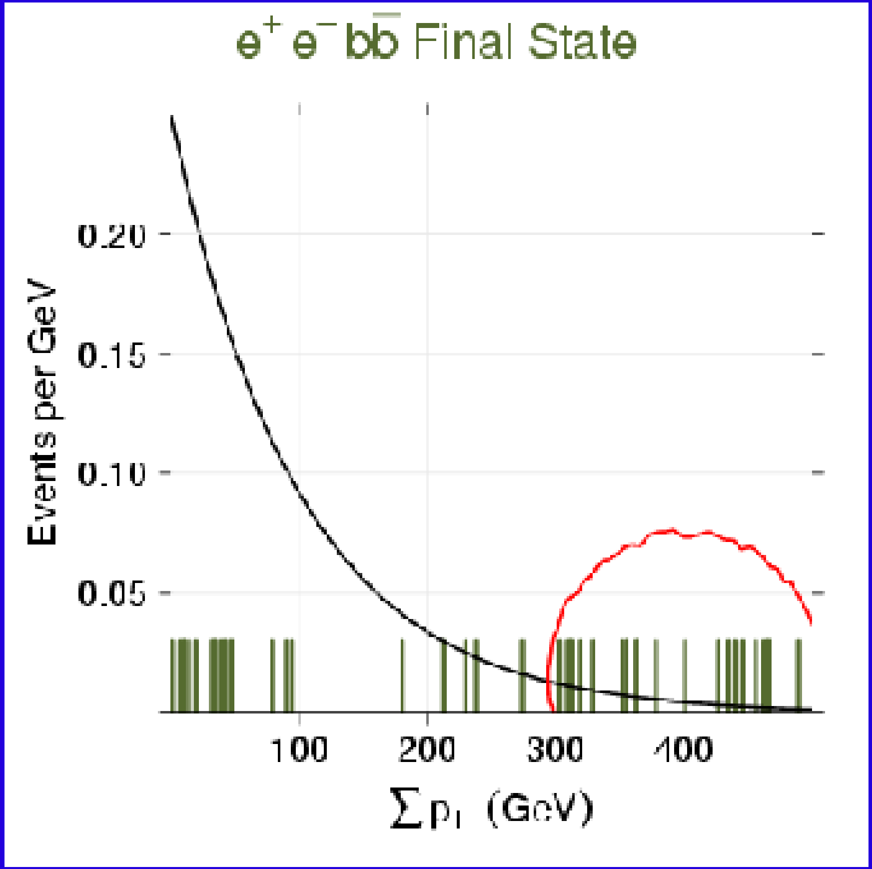
How would you understand this?

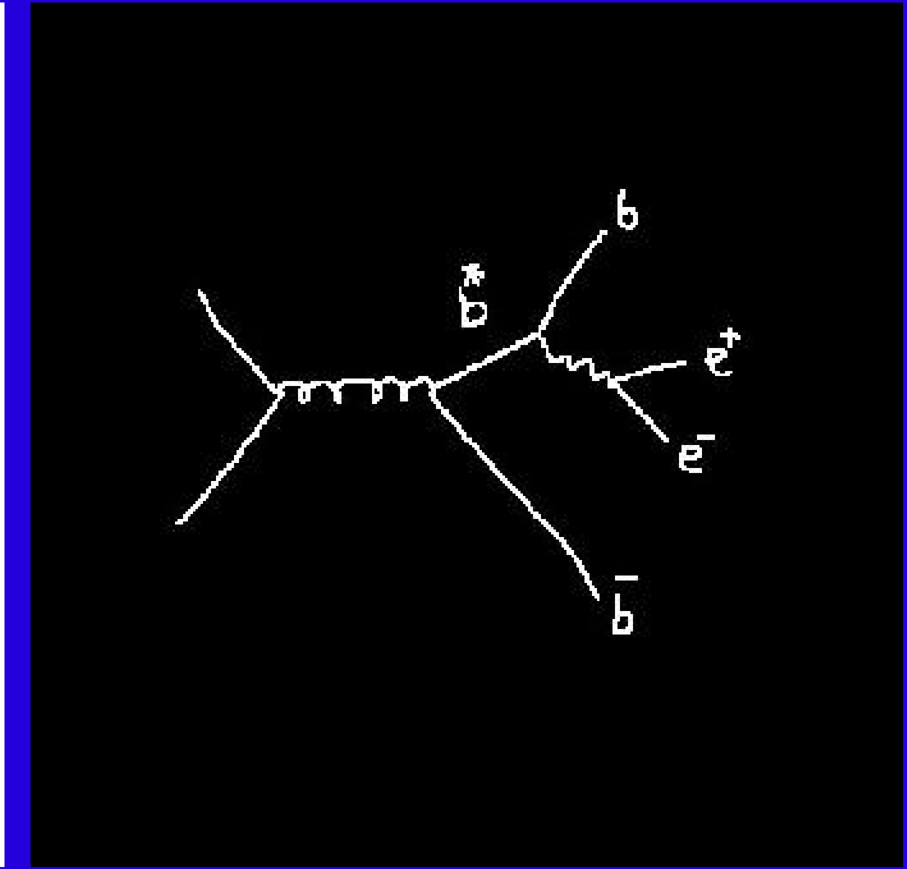
Different Views about New Physics

(Lepton Photon 2005, Th June 30 11:15-11:45 am)



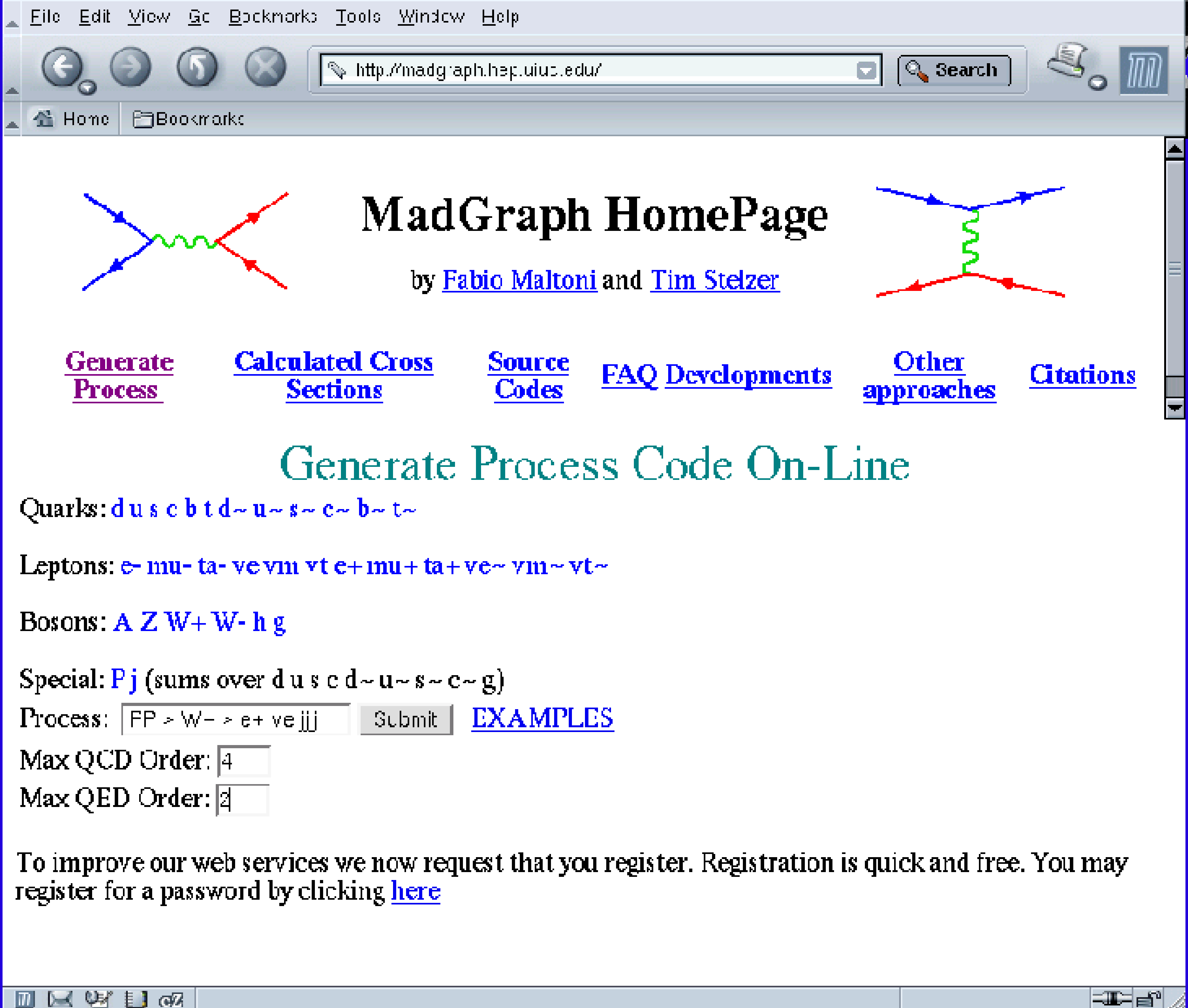

SUSY
technicolor
composite Higgs
TC - TC
hypercolor
supercolor
technicolor-QSM
extended TC
NOT YET THOUGHT OF
NOT YET THOUGHT OF
NMSSM
MSSM + ν_R
unified
6th gen
5th gen
4th gen
leptoquark
sterile ν
heavy Majorana ν
vector-like fermions
fractionally charged
milli-charged
S, T, U
shadow matter
triplet Higgs
doubly charged Higgs
Type 1
Type II
general 2HDM
spontaneous CP
superweak
milli-weak
Weinberg's 3HD
Majoron
axion
familon
NGB
quintessence
k-essence
composite W, Z
contact int.
string
extra dim.
NOT THOUGHT


$e^+ e^- b\bar{b}$ Final State
Events per GeV
0.20
0.15
0.10
0.05
100
200
300
400
$\sum p_t$ (GeV)


b
b^*
e^+
e^-
$\bar{b}$

Shakespeare's writing style

- Develop a large vocabulary
- Play with words
- Invent new words and phrases
- Develop the common touch
- Read great literature
- Study the great orators, actors and the popular
- Live with passion
- Write, write, write!!!



MadGraph HomePage

by Fabio Maltoni and Tim Stelzer

Generate Process | Calculated Cross Sections | Source Codes | FAQ | Developments | Other approaches | Citations

Generate Process Code On-Line

Quarks: d u s c b t d~ u~ s~ c~ b~ t~

Leptons: e- mu- ta- ve vm vt e+ mu+ ta+ ve~ vm~ vt~

Bosons: A Z W+ W- h g

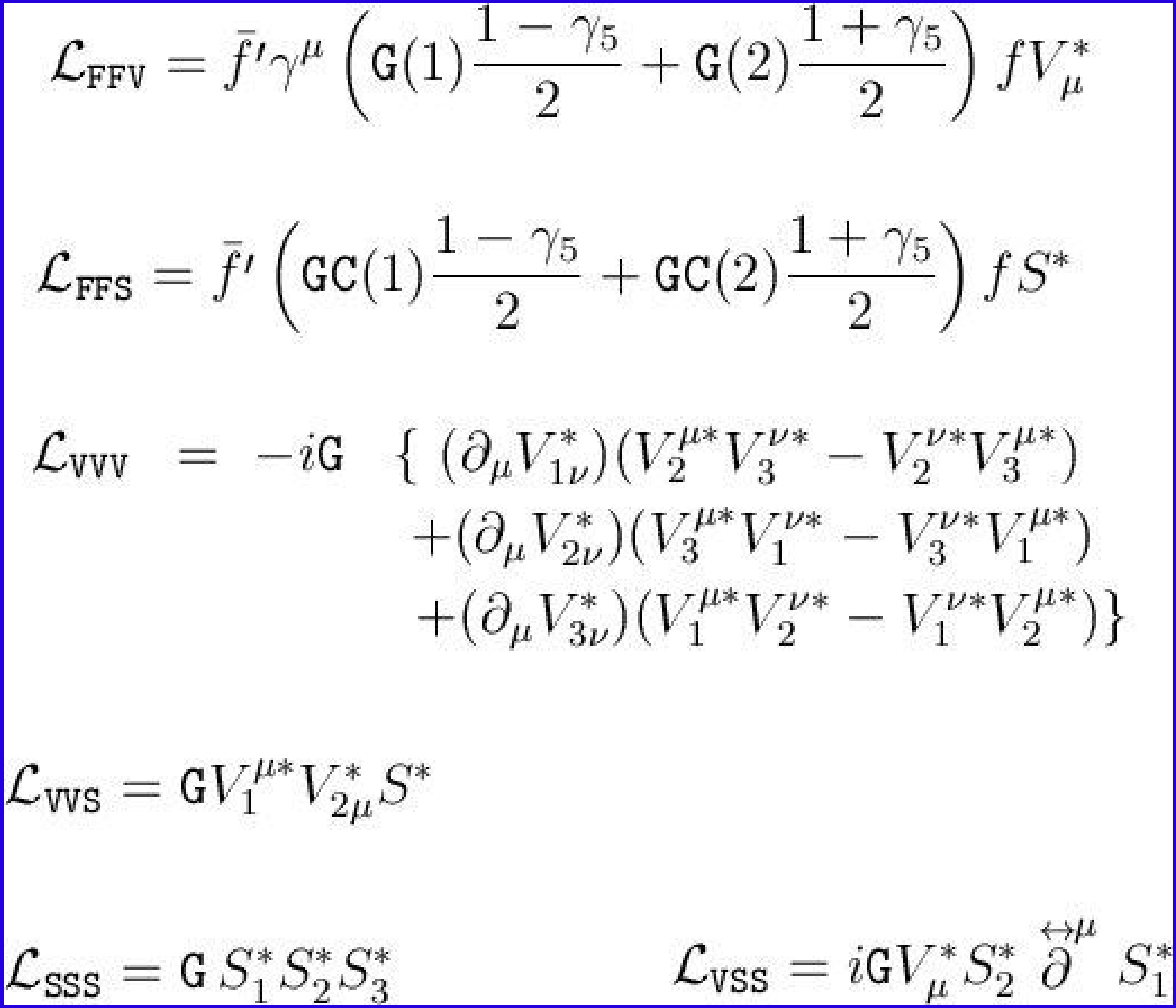
Special: P j (sums over d u s c d~ u~ s~ c~ g)

Process: PP > W- > e+ ve jjj Submit EXAMPLES

Max QCD Order: 4

Max QED Order: 2

To improve our web services we now request that you register. Registration is quick and free. You may register for a password by clicking here



$$\mathcal{L}_{\mathtt{FFV}} = \bar{f}'\gamma^{\mu}\left(\mathtt{G}(1)\frac{1-\gamma_5}{2} + \mathtt{G}(2)\frac{1+\gamma_5}{2}\right) f V_{\mu}^{*}$$

$$\mathcal{L}_{\mathtt{FFS}} = \bar{f}'\left(\mathtt{GC}(1)\frac{1-\gamma_5}{2} + \mathtt{GC}(2)\frac{1+\gamma_5}{2}\right) f S^{*}$$

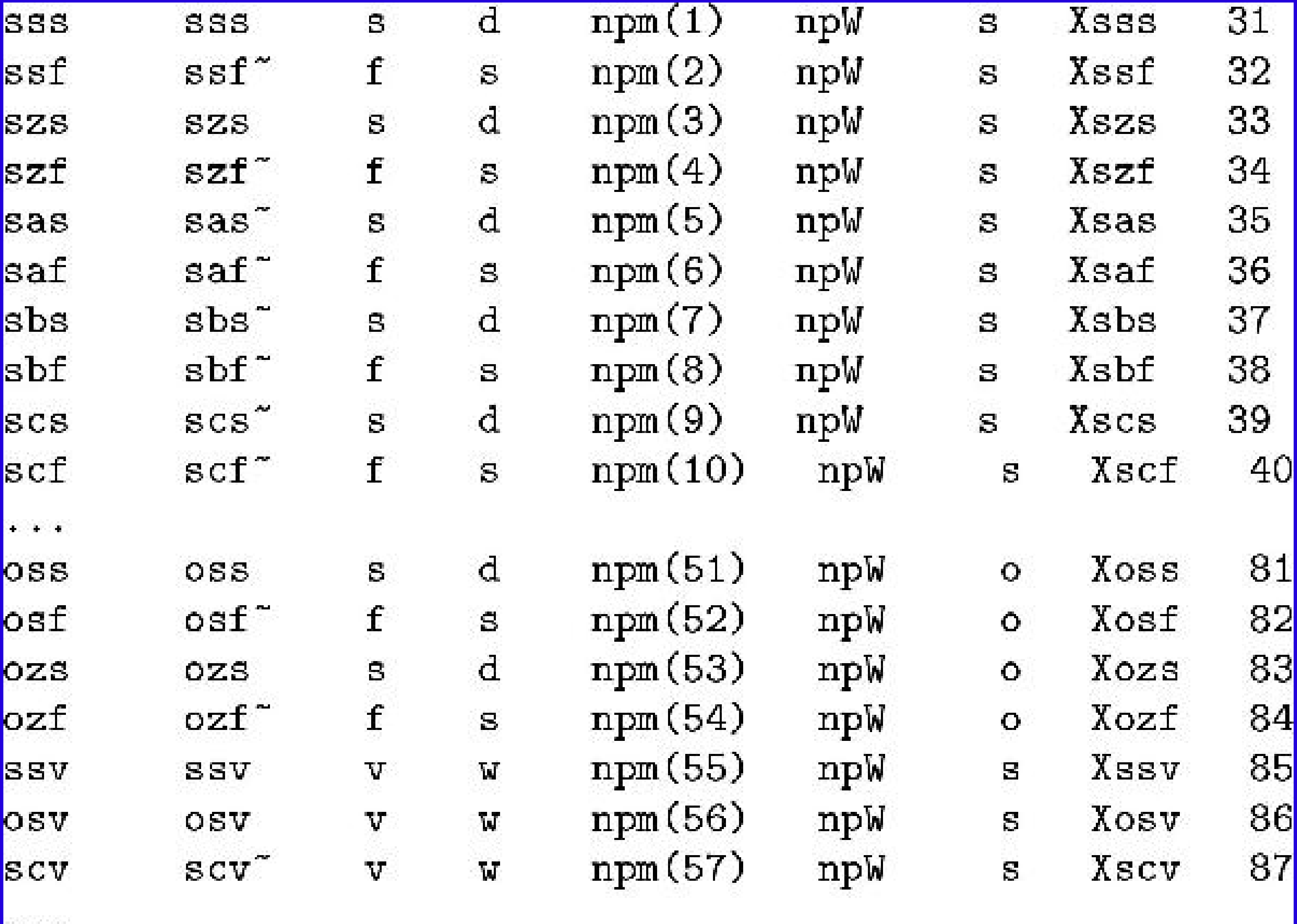
$$\begin{aligned}\mathcal{L}_{\mathtt{VVV}} \;=\; -i\mathtt{G}\; \{ & (\partial_{\mu}V_{1\nu}^{*})(V_2^{\mu *}V_3^{\nu *} - V_2^{\nu *}V_3^{\mu *}) \\ & +(\partial_{\mu}V_{2\nu}^{*})(V_3^{\mu *}V_1^{\nu *} - V_3^{\nu *}V_1^{\mu *}) \\ & +(\partial_{\mu}V_{3\nu}^{*})(V_1^{\mu *}V_2^{\nu *} - V_1^{\nu *}V_2^{\mu *})\}\end{aligned}$$

$$\mathcal{L}_{\mathtt{VVS}} = \mathtt{G}V_1^{\mu *}V_{2\mu}^{*}S^{*}$$

$$\mathcal{L}_{\mathtt{SSS}} = \mathtt{G}\,S_1^{*}S_2^{*}S_3^{*}$$

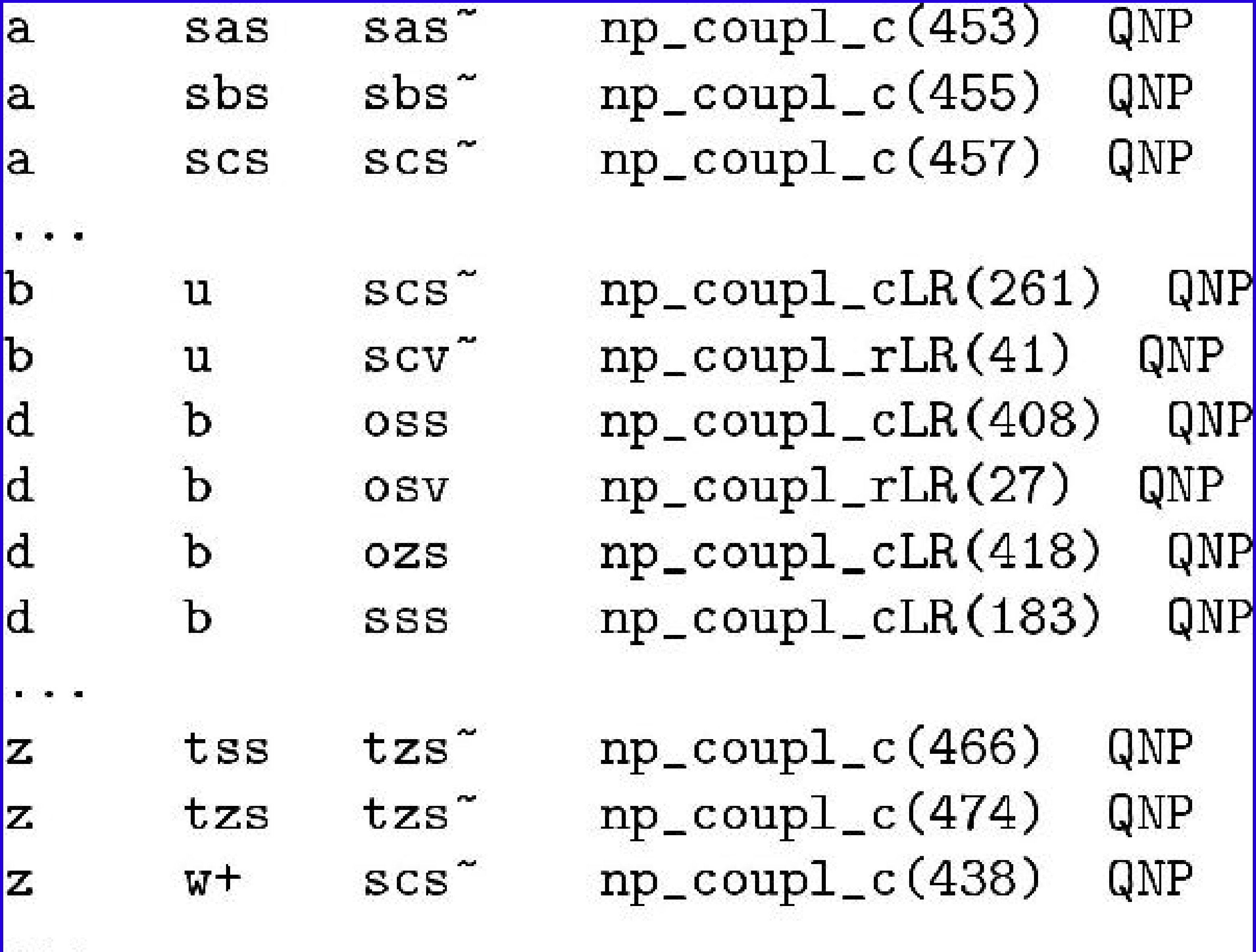
$$\mathcal{L}_{\mathtt{VSS}} = i\mathtt{G}V_{\mu}^{*}S_2^{*}\overleftrightarrow{\partial}^{\mu}S_1^{*}$$

The Actors



sss	sss	s	d	npm(1)	npW	s	Xsss	31	
ssf	ssf~	f	s	npm(2)	npW	s	Xssf	32	
szs	szs	s	d	npm(3)	npW	s	Xszs	33	
szf	szf~	f	s	npm(4)	npW	s	Xszf	34	
sas	sas~	s	d	npm(5)	npW	s	Xsas	35	
saf	saf~	f	s	npm(6)	npW	s	Xsaf	36	
sbs	sbs~	s	d	npm(7)	npW	s	Xsbs	37	
sbf	sbf~	f	s	npm(8)	npW	s	Xsbf	38	
scs	scs~	s	d	npm(9)	npW	s	Xscs	39	
scf	scf~	f	s	npm(10)	npW	s	Xscf	40	
...									
oss	oss	s	d	npm(51)	npW	o	Xoss	81	
osf	osf~	f	s	npm(52)	npW	o	Xosf	82	
ozs	ozs	s	d	npm(53)	npW	o	Xozs	83	
ozf	ozf~	f	s	npm(54)	npW	o	Xozf	84	
ssv	ssv	v	w	npm(55)	npW	s	Xssv	85	
osv	osv	v	w	npm(56)	npW	s	Xosv	86	
scv	scv~	v	w	npm(57)	npW	s	Xscv	87	
...									

The Grammar



```
a     sas   sas~   np_coupl_c(453)    QNP
a     sbs   sbs~   np_coupl_c(455)    QNP
a     scs   scs~   np_coupl_c(457)    QNP
...
b     u     scs~   np_coupl_cLR(261)   QNP
b     u     scv~   np_coupl_rLR(41)   QNP
d     b     oss    np_coupl_cLR(408)   QNP
d     b     osv    np_coupl_rLR(27)   QNP
d     b     ozs    np_coupl_cLR(418)   QNP
d     b     sss    np_coupl_cLR(183)   QNP
...
z     tss   tzs~   np_coupl_c(466)    QNP
z     tzs   tzs~   np_coupl_c(474)    QNP
z     w+    scs~   np_coupl_c(438)    QNP
...
```

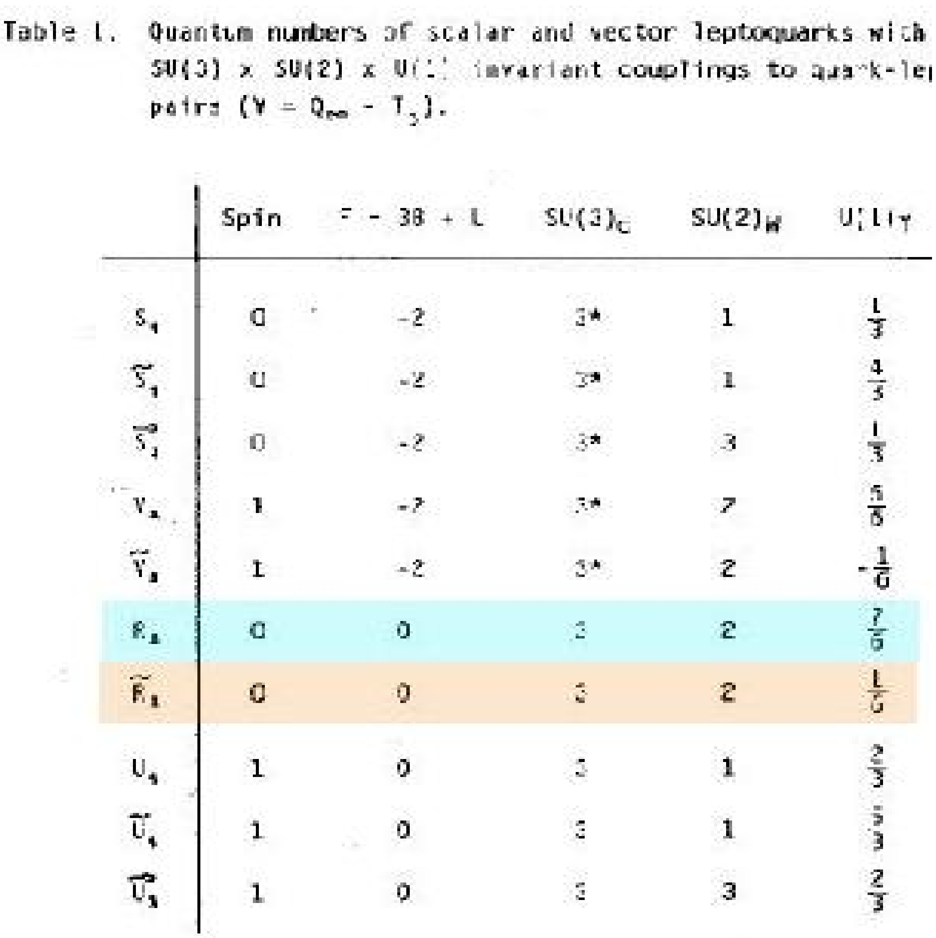


Table 1. Quantum numbers of scalar and vector leptoquarks with SU(3) x SU(2) x U(1) invariant couplings to quark-lep pairs ($Y = Q_{em} - T_3$).

	Spin	F = 3B + L	$SU(3)_C$	$SU(2)_W$	$U(1)_Y$
S_1	0	-2	3*	1	$\frac{1}{3}$
$\tilde{S}_1$	0	-2	3*	1	$\frac{4}{3}$
$\vec{S}_3$	0	-2	3*	3	$\frac{1}{3}$
V_2	1	-2	3*	2	$\frac{5}{6}$
$\tilde{V}_2$	1	-2	3*	2	$-\frac{1}{6}$
R_2	0	0	3	2	$\frac{7}{6}$
$\tilde{R}_2$	0	0	3	2	$\frac{1}{6}$
U_1	1	0	3	1	$\frac{2}{3}$
$\tilde{U}_1$	1	0	3	1	$\frac{5}{3}$
$\vec{U}_3$	1	0	3	3	$\frac{2}{3}$

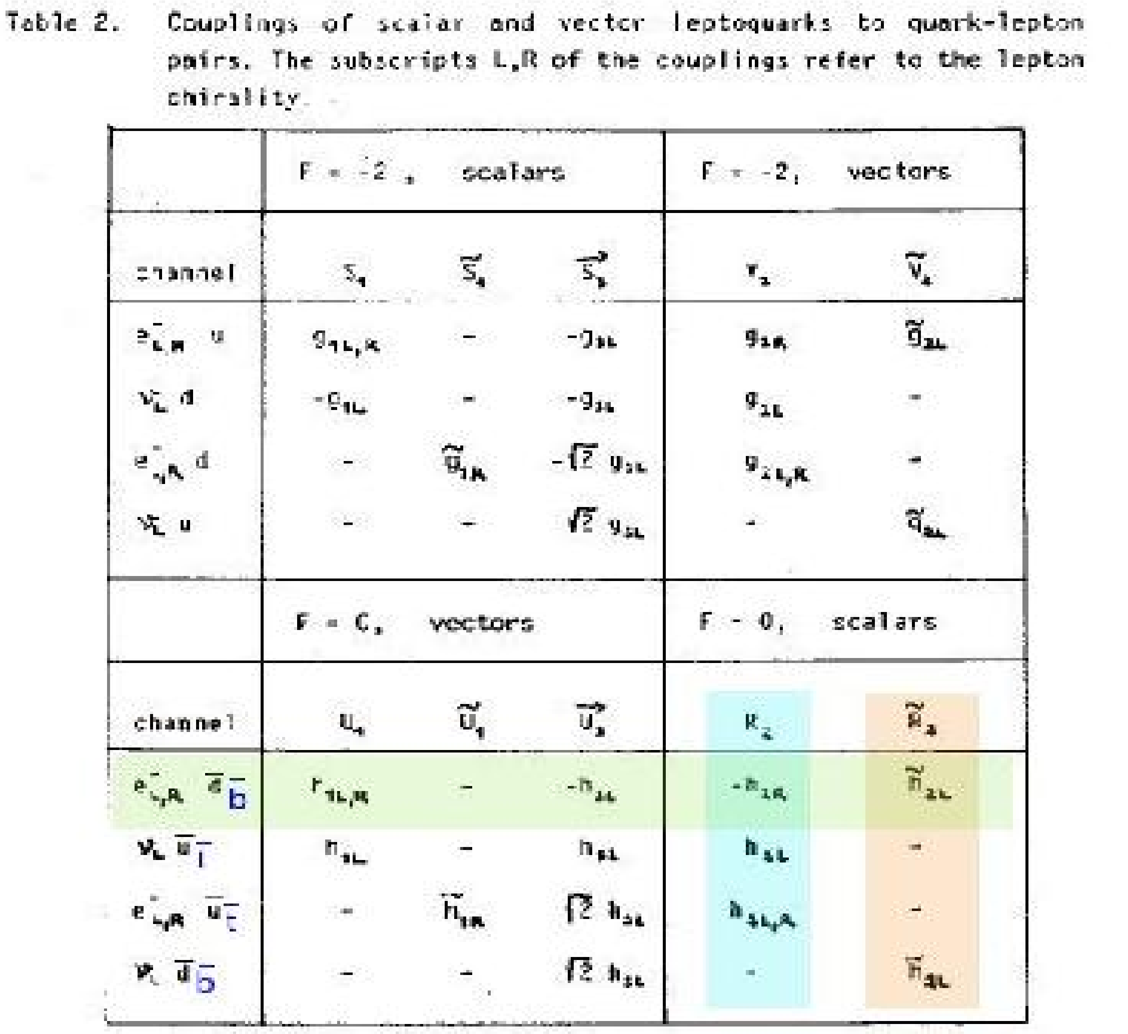
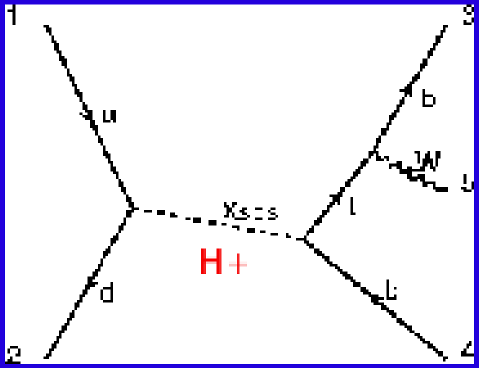
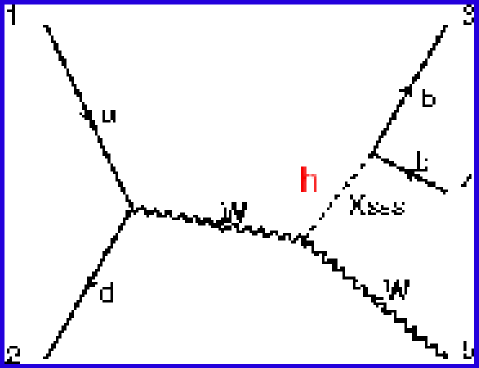


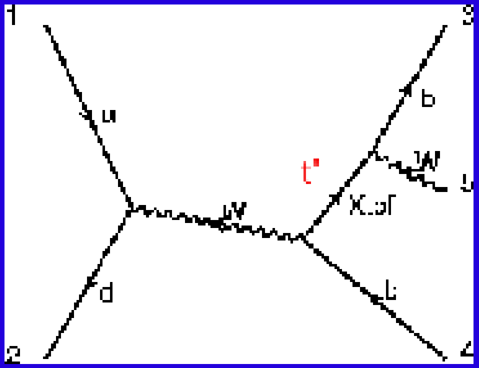
Table 2. Couplings of scalar and vector leptoquarks to quark-lepton pairs. The subscripts L,R of the couplings refer to the lepton chirality.

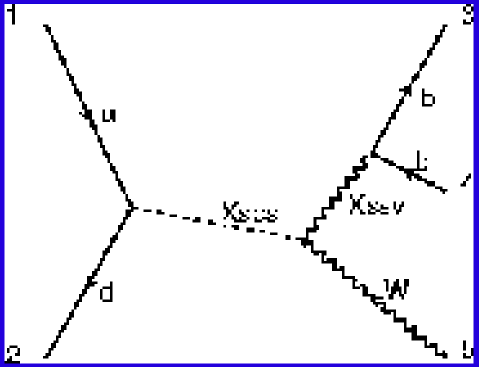
	F = -2, scalars			F = -2, vectors	
channel	S_1	$\tilde{S}_1$	$\vec{S}_3$	V_2	$\tilde{V}_2$
$e^-_{L,R}$ u	$g_{1L,R}$	-	$-g_{3L}$	g_{2R}	$\tilde{g}_{2L}$
ν_L d	$-g_{1L}$	-	$-g_{3L}$	g_{2L}	-
$e^-_{L,R}$ d	-	$\tilde{g}_{1R}$	$-\sqrt{2}\, g_{3L}$	$g_{2L,R}$	-
ν_L u	-	-	$\sqrt{2}\, g_{3L}$	-	$\tilde{g}_{2L}$
	F = 0, vectors			F = 0, scalars	
channel	U_1	$\tilde{U}_1$	$\vec{U}_3$	R_2	$\tilde{R}_2$
$e^-_{L,R}$ $\bar{d}$ $\bar{b}$	$h_{1L,R}$	-	$-h_{3L}$	$-h_{2R}$	$\tilde{h}_{2L}$
ν_L $\bar{u}$ $\bar{t}$	h_{1L}	-	h_{3L}	h_{2L}	-
$e^-_{L,R}$ $\bar{u}$ $\bar{t}$	-	$\tilde{h}_{1R}$	$\sqrt{2}\, h_{3L}$	$h_{2L,R}$	-
ν_L $\bar{d}$ $\bar{b}$	-	-	$\sqrt{2}\, h_{3L}$	-	$\tilde{h}_{2L}$

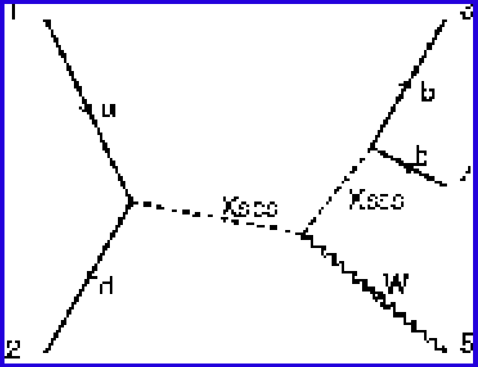
$W^+ b\bar{b}$ Anomaly

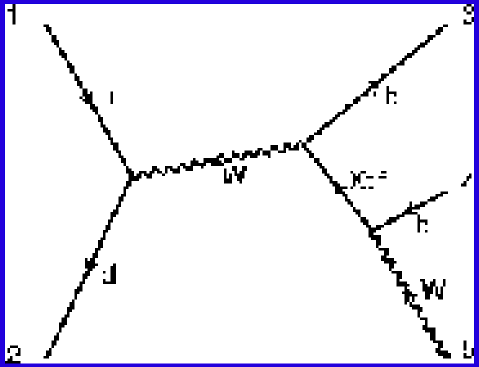


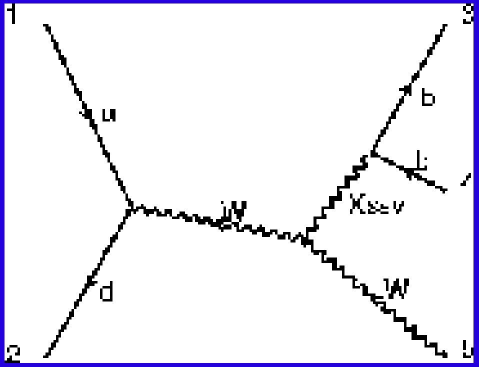


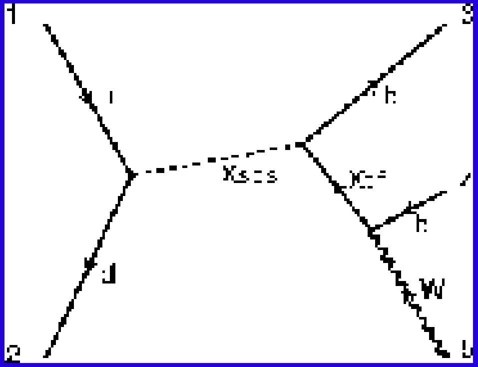


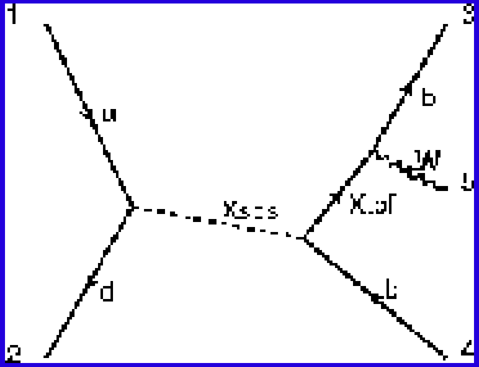

1
u
d
2
Xscs
Xsev
b
b
W
3
4
5


1
u
d
2
Xscs
Xscs
b
b
W
3
4
5


1
u
d
2
W
b
Xc+
b
W
3
4
5

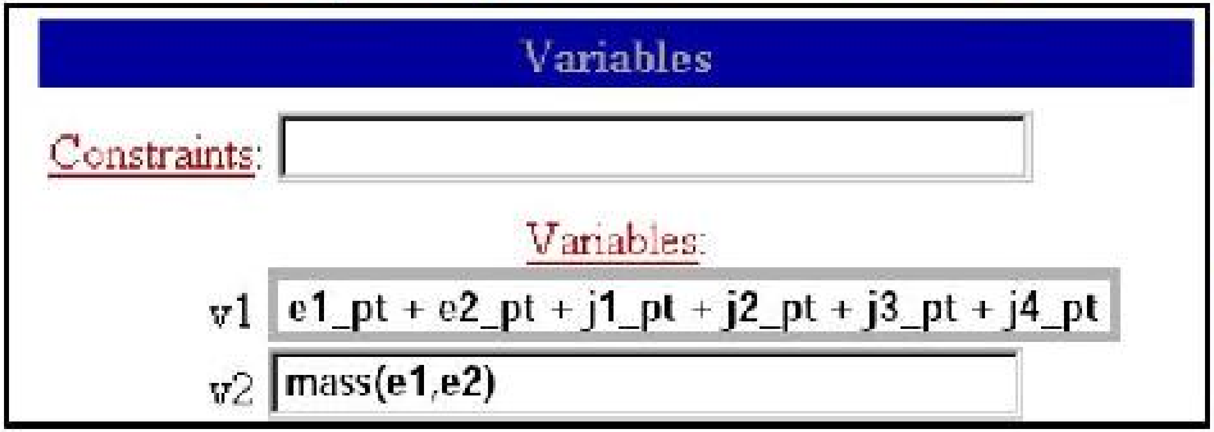

1
u
d
2
W
Xsev
b
b
W
3
4
5


1
u
d
2
Xscs
b
Xc+
b
W
3
4
5


1
u
d
2
Xscs
b
W
Xc+
b
3
4
5

Examples #11

Leptoquarks → ee 2j



Variables

Constraints:

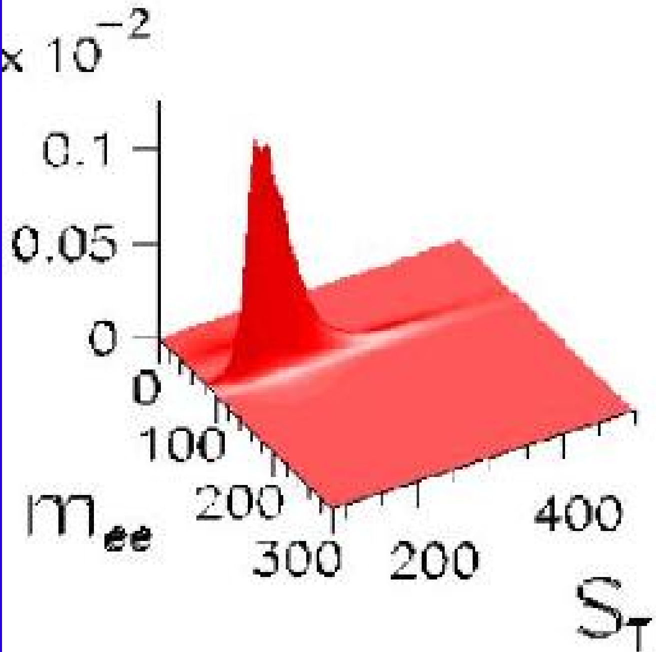
Variables:

v1 e1_pt + e2_pt + j1_pt + j2_pt + j3_pt + j4_pt

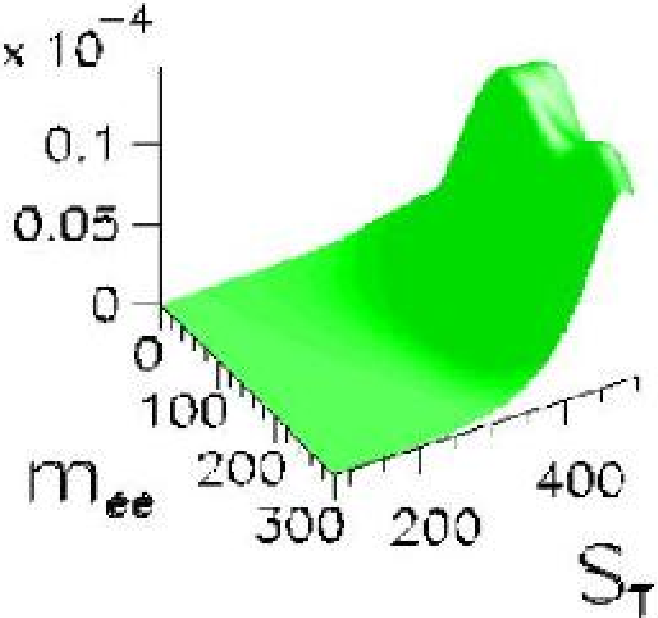
v2 mass(e1,e2)

ε_{sig}	33%
$\hat{b}$	0.3 ± 0.1
N_{obs}	0
$\sigma^{95\%} \times \mathcal{B}$	0.07 pb

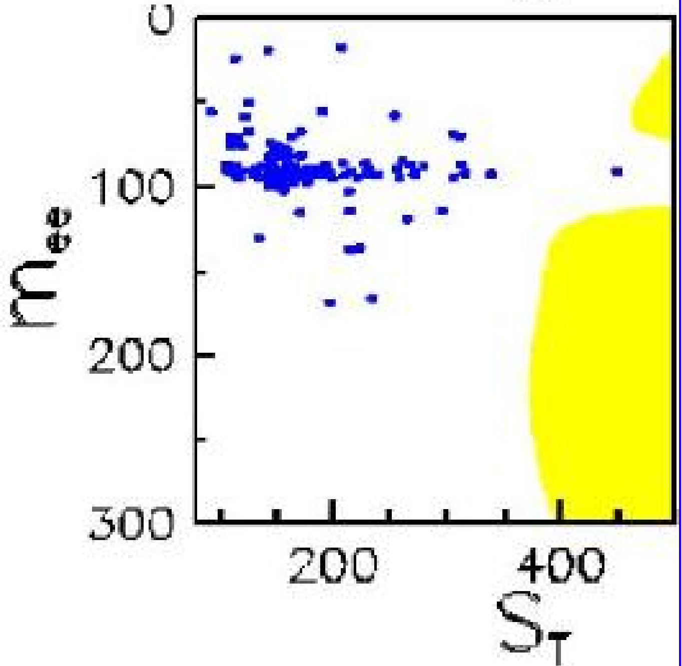
Background density



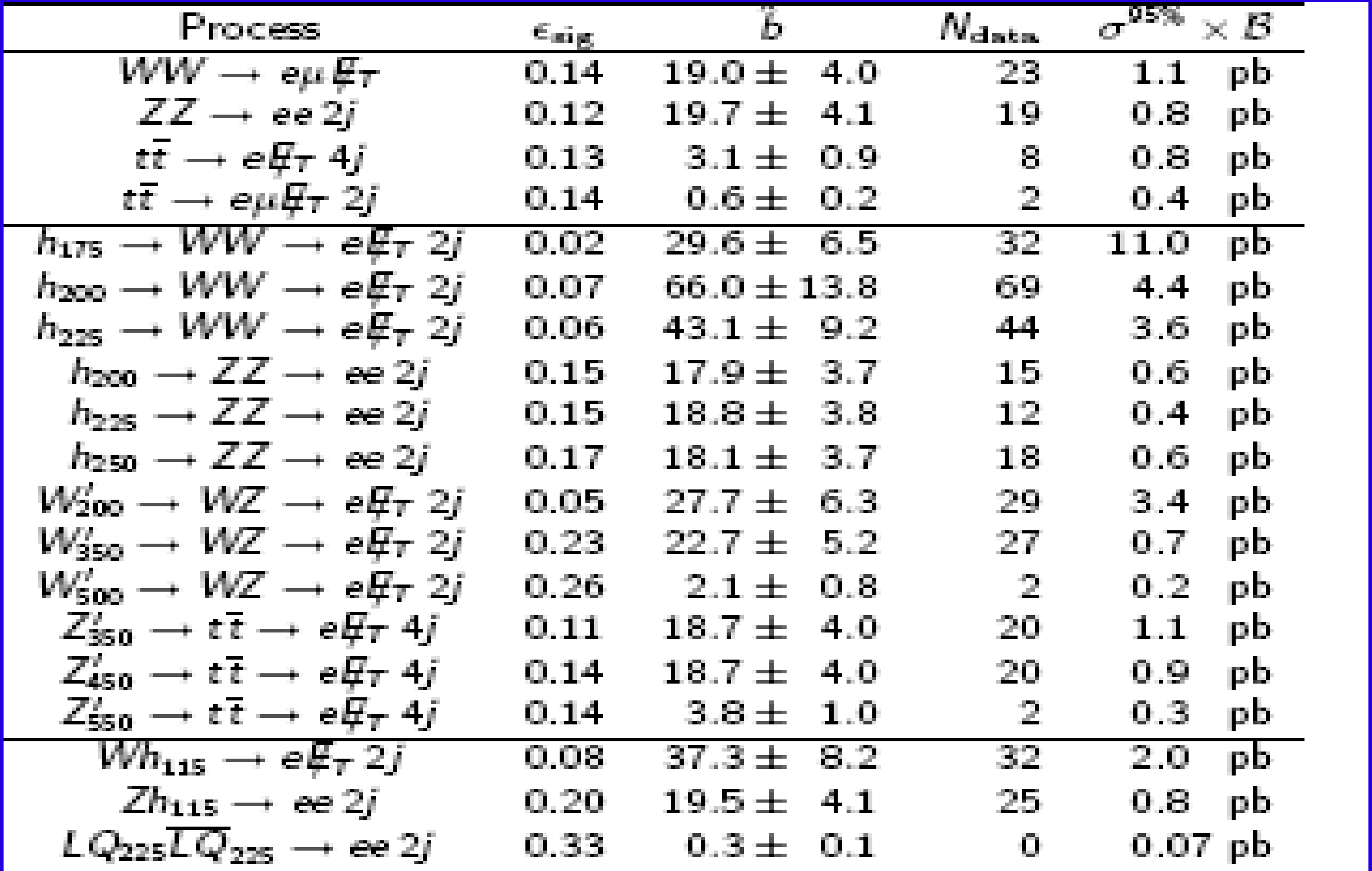
Signal density



Selected region



Quaero: DØ, hep-ex/0106039

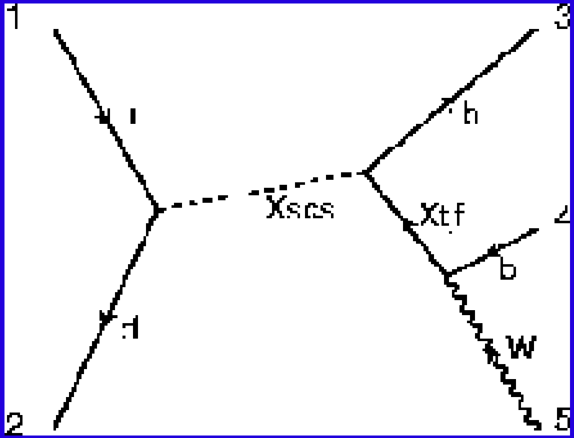


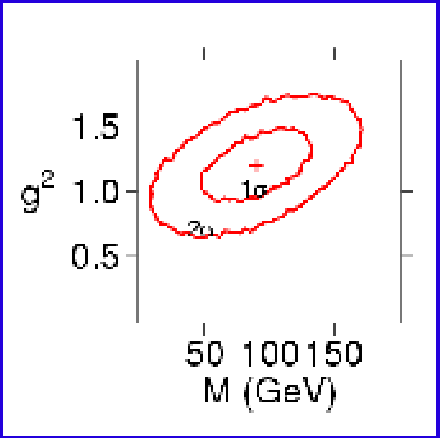
Process	$\epsilon_{\rm sig}$	$\breve{b}$	$N_{\rm data}$	$\sigma^{95\%} \times B$
$WW \to e\mu \not\!\!E_T$	0.14	19.0 ± 4.0	23	1.1 pb
$ZZ \to ee\,2j$	0.12	19.7 ± 4.1	19	0.8 pb
$t\bar{t} \to e \not\!\!E_T\,4j$	0.13	3.1 ± 0.9	8	0.8 pb
$t\bar{t} \to e\mu \not\!\!E_T\,2j$	0.14	0.6 ± 0.2	2	0.4 pb
$h_{175} \to WW \to e \not\!\!E_T\,2j$	0.02	29.6 ± 6.5	32	11.0 pb
$h_{200} \to WW \to e \not\!\!E_T\,2j$	0.07	66.0 ± 13.8	69	4.4 pb
$h_{225} \to WW \to e \not\!\!E_T\,2j$	0.06	43.1 ± 9.2	44	3.6 pb
$h_{200} \to ZZ \to ee\,2j$	0.15	17.9 ± 3.7	15	0.6 pb
$h_{225} \to ZZ \to ee\,2j$	0.15	18.8 ± 3.8	12	0.4 pb
$h_{250} \to ZZ \to ee\,2j$	0.17	18.1 ± 3.7	18	0.6 pb
$W'_{200} \to WZ \to e \not\!\!E_T\,2j$	0.05	27.7 ± 6.3	29	3.4 pb
$W'_{350} \to WZ \to e \not\!\!E_T\,2j$	0.23	22.7 ± 5.2	27	0.7 pb
$W'_{500} \to WZ \to e \not\!\!E_T\,2j$	0.26	2.1 ± 0.8	2	0.2 pb
$Z'_{350} \to t\bar{t} \to e \not\!\!E_T\,4j$	0.11	18.7 ± 4.0	20	1.1 pb
$Z'_{450} \to t\bar{t} \to e \not\!\!E_T\,4j$	0.14	18.7 ± 4.0	20	0.9 pb
$Z'_{550} \to t\bar{t} \to e \not\!\!E_T\,4j$	0.14	3.8 ± 1.0	2	0.3 pb
$Wh_{115} \to e \not\!\!E_T\,2j$	0.08	37.3 ± 8.2	32	2.0 pb
$Zh_{115} \to ee\,2j$	0.20	19.5 ± 4.1	25	0.8 pb
$LQ_{225}\overline{LQ}_{225} \to ee\,2j$	0.33	0.3 ± 0.1	0	0.07 pb

Story

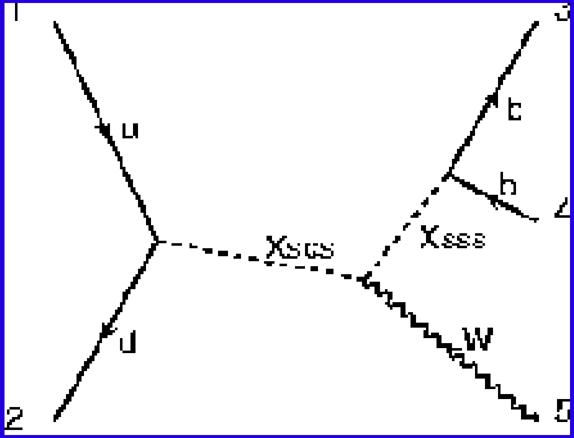
Fit

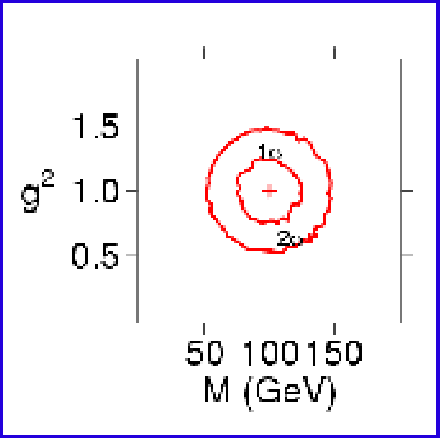
$$\log_{10}\left\{\frac{p(s+b)}{p(b)}\right\}$$



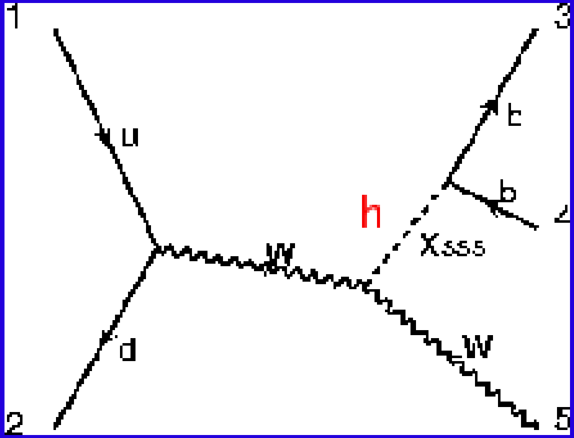


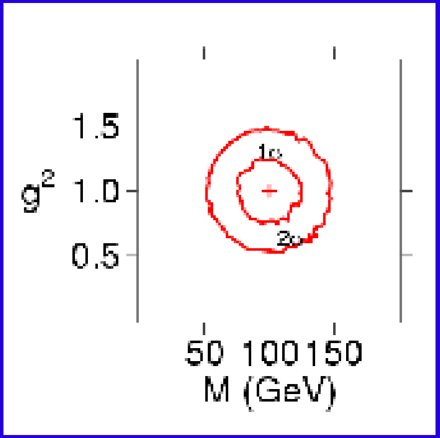
7



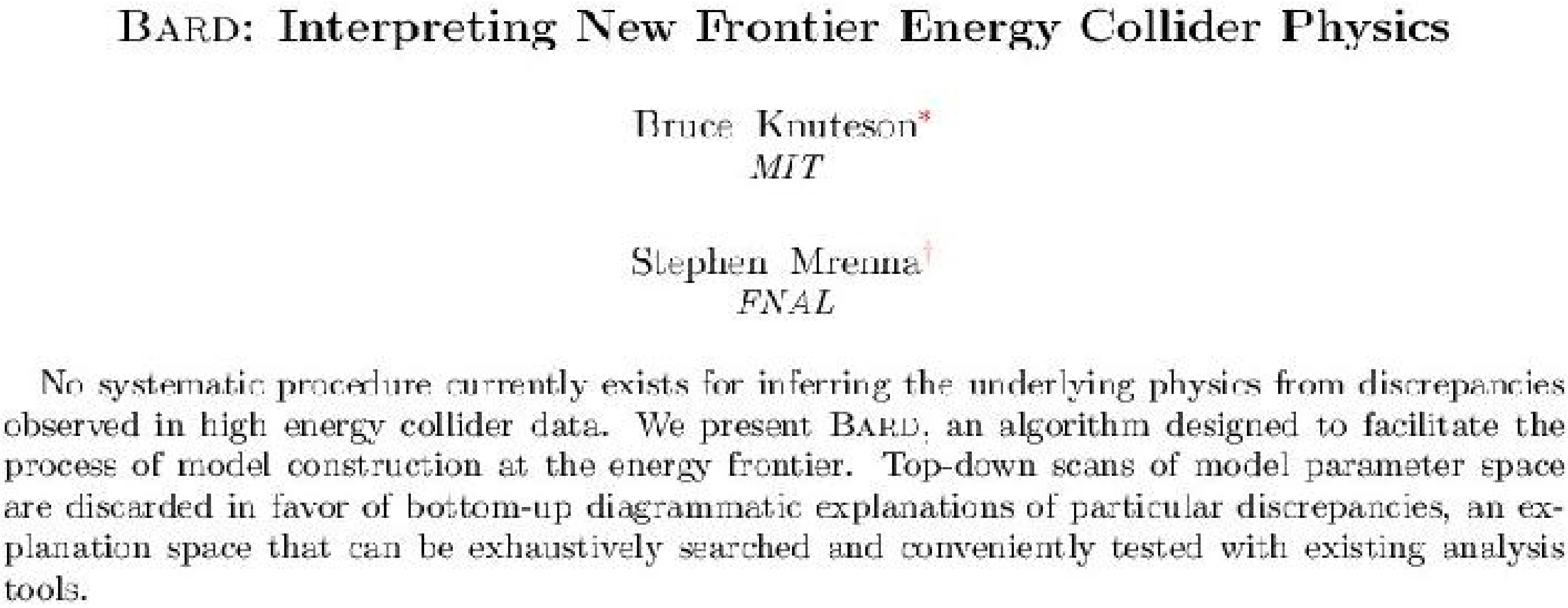


5





3



BARD: Interpreting New Frontier Energy Collider Physics

Bruce Knuteson[*]
MIT

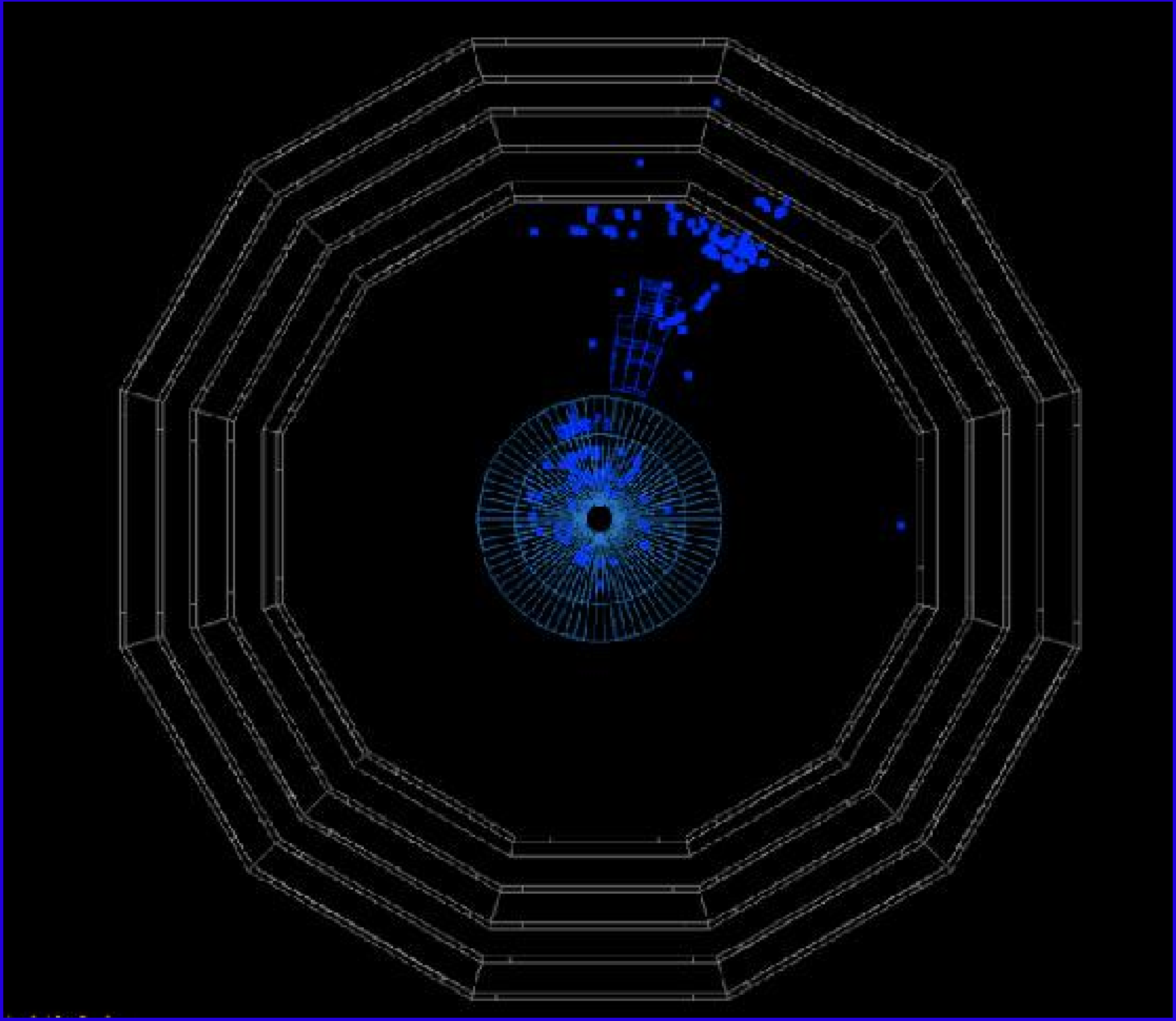
Stephen Mrenna[†]
FNAL

No systematic procedure currently exists for inferring the underlying physics from discrepancies observed in high energy collider data. We present BARD, an algorithm designed to facilitate the process of model construction at the energy frontier. Top-down scans of model parameter space are discarded in favor of bottom-up diagrammatic explanations of particular discrepancies, an explanation space that can be exhaustively searched and conveniently tested with existing analysis tools.

Marmoset is a simplified way
to do much the same thing

Obsolete?

R-hadron decay in the middle of CMS



New Maximally Weird

- Hidden Valleys?
- Quirks?
- Fireballs?
- ...?

What can we
expect at the LHC?

Can we understand it?

Possible LHC Outcomes

Something so striking
you can't miss it

$$Z^{'} \rightarrow \mu^{+}\mu^{-}$$

$$BH \rightarrow 100\ \mathrm{Z/W/t/h}$$

~100 GeV particles
with cascade decays

New exotica
(quirks, hidden valley,...)

Nothing

(except marginal
WW scattering)

Consequences

Easy Use sideband data as your "Monte Carlo" (probably something else to complete the picture)	**Challenging** (Control regions are all mixed up)
More Challenging Requires detailed understanding of SM (and detector) tails	**Most Challenging** When do you give up?

Conclusions

We are prepared for the challenging case. We can improve our current tools with manpower and some mindpower and understand cross sections @LHC

In CDF RunII data, a global test of our tools works very well in estimating counts, less so in kinematic distributions (about 6% have KS>1%)

Distribution problems are likely a deficiency of parton shower programs (all?) and appear at low scales (low m_j and low end of P_T)

There is no indication (as yet) of new physics