Results of a Global Search for New Physics at CDF

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on behalf of the CDF Collaboration

Fermilab Wine and Cheese Seminar
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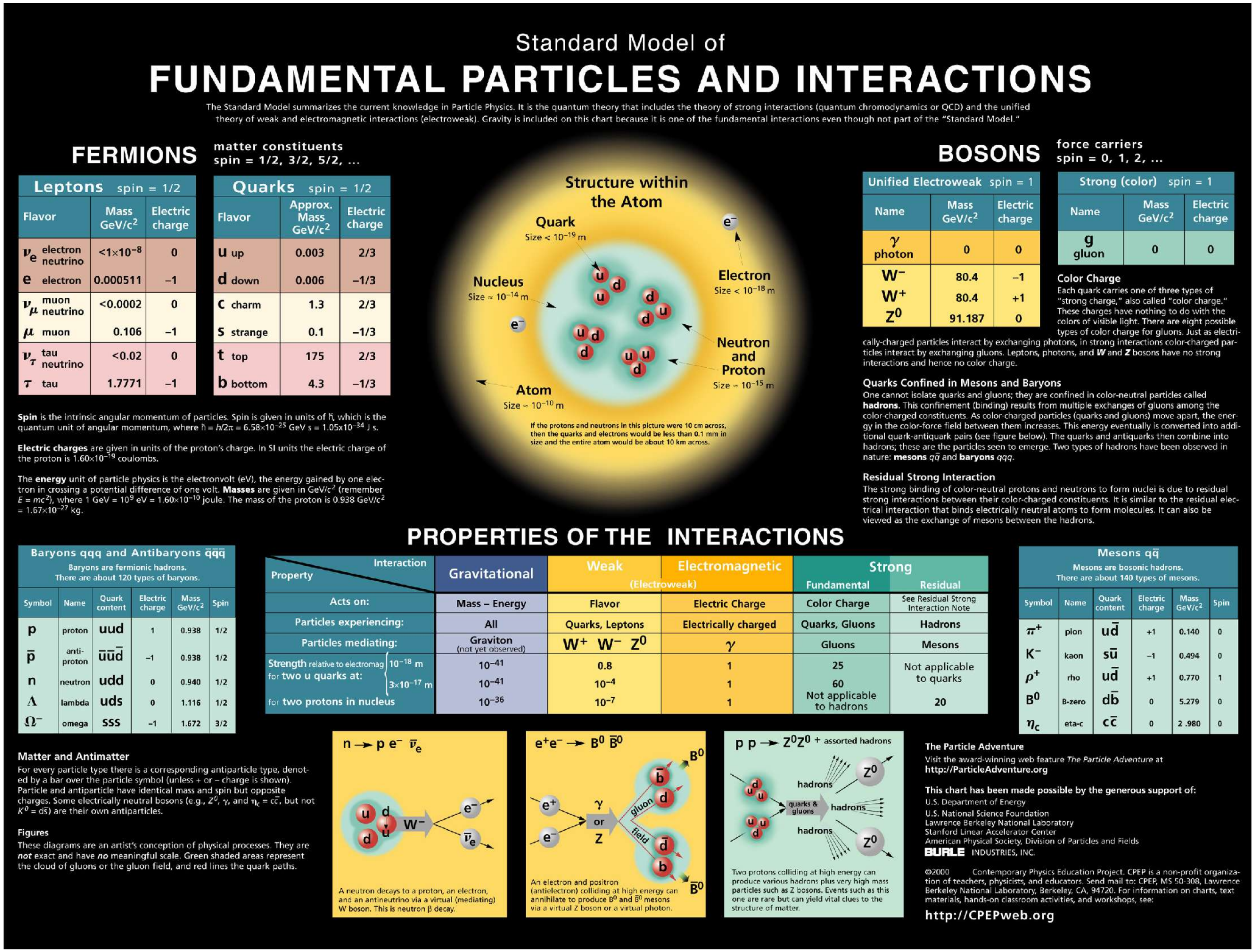
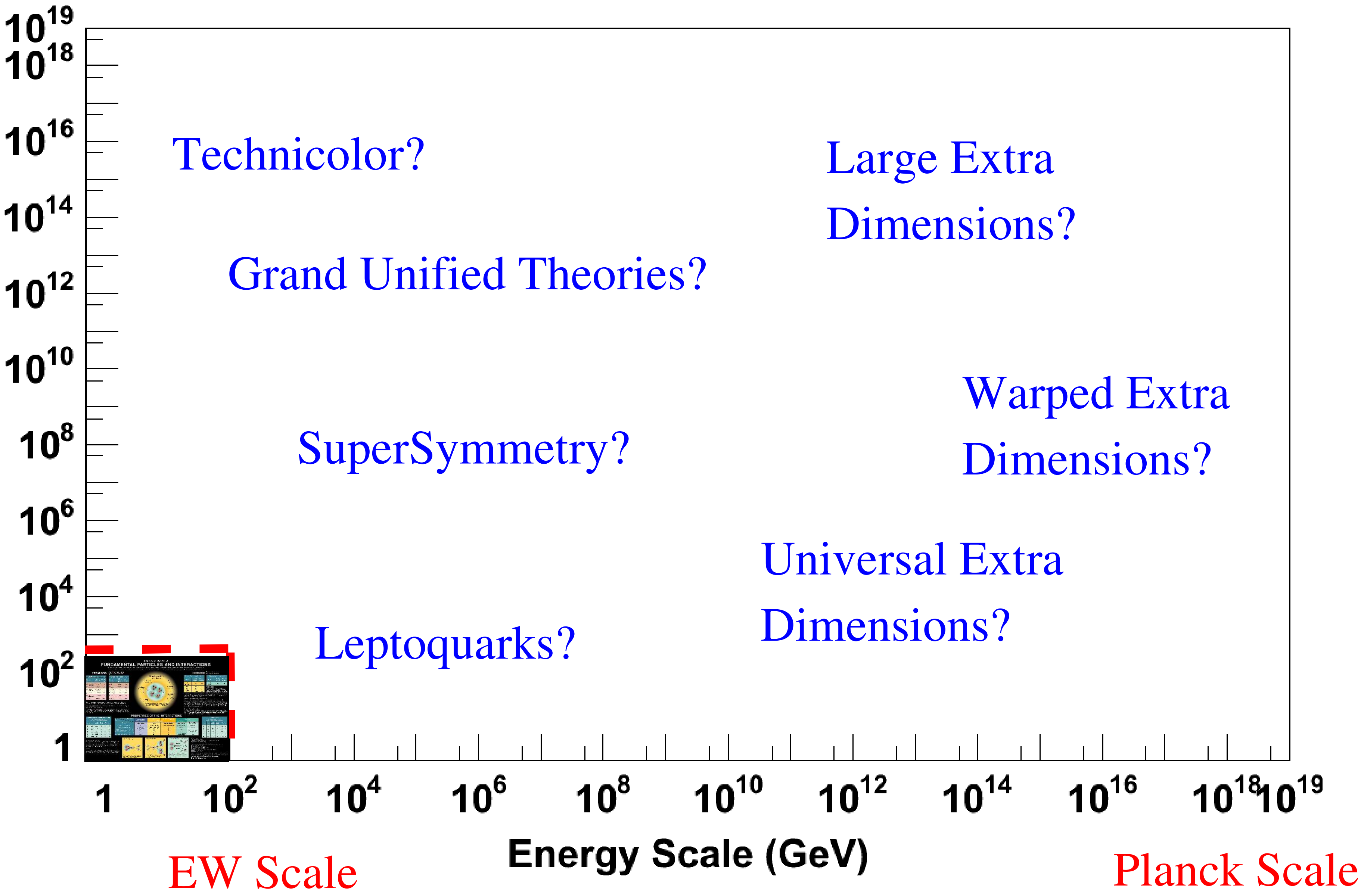
Rise and Fall of the Standard Model?



- Standard Model has been remarkably successful...
- But we do not expect it to describe Nature up to the Planck Scale

From Electroweak to Planck Scale



Searching for Physics Beyond the Standard Model

- How should we search for new physics when we really do not know what to expect?
- **Let the data itself be our guide**
- Perform global search for significant discrepancies between the observed data and the Standard Model prediction
- Make sure we do not miss evidence of new physics because we did not look in the right place!

CDF Global Search Strategy

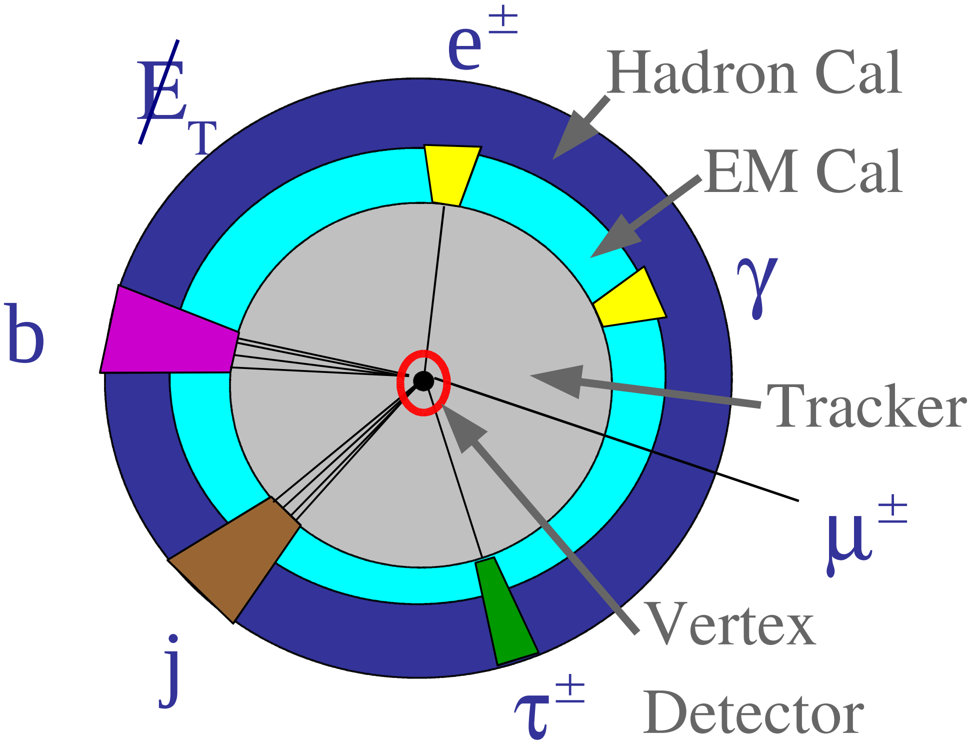
- Generate our best attempt at a global Standard Model prediction; compare to the CDF data
- Then use various algorithms to search for discrepancies:
  - Vista considers the populations of final states and shapes of kinematic distributions
  - Bump Hunter scans mass distributions for resonances
  - Sleuth searches for excesses in the Σp_T tails
- Seek significant (~5σ) discrepancies in the data that may indicate the presence of new physics
  - any observed discrepancy triggers further scrutiny

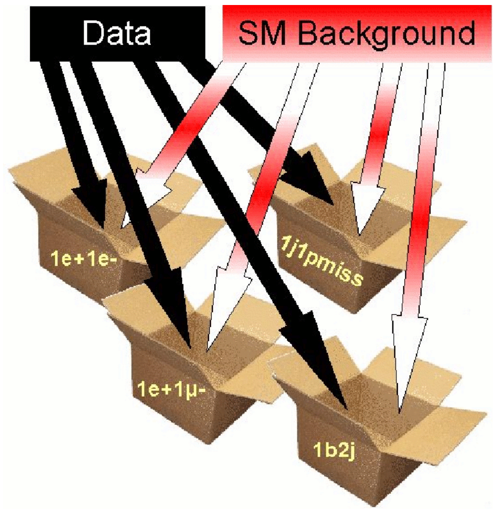
Strengths and Limitations

- Strengths:
  - Model independent
  - Looks in many places (in case Nature surprises us!)
- Limitations:
  - Will not be sensitive to low cross-section new physics that occurs in the bulk
  - Not optimized for any specific model of new physics
  - Some systematic uncertainties are not incorporated
- 1.0 fb^{-1} publication: arXiv:0712.1311, accepted by Phys Rev D

Overview of Vista I

- Identify physics objects
  - $e^{\pm}, \mu^{\pm}, \tau^{\pm}, \gamma$, j, b, $\not{E}_T$
  - require $p_T > 17$ GeV
- Select events
  - require high-p_T lepton, photon, jet triggers
- Partition events into ~400 exclusive final states
  - boxes created if populated by data





Overview of Vista II

- Generate our implementation of Standard Model
  - use HEP event generators: Pythia, Alpgen, MadEvent
  - simulate detector with GEANT-based CDFSim
- Determine correction factors
- Perform Vista global comparison
- Look for discrepancies in bulk of data

The Vista Correction Model

- To obtain true Standard Model prediction, some parameters must be obtained from the data itself
- Theoretical k-factors for cross-sections of SM processes:
  - QCD multi-jets; W, Z + jets; photon+jets
- Experimental probabilities for reconstructing objects with the CDF detector
  - e.g. electron efficiency; rate for quark to 'fake' a photon etc...
- Trigger efficiencies
- 43 correction factors used in total

Determining the Correction Factors

- Obtain values (and errors) for correction factors by fitting to the observed data

$$\chi^2(\vec{s}) = \left(\sum_{k \in \text{bins}} \chi_k^2(\vec{s}) \right) + \chi^2_{\text{constraints}}(\vec{s})$$

$$\chi_k^2(\vec{s}) = \frac{(\text{Data}[k] - \text{SM}[k])^2}{\delta \text{SM}[k]^2 + \sqrt{\text{SM}[k]}^2}$$

- Fit seeks to maximize global agreement between our Standard Model implementation and the data
- Available external information is used to constrain ~40% of the correction factors
  - e.g. constraints on k-factors from higher-order calculations

Is This A Blind Analysis?

- No. We started with a crude correction model, and refined it after looking to see where it failed to describe the data
- The development of the correction model and associated debugging is not an automated process
- Refining the correction model requires judgement, and all adjustments must be physically motivated
- This process ends when either:
  - a clear case for new physics can be made
  - or there remain no discrepancies that motivate a case for new physics

Vista Global Comparison

- 399 exclusive final states considered
- Data compared to SM events in each final state
- Evaluation of statistical discrepancy accounts for trials factor
- Systematic uncertainties not included

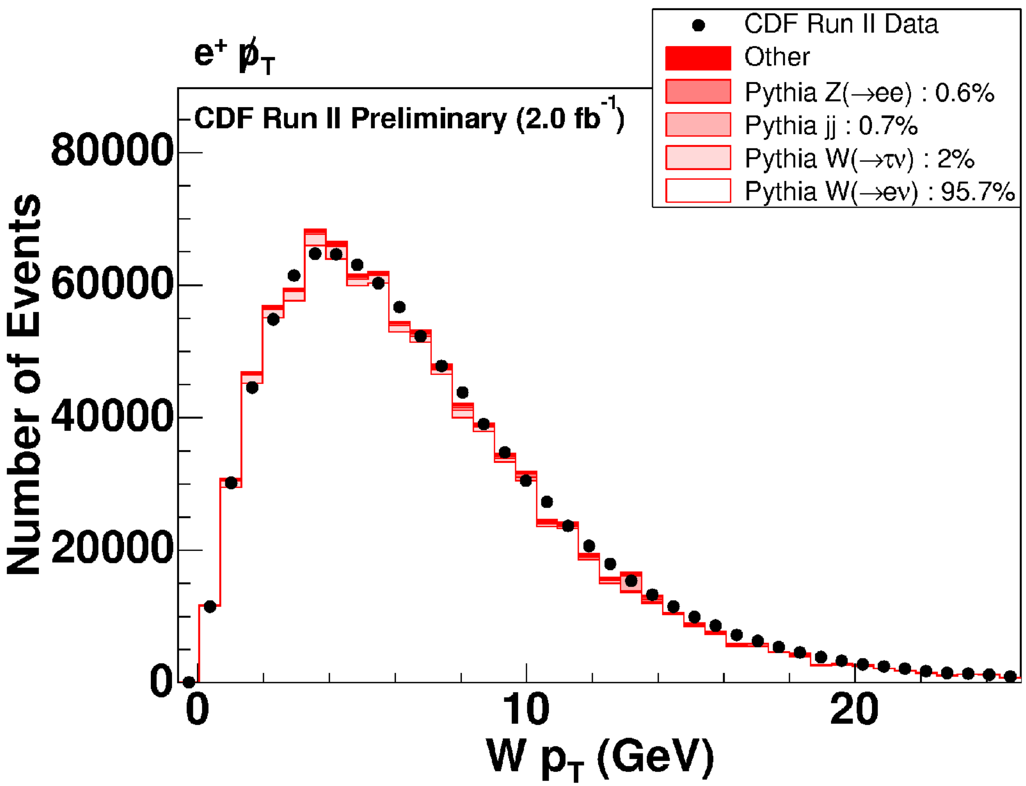
CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

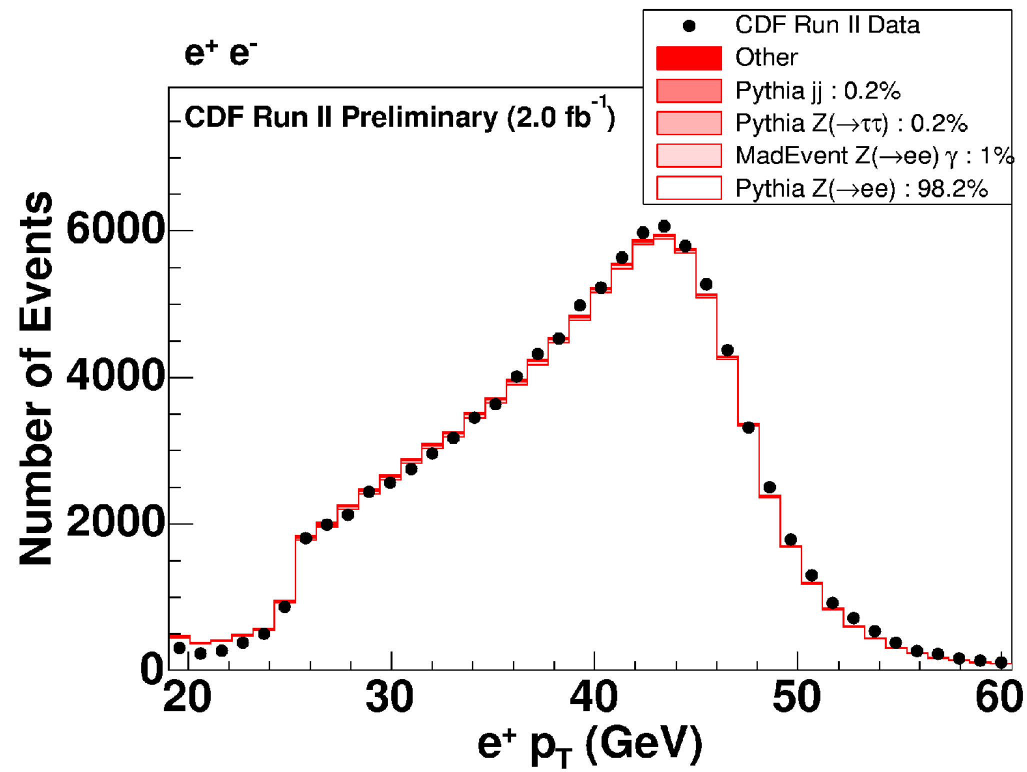
Final State	Data	Background
b$e^{\pm}\not{p}$	690	817.7 ± 9.2
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8
b2j$\not{p}$ high-Σp_T	255	327.2 ± 8.9
2j$\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6
3j$\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2
$e^{\pm}\not{p}\tau^{\pm}$	36	17.2 ± 1.7
2j$\tau^{\pm}\tau^{\mp}$	33	62.1 ± 4.3
$e^{\pm}$j	741710	764832 ± 6447.2
j2$\tau^{\pm}$	105	150.8 ± 6.3
$e^{\pm}$2j	256946	249148 ± 2201.5
2bj low-Σp_T	279	352.5 ± 11.9
j$\tau^{\pm}$ low-Σp_T	1385	1525.8 ± 15
2b2j low-Σp_T	108	153.5 ± 6.8
b$\mu^{\pm}\not{p}$	528	613.5 ± 8.7
$\mu^{\pm}\gamma\not{p}$	523	611 ± 12.1
2bγ	108	70.5 ± 7.9
8j	14	13.1 ± 4.4
7j	103	97.8 ± 12.2
6j	653	659.7 ± 37.3
5j	3157	3178.7 ± 67.1
4j high-Σp_T	88546	89096.6 ± 935.2
4j low-Σp_T	14872	14809.6 ± 186.3
4j2γ	46	46.4 ± 3.9
4j$\tau^{\pm}$ high-Σp_T	29	26.6 ± 1.7
4j$\tau^{\pm}$ low-Σp_T	43	63.1 ± 3.3
4j$\not{p}$ high-Σp_T	1064	1012 ± 62.9
4j$\gamma\tau^{\pm}$	19	10.8 ± 2
4j$\gamma\not{p}$	62	104.2 ± 22.4
4jγ	7962	8271.2 ± 245.1
4j$\mu^{\pm}\not{p}$	574	590.5 ± 13.6
4j$\mu^{\pm}\mu^{\mp}$	38	48.4 ± 6.2
4j$\mu^{\pm}$	1363	1350.1 ± 37.7
3j high-Σp_T	159926	159143 ± 1061.9
3j low-Σp_T	62681	64213.1 ± 496
3j2γ	151	177.5 ± 7.1
3j$\tau^{\pm}$ high-Σp_T	68	76.9 ± 3
3j$\not{p}$ high-Σp_T	1706	1899.4 ± 77.6
3j$\not{p}$ low-Σp_T	42	36.2 ± 5.7
3j$\gamma\tau^{\pm}$	39	37.8 ± 3.6
3j$\gamma\not{p}$	204	249.8 ± 24.4
3jγ	24639	24899.4 ± 372.4
3j$\mu^{\pm}\not{p}$	2884	2971.5 ± 52.1
3j$\mu^{\pm}\gamma\not{p}$	10	3.6 ± 1.9
3j$\mu^{\pm}\gamma$	15	7.9 ± 2.9
3j$\mu^{\pm}\mu^{\mp}$	175	177.8 ± 16.2
3j$\mu^{\pm}$	5032	4989.5 ± 108.9
3b2j	23	28.9 ± 4.7
3bj	82	82.6 ± 5.7
3b	67	85.6 ± 7.7
2$\tau^{\pm}$	498	512.7 ± 14.2
2$\gamma\not{p}$	128	107.2 ± 6.9
2γ	5548	5562.8 ± 40.5
2j high-Σp_T	190773	190842 ± 781.2
2j low-Σp_T	165984	162530 ± 1581
2j2$\tau^{\pm}$	22	40.6 ± 3.2
2j2$\gamma\not{p}$	11	8 ± 2.4
2j2γ	580	581 ± 13.7
2j$\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3

Final State	Data	Background
2j$\not{p}$ high-Σp_T	87	80.9 ± 6.8
2j$\not{p}$ low-Σp_T	114	79.5 ± 100.8
2j$\not{p}\tau^{\pm}$	18	13.2 ± 2.2
2j$\gamma\tau^{\pm}$	142	144.6 ± 5.7
2j$\gamma\not{p}$	908	980.3 ± 63.7
2jγ	71364	73021.4 ± 595.9
2j$\mu^{\pm}\tau^{\mp}$	16	19.3 ± 2.2
2j$\mu^{\pm}\not{p}$	17927	18340.6 ± 201.9
2j$\mu^{\pm}\gamma\not{p}$	31	27.7 ± 7.7
2j$\mu^{\pm}\gamma$	57	58.2 ± 13
2j$\mu^{\pm}\mu^{\mp}\not{p}$	11	7.8 ± 2.7
2j$\mu^{\pm}\mu^{\mp}$	956	924.9 ± 61.2
2j$\mu^{\pm}$	22461	23111.4 ± 366.6
2$e^{\pm}$j	14	13.8 ± 2.3
2$e^{\pm}e^{\mp}$	20	17.5 ± 1.7
2$e^{\pm}$	32	49.2 ± 3.4
2b high-Σp_T	666	689 ± 9.4
2b low-Σp_T	323	313.2 ± 10.3
2b3j low-Σp_T	53	57.4 ± 6.5
2b2j high-Σp_T	718	803.3 ± 12.7
2b2j$\not{p}$ high-Σp_T	15	21.8 ± 2.8
2b2jγ	32	39.7 ± 6.2
2b2j$\mu^{\pm}\not{p}$	14	17.3 ± 1.9
2b2j$\mu^{\pm}$	22	21.8 ± 2
2b$\mu^{\pm}\not{p}$	11	14.4 ± 2.1
2bj high-Σp_T	891	967.1 ± 13.2
2bj$\not{p}$ high-Σp_T	25	31.3 ± 3.1
2bjγ	71	54.5 ± 7.1
2bj$\mu^{\pm}\not{p}$	12	10.7 ± 1.9
2b$e^{\pm}$2j$\not{p}$	30	27.3 ± 2.2
2b$e^{\pm}$2j	72	66.5 ± 2.9
2b$e^{\pm}\not{p}$	22	19.1 ± 2.2
2b$e^{\pm}$j$\not{p}$	19	19.4 ± 2.2
2b$e^{\pm}$j	63	63 ± 3.4
2b$e^{\pm}$	96	92.1 ± 4.1
$\tau^{\pm}\tau^{\mp}$	856	872.5 ± 19
$\gamma\not{p}$	3793	3770.7 ± 127.3
$\mu^{\pm}\tau^{\mp}$	381	440.9 ± 7.3
$\mu^{\pm}\not{p}\tau^{\mp}$	60	75.7 ± 3.4
$\mu^{\pm}\not{p}\tau^{\pm}$	15	12 ± 2
$\mu^{\pm}\not{p}$	734290	734296 ± 4897.
$\mu^{\pm}\gamma$	475	469.8 ± 12.5
$\mu^{\pm}\mu^{\mp}\not{p}$	169	198.5 ± 8.2
$\mu^{\pm}\mu^{\mp}\gamma$	83	60 ± 3.1
$\mu^{\pm}\mu^{\mp}$	25283	25178.5 ± 86.5
j2$\gamma\not{p}$	36	30.4 ± 4.2
j2γ	1822	1813.2 ± 27.4
j$\tau^{\pm}$ high-Σp_T	52	56.2 ± 2.5
j$\tau^{\pm}\tau^{\mp}$	203	252.2 ± 8.7
j$\not{p}$ high-Σp_T	4432	4431.7 ± 45.2
j$\gamma\tau^{\pm}$	526	476 ± 9.3
j$\gamma\not{p}$	1882	1791.9 ± 72.3
jγ	103319	102124 ± 570.6
j$\mu^{\pm}\tau^{\mp}$	71	98 ± 3.9
j$\mu^{\pm}\tau^{\pm}$	15	12 ± 2
j$\mu^{\pm}\not{p}\tau^{\mp}$	26	30.8 ± 2.6
j$\mu^{\pm}\not{p}$	109081	108323 ± 707.7
j$\mu^{\pm}\gamma\not{p}$	171	171.1 ± 31
j$\mu^{\pm}\gamma$	152	190 ± 39.3

Final State	Data	Background
j$\mu^{\pm}\mu^{\mp}\not{p}$	32	32.2 ± 10.9
j$\mu^{\pm}\mu^{\mp}\gamma$	14	11.5 ± 2.6
j$\mu^{\pm}\mu^{\mp}$	4852	4271.2 ± 185.4
j$\mu^{\pm}$	77689	76987.5 ± 930.2
$e^{\pm}$4j$\not{p}$	903	830.6 ± 13.2
$e^{\pm}$4jγ	25	29.2 ± 3.6
$e^{\pm}$4j	15750	16740.4 ± 390.5
$e^{\pm}$3j$\tau^{\mp}$	15	21.1 ± 2.2
$e^{\pm}$3j$\not{p}$	4054	4077.2 ± 63.6
$e^{\pm}$3jγ	108	79.3 ± 5
$e^{\pm}$3j	60725	60409.3 ± 723.3
$e^{\pm}$2γ	41	34.2 ± 2.6
$e^{\pm}$2j$\tau^{\pm}$	37	47.2 ± 2.2
$e^{\pm}$2j$\tau^{\mp}$	109	95.9 ± 6.8
$e^{\pm}$2j$\not{p}$	25725	25403.1 ± 209.4
$e^{\pm}$2j$\gamma\not{p}$	30	31.8 ± 4.8
$e^{\pm}$2jγ	398	342.8 ± 15.7
$e^{\pm}$2j$\mu^{\mp}\not{p}$	22	14.8 ± 1.9
$e^{\pm}$2j$\mu^{\mp}$	23	15.8 ± 2
$e^{\pm}\tau^{\pm}$	437	387 ± 5.3
$e^{\pm}\tau^{\mp}$	1333	1266 ± 12.3
$e^{\pm}\not{p}\tau^{\mp}$	109	106.1 ± 2.7
$e^{\pm}\not{p}$	960826	956579 ± 3077.7
$e^{\pm}\gamma\not{p}$	497	496.8 ± 10.3
$e^{\pm}\gamma$	3578	3589.9 ± 24.1
$e^{\pm}\mu^{\pm}\not{p}$	31	29.9 ± 1.6
$e^{\pm}\mu^{\mp}\not{p}$	109	99.4 ± 2.4
$e^{\pm}\mu^{\pm}$	45	28.5 ± 1.8
$e^{\pm}\mu^{\mp}$	350	313 ± 5.4
$e^{\pm}$j2γ	13	16.1 ± 3.9
$e^{\pm}$j$\tau^{\mp}$	386	418 ± 18.9
$e^{\pm}$j$\tau^{\pm}$	160	162.8 ± 3.5
$e^{\pm}$j$\not{p}\tau^{\mp}$	48	44.6 ± 3.3
$e^{\pm}$j$\not{p}\tau^{\pm}$	11	8.3 ± 1.5
$e^{\pm}$j$\not{p}$	121431	121023 ± 747.6
$e^{\pm}$j$\gamma\not{p}$	159	192.6 ± 10.9
$e^{\pm}$jγ	1389	1368.9 ± 38.9
$e^{\pm}$j$\mu^{\mp}\not{p}$	42	33 ± 2.9
$e^{\pm}$j$\mu^{\pm}\not{p}$	16	9.2 ± 1.9
$e^{\pm}$j$\mu^{\mp}$	62	63.8 ± 3.2
$e^{\pm}$j$\mu^{\pm}$	13	8.2 ± 2
$e^{\pm}e^{\mp}$4j	148	159.1 ± 7
$e^{\pm}e^{\mp}$3j	717	743.6 ± 24.4
$e^{\pm}e^{\mp}$2j$\not{p}$	32	41.4 ± 5.6
$e^{\pm}e^{\mp}$2jγ	10	11.4 ± 2.9
$e^{\pm}e^{\mp}$2j	3638	3566.8 ± 72
$e^{\pm}e^{\mp}\tau^{\pm}$	18	16.1 ± 1.7
$e^{\pm}e^{\mp}\not{p}$	822	831.8 ± 13.6
$e^{\pm}e^{\mp}\gamma$	191	221.9 ± 5.1
$e^{\pm}e^{\mp}$j$\not{p}$	155	170.8 ± 12.4
$e^{\pm}e^{\mp}$jγ	48	45 ± 3.9
$e^{\pm}e^{\mp}$j	17903	18258.2 ± 204.4
$e^{\pm}e^{\mp}$	98901	99086.9 ± 147.8
b6j	51	42.3 ± 3.8
b5j	237	192.5 ± 7.1
b4j high-Σp_T	26	23.4 ± 2.6
b4j low-Σp_T	836	821.7 ± 15.9
b3j high-Σp_T	12081	12071 ± 84.1
b3j low-Σp_T	2974	2873 ± 31

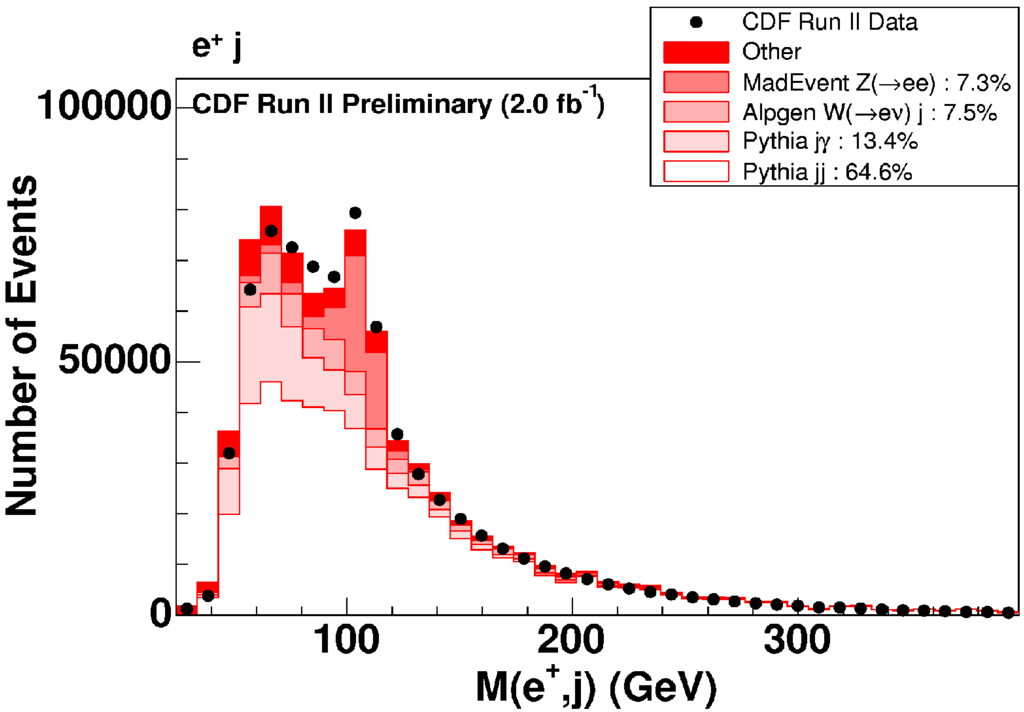
Vista Examples: W & Z Production

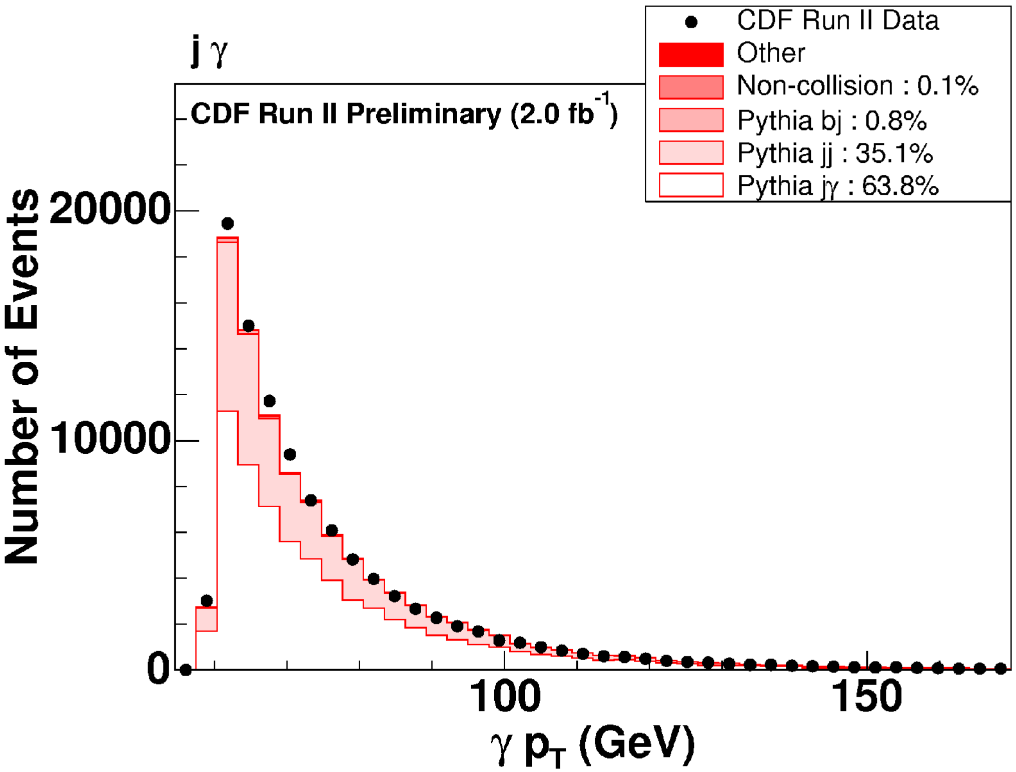




- W & Z k-factors well-constrained from NNLO calculations
- Act as constraints on luminosity of data sample

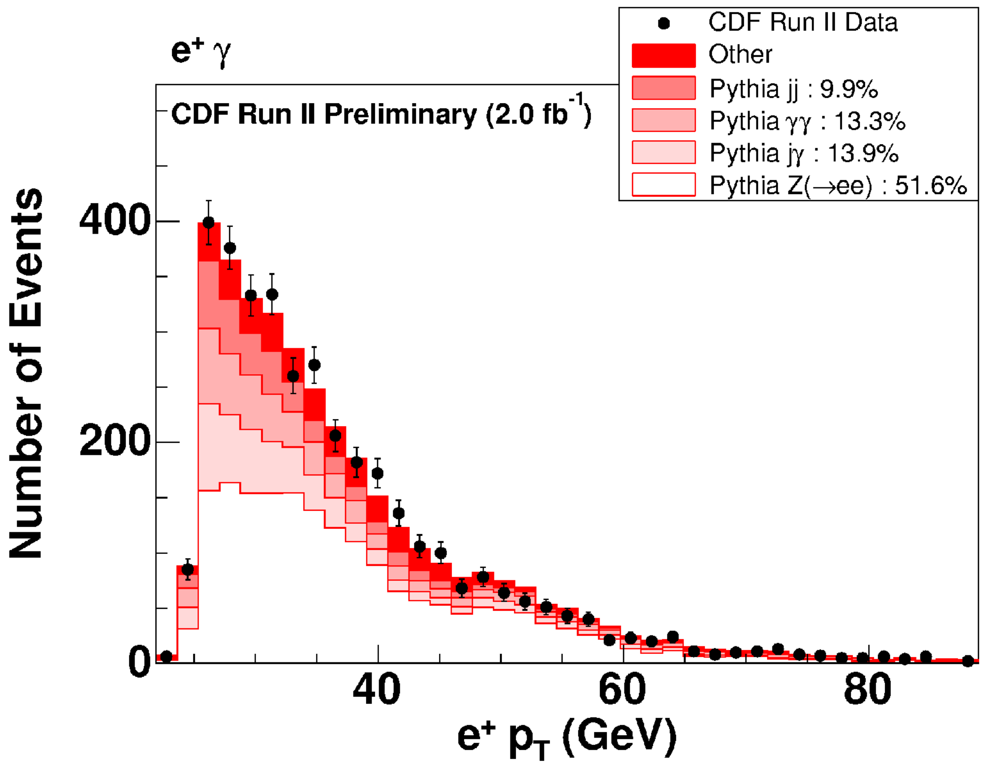
Vista Examples: Determining Fake Rates

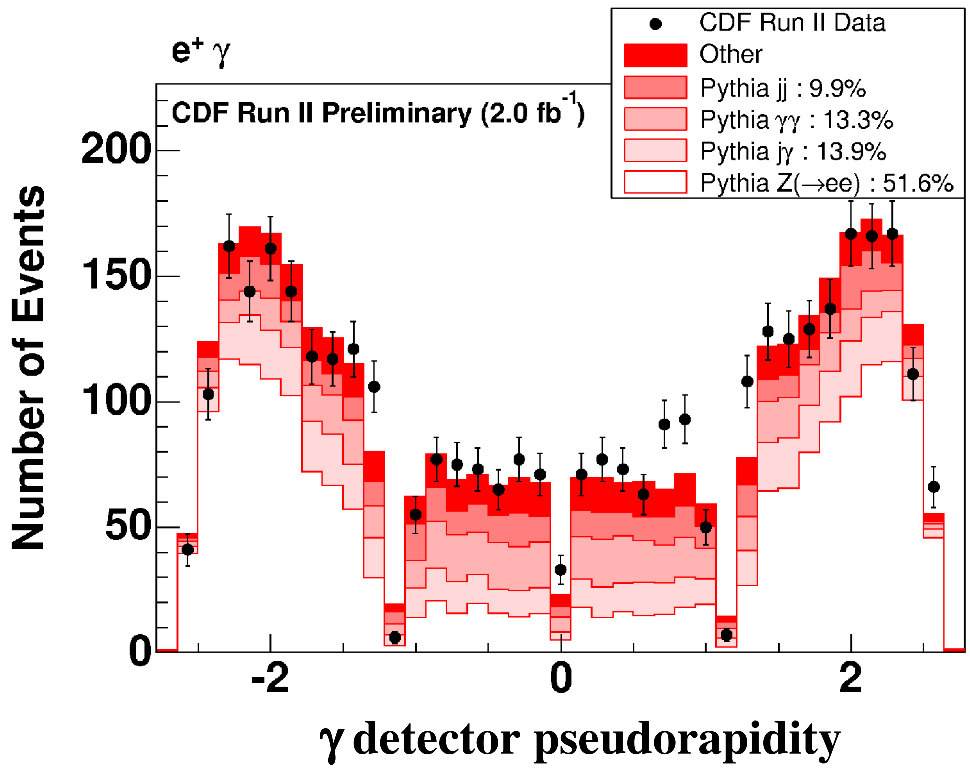




- Electron-jet final state:
  - mainly jets faking electrons
  - also peak ~ M_Z, where electron misreconstructed as a jet
- Photon-jet final state:
  - real SM photon+jet events
  - plus QCD dijets with jet faking photon

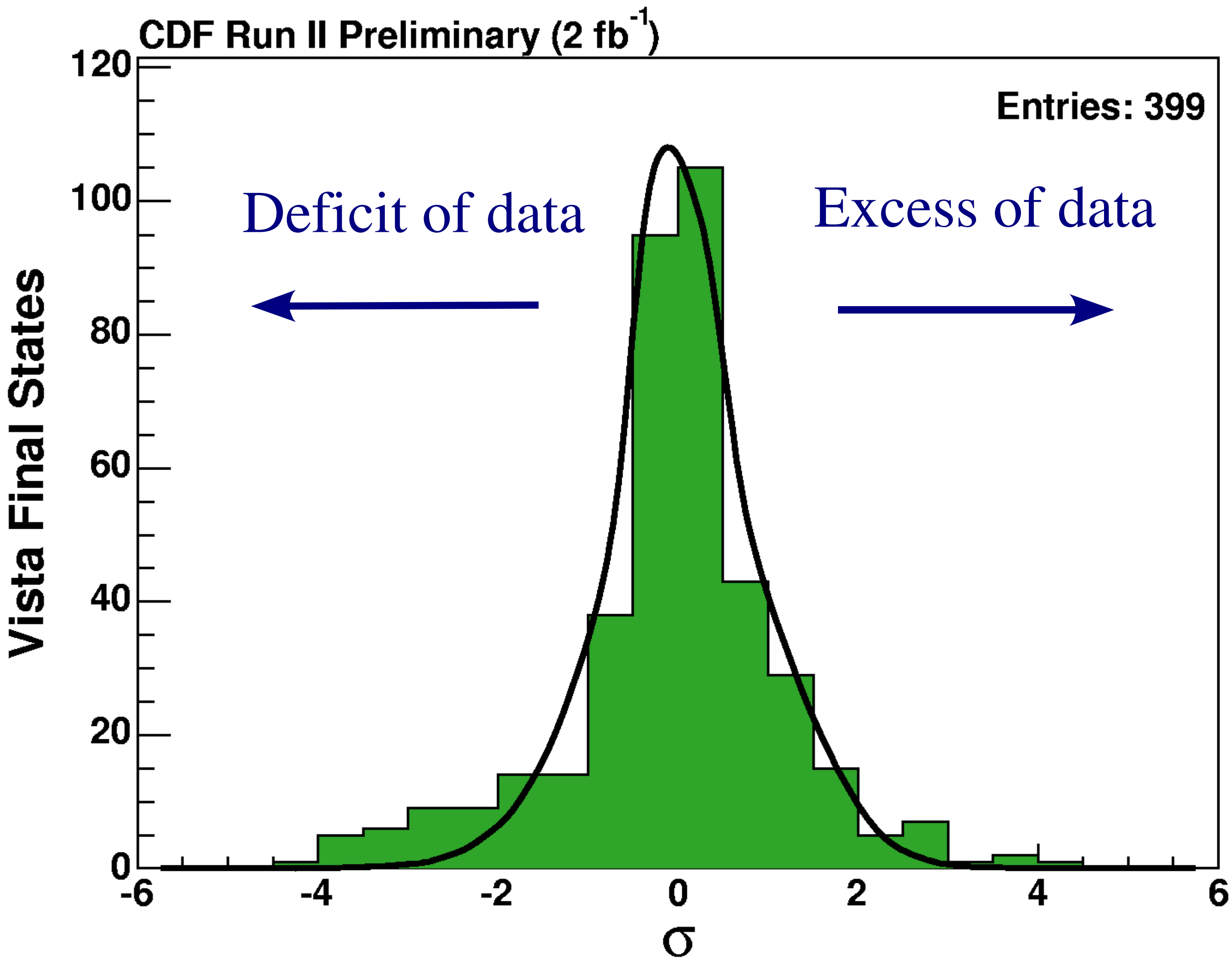
Vista: Studying Fake Rates





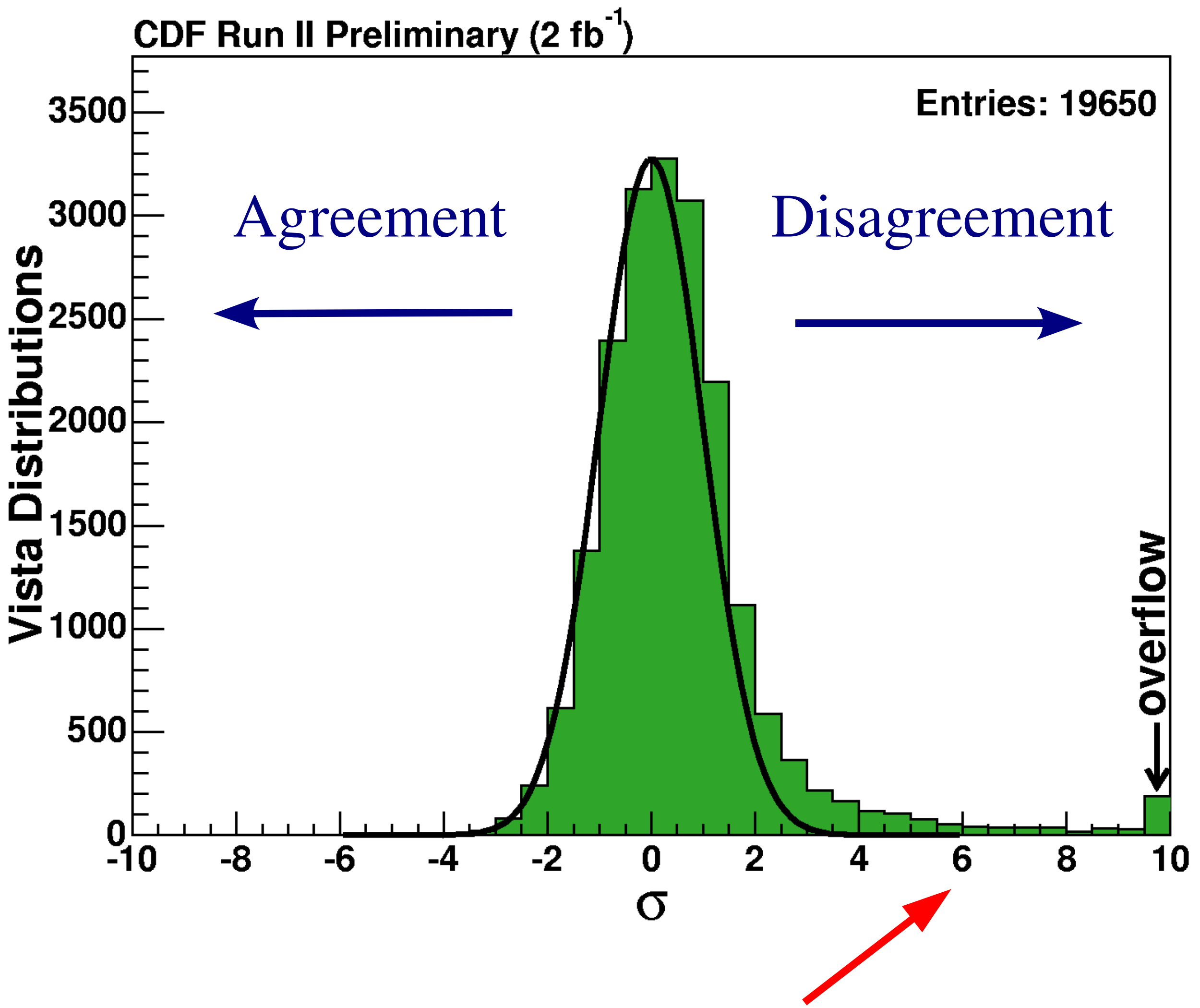
- Electron+photon final state is good test, because many fake processes contribute:
  - electron faking photon
  - jet faking electron
  - photon faking electron
  - jet faking photon

Vista Final State Populations Summary



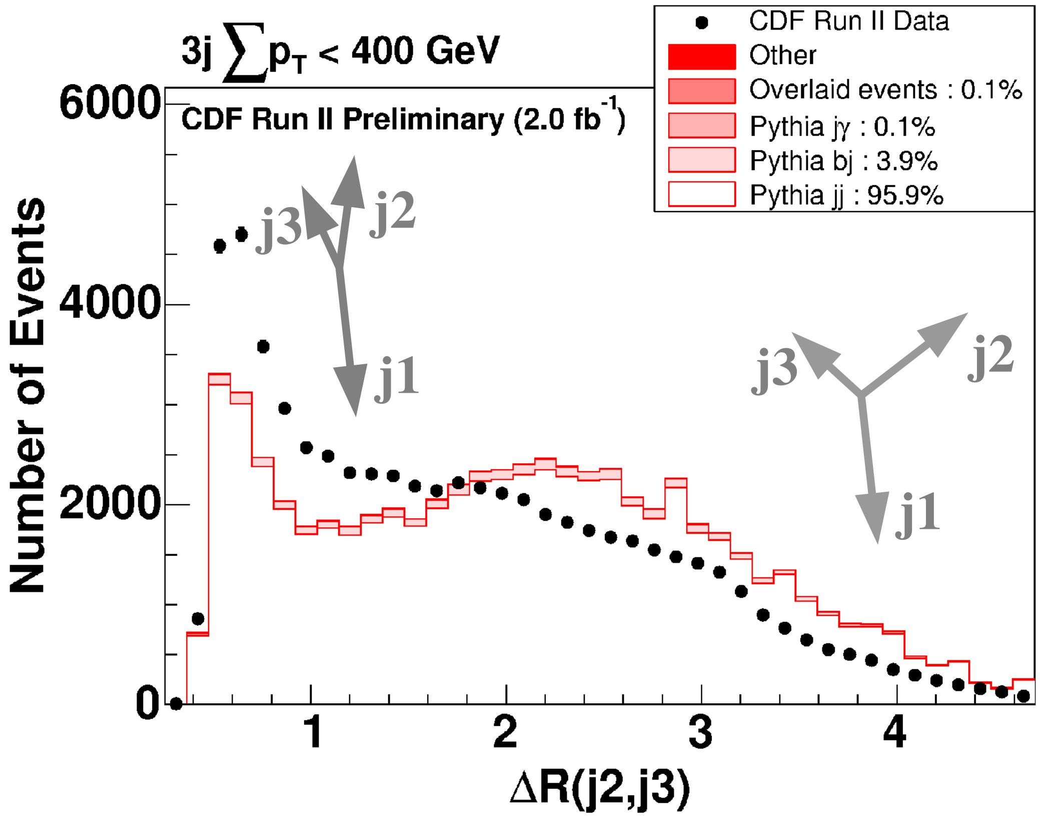
No final state exhibits a significant population discrepancy, after accounting for the trials factor

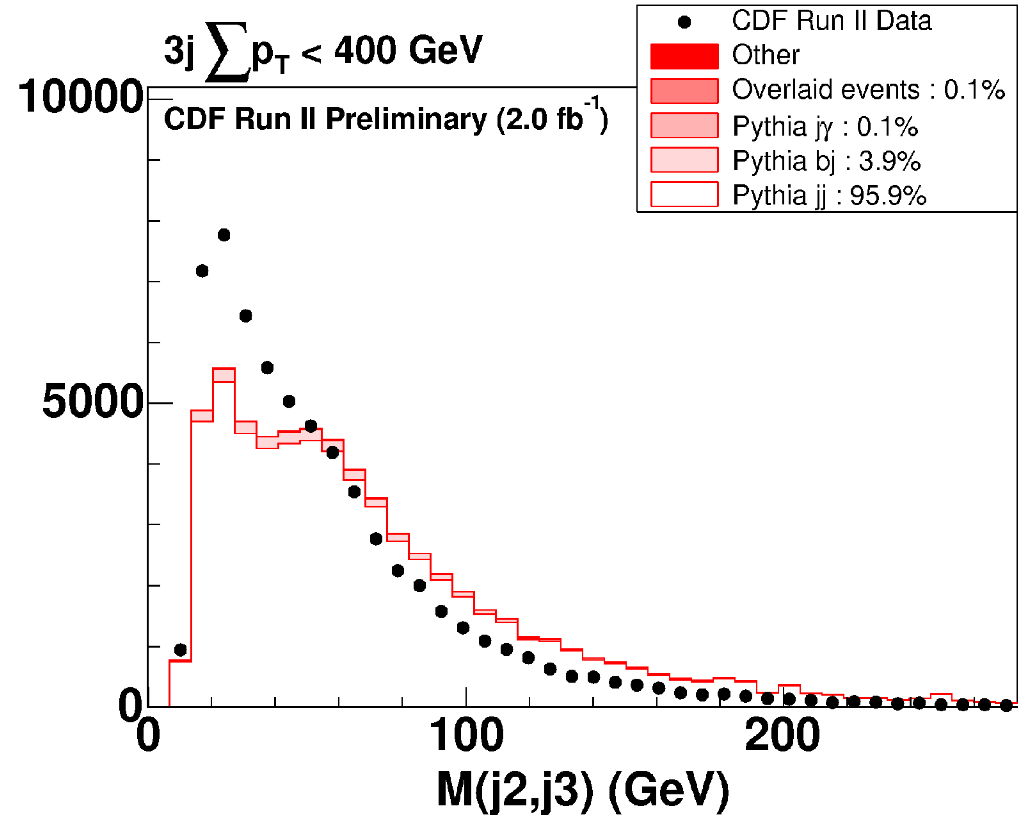
Vista Shapes Summary



Interest is focused on these 559 shapes
that show significant discrepancy

Vista Shape Discrepancies

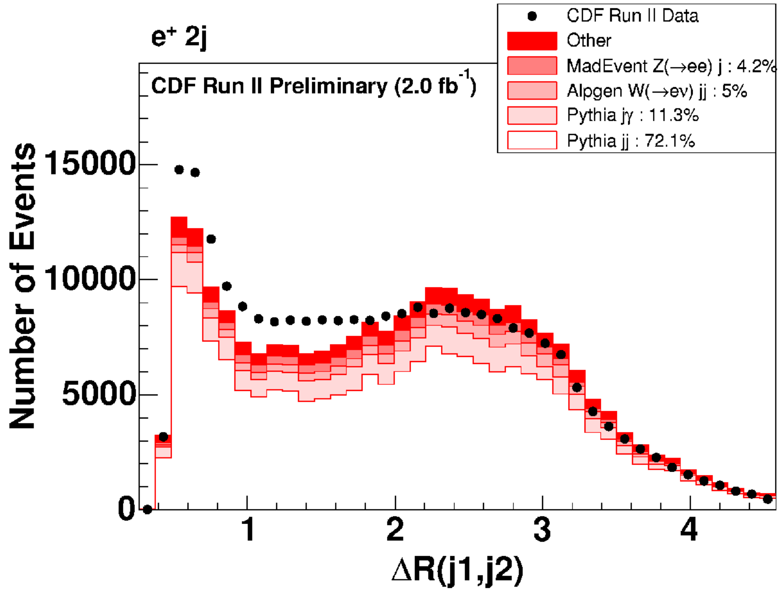


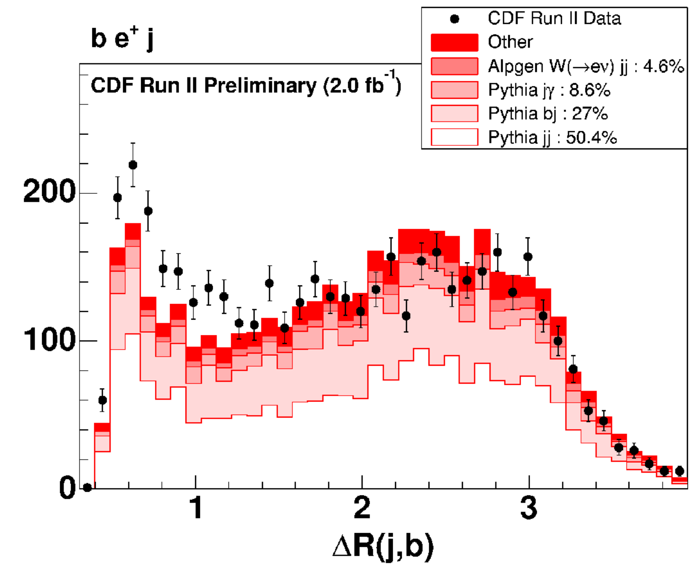


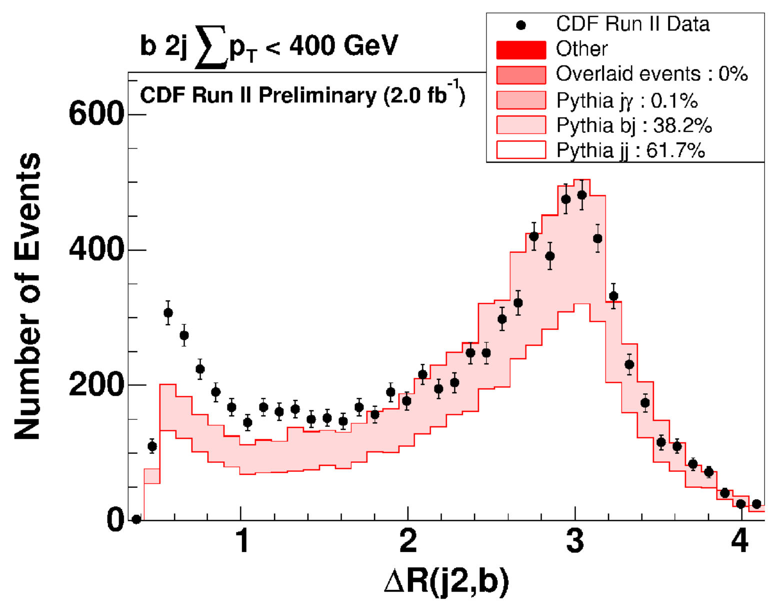
- Observe difficulty in modelling soft QCD jet emission

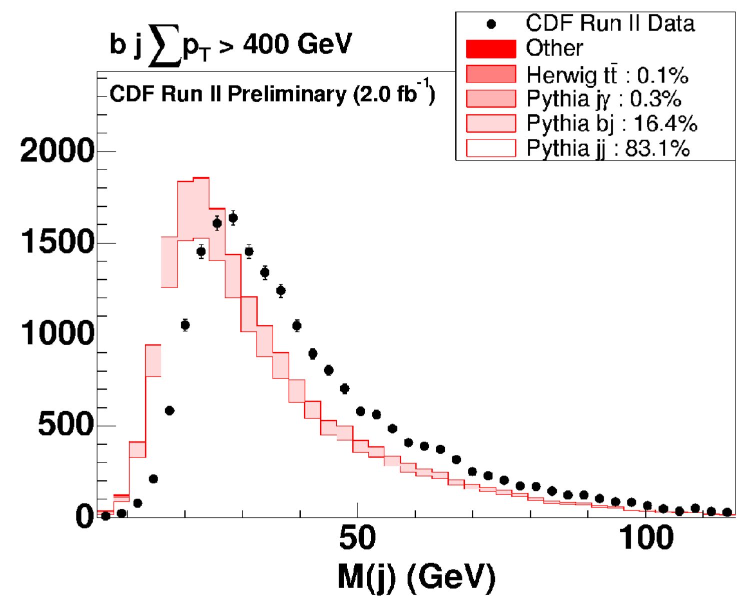
Same Discrepancy in Many Final States

- Same underlying discrepancy manifest in many related final states
  - bjj, ejj, bej, etc…









Summary of Vista

- Vista attempts to understand bulk features of high-p_T collider data in terms of the Standard Model
- Identify objects, select and partition events, implement Standard Model prediction; novel approach to determine correction factors
- Perform global comparison of Standard Model to data:
  - reasonable description obtained
  - some discrepancies remain in kinematic variable distributions
  - none motivate a new physics claim

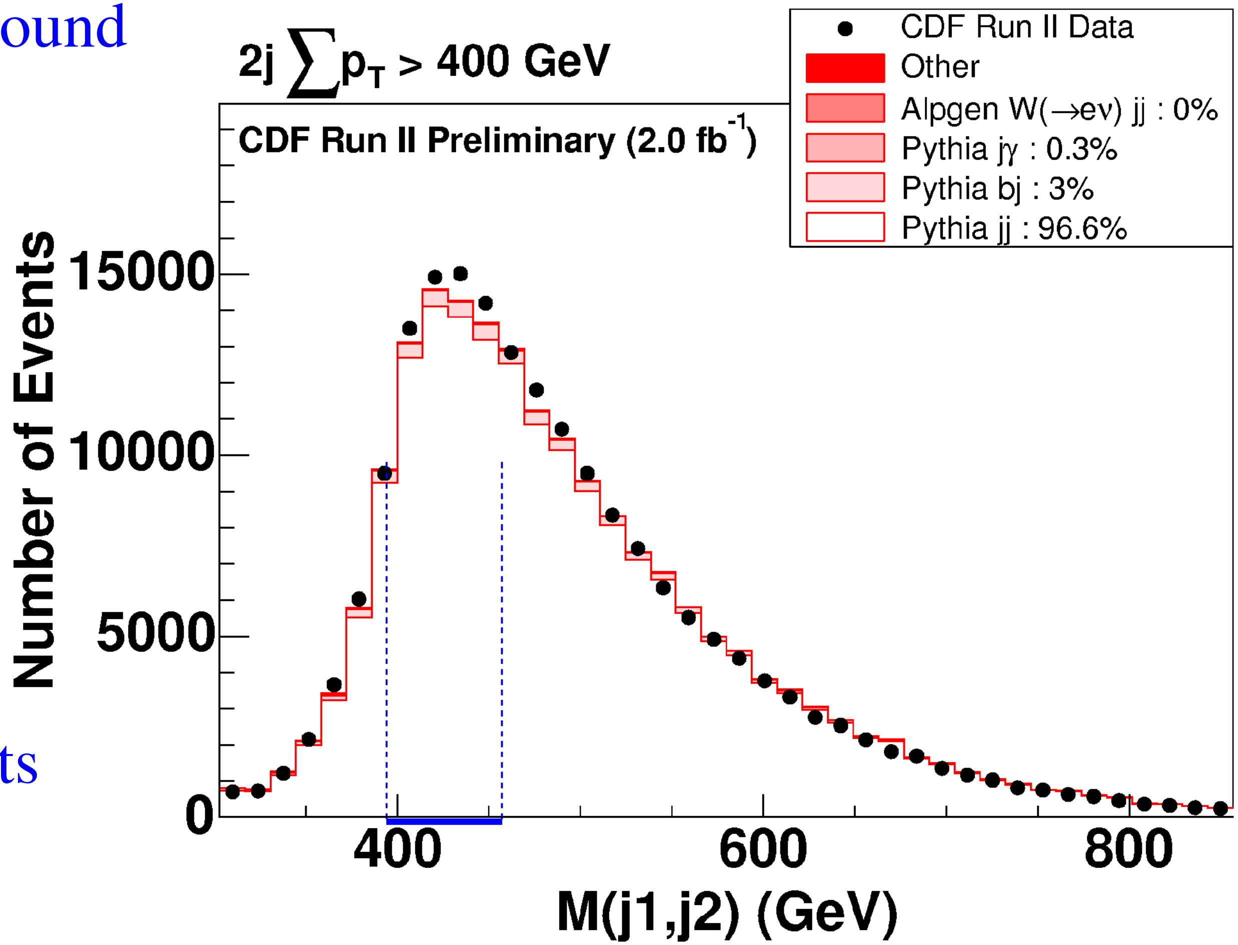
From Vista to the Bump Hunter and Sleuth

- Understand bulk of high-p_T data – Vista
- Generate a good global SM prediction

- Then focus on search for new physics:
  - Bump Hunter
  - Sleuth

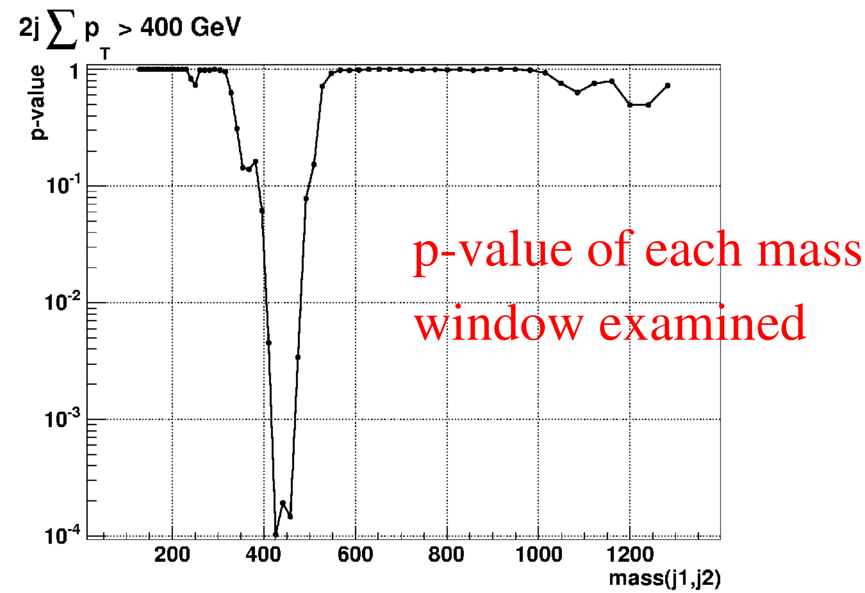
Bump Hunter

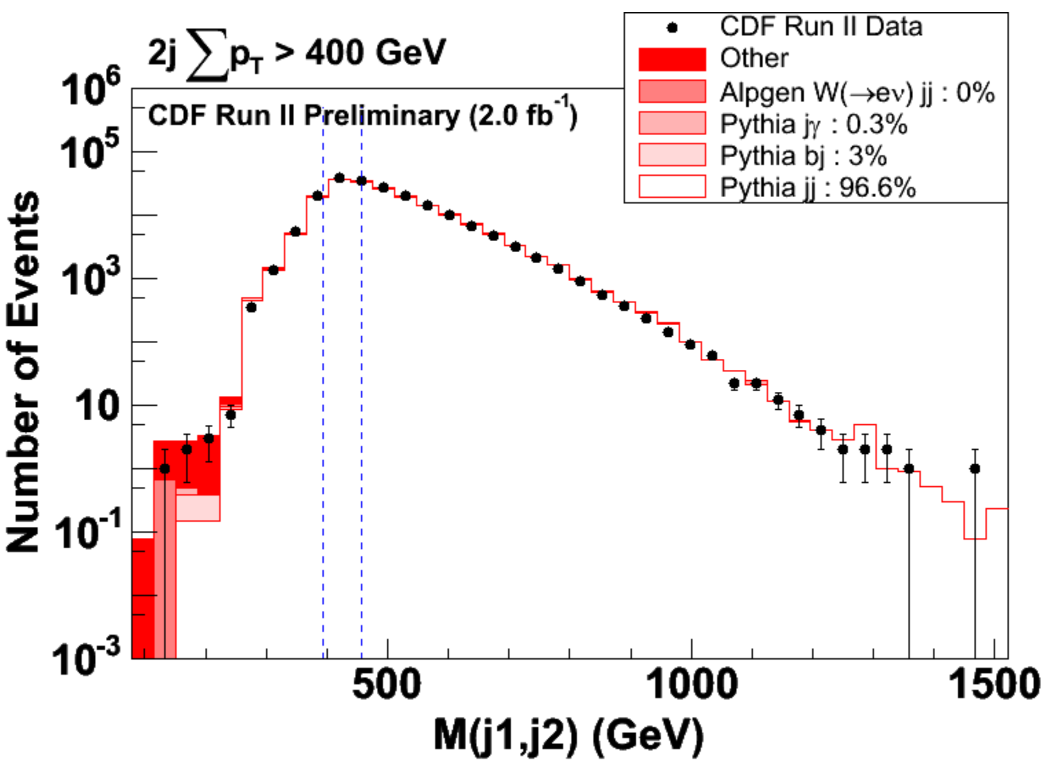
- Search for narrow resonances in invariant masses
- Define a search window of 2ΔM (ΔM = expected detector mass resolution)
- Compare data to SM background
- Define a possible 'bump':
  - at least 5 data events
  - verify that 'side-bands' agree better than center
- Estimate significance of bumps by pseudo-experiments

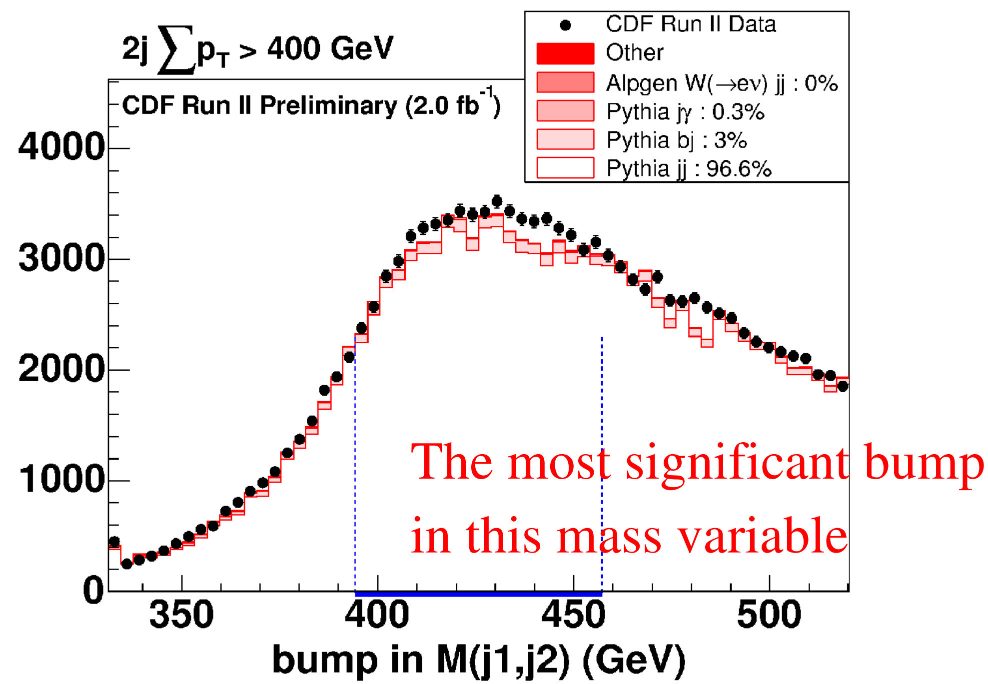


Bump Hunter Study: Dijets

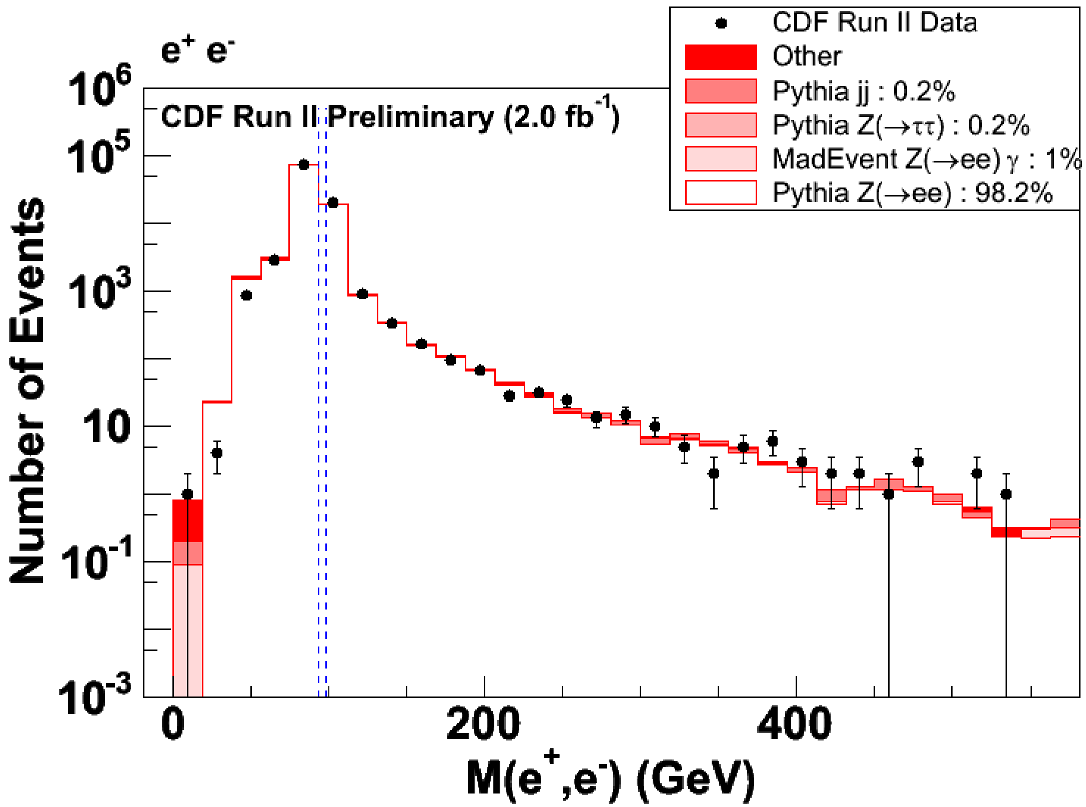
- Results of Bump Hunter scanning the dijet invariant mass distribution
- No significant bumps found here

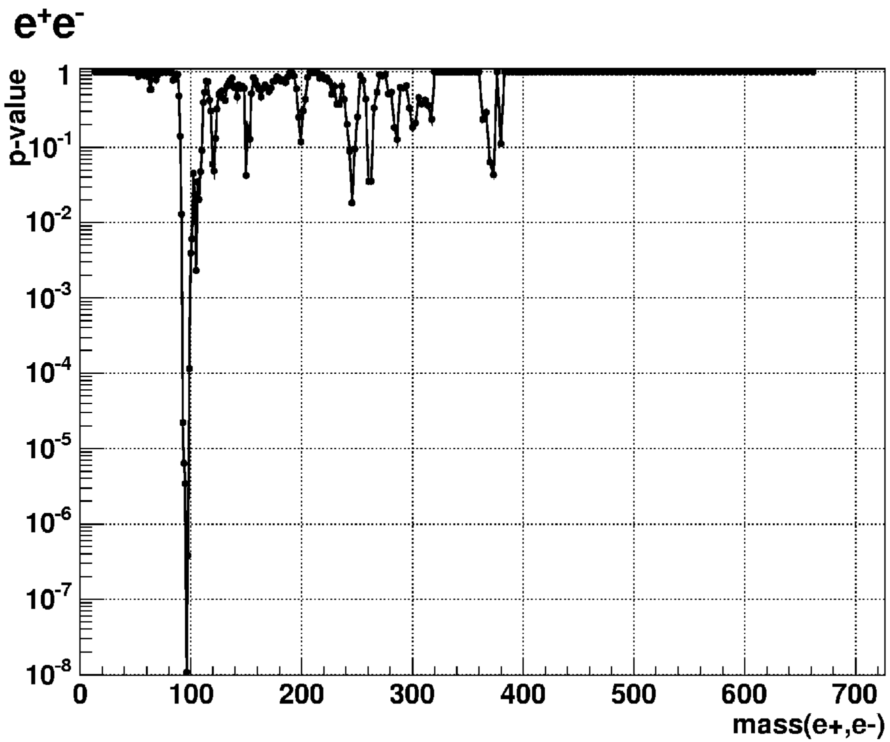






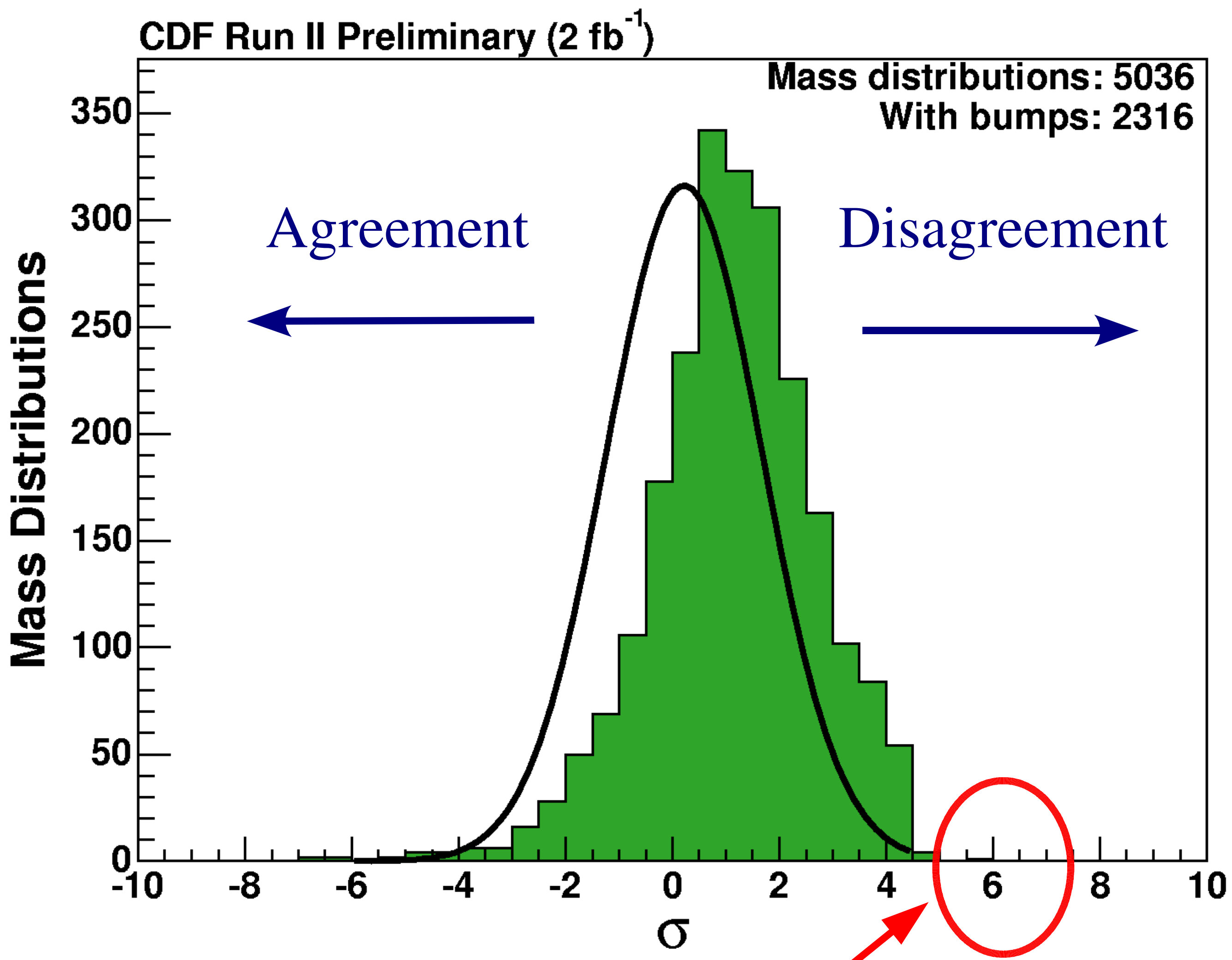
Bump Hunter Study: Di-electrons





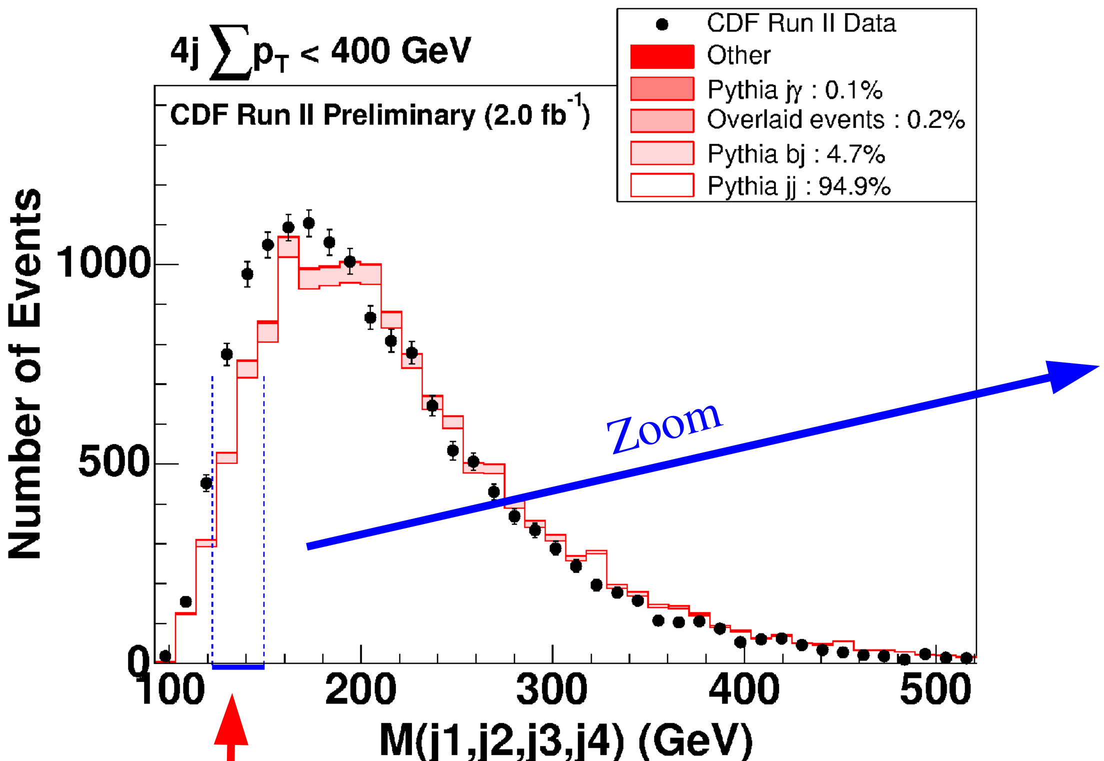
- Results of Bump Hunter scanning the di-electron invariant mass distribution
- Z-peak could be better tuned, but otherwise no significant bumps found here

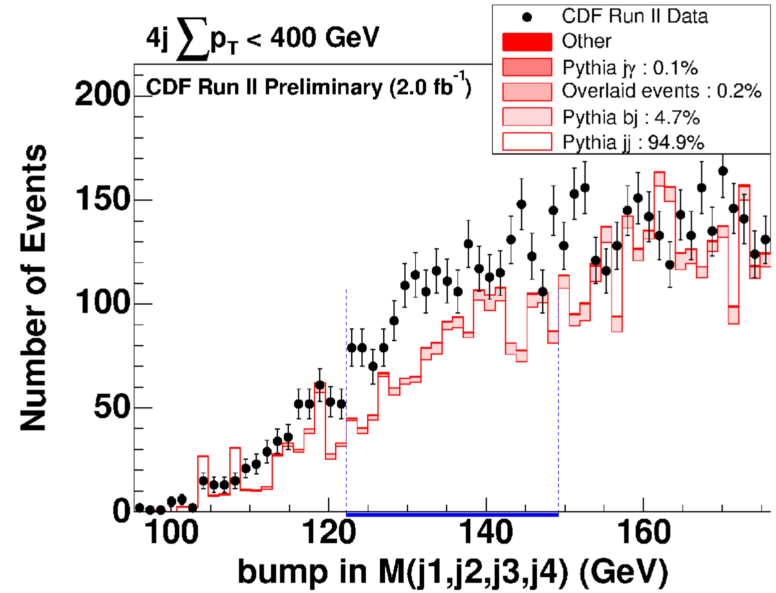
Bump Hunter Results Overview



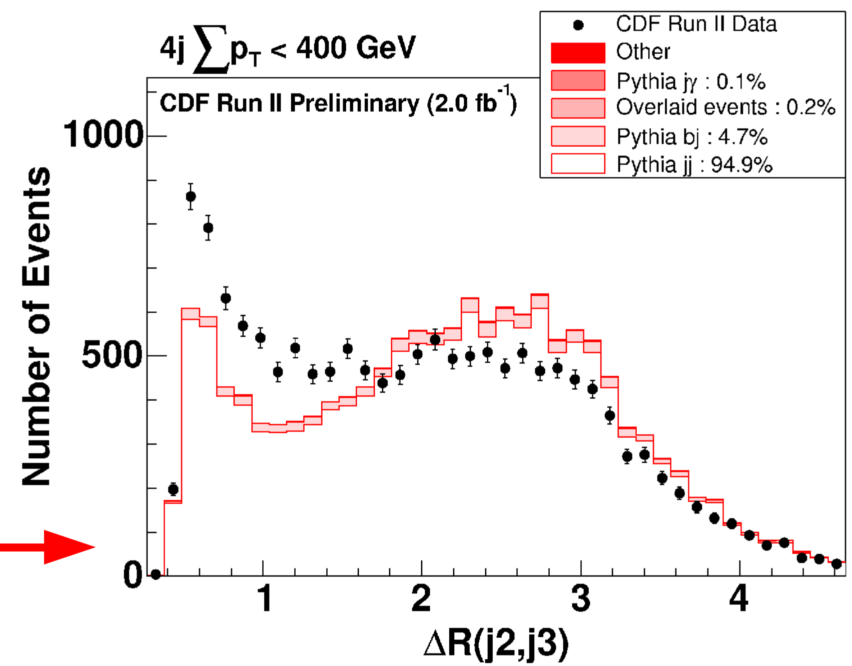
Only 1 invariant mass distribution has a bump with significance above the discovery threshold

Bump Hunter Results





- This is the only 'discovery-level' bump found
- But we do not believe this indicates new physics – attribute it to the QCD soft jet modelling problem seen earlier



Bump Hunter Summary

- Bump Hunter scans invariant mass distributions for bumps that could indicate resonant production of new particles
- 5036 mass distributions searched in 2.0 fb^{-1}

  $\rightarrow$ 1 found to have 'discovery-level' bump
- But we believe this is due to same difficulty modelling soft QCD jets as seen earlier
- No new physics claim from the Bump Hunter

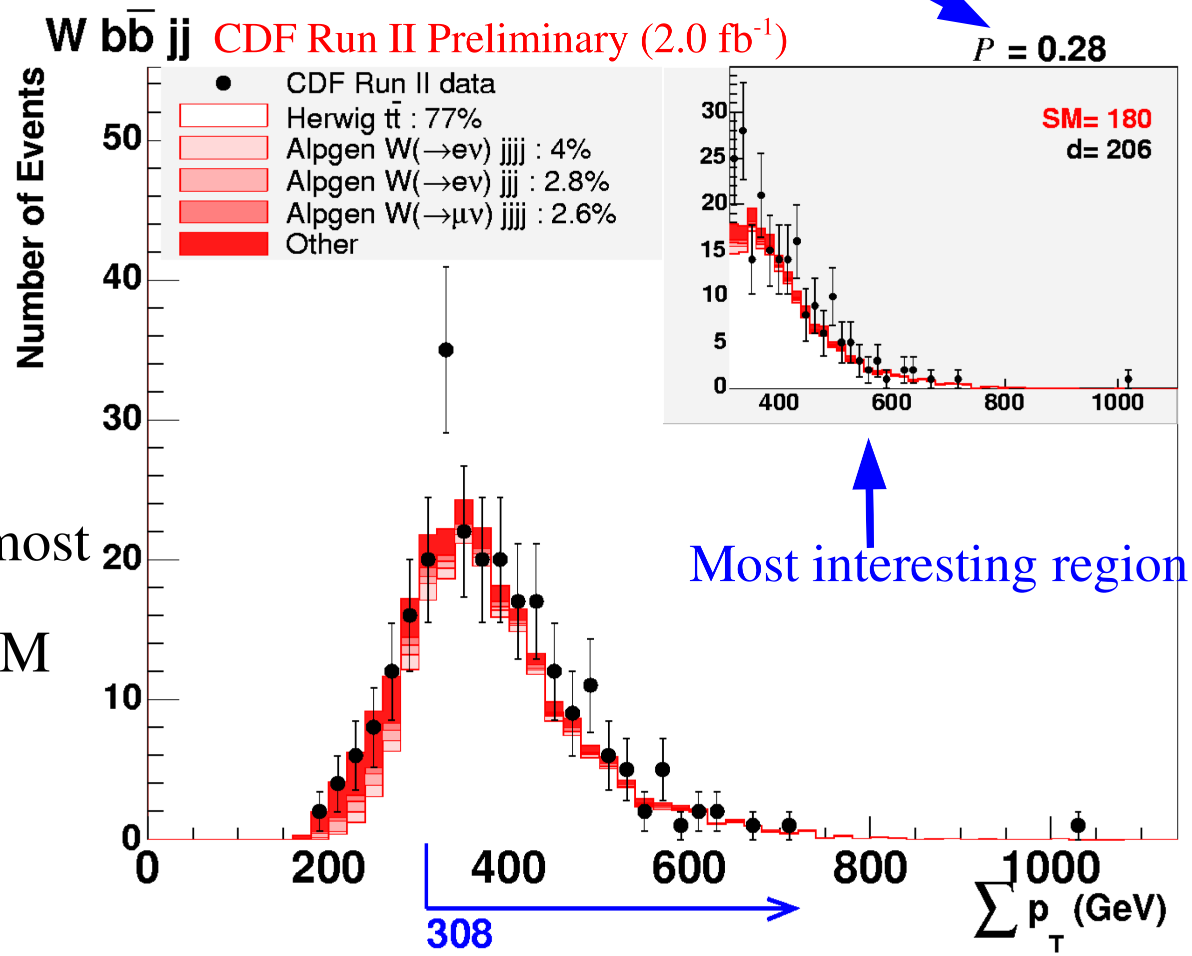
Sleuth

- Sleuth assumption:
  - new physics will appear as an excess of data at high Σp_T predominantly in one final state
- Sleuth's variable:

$$\sum p_T \equiv \sum_i |\vec{p}_i| + \left|\overrightarrow{\mathrm{uncl}}\right| + \left|\vec{\not{p}}\right| ,$$

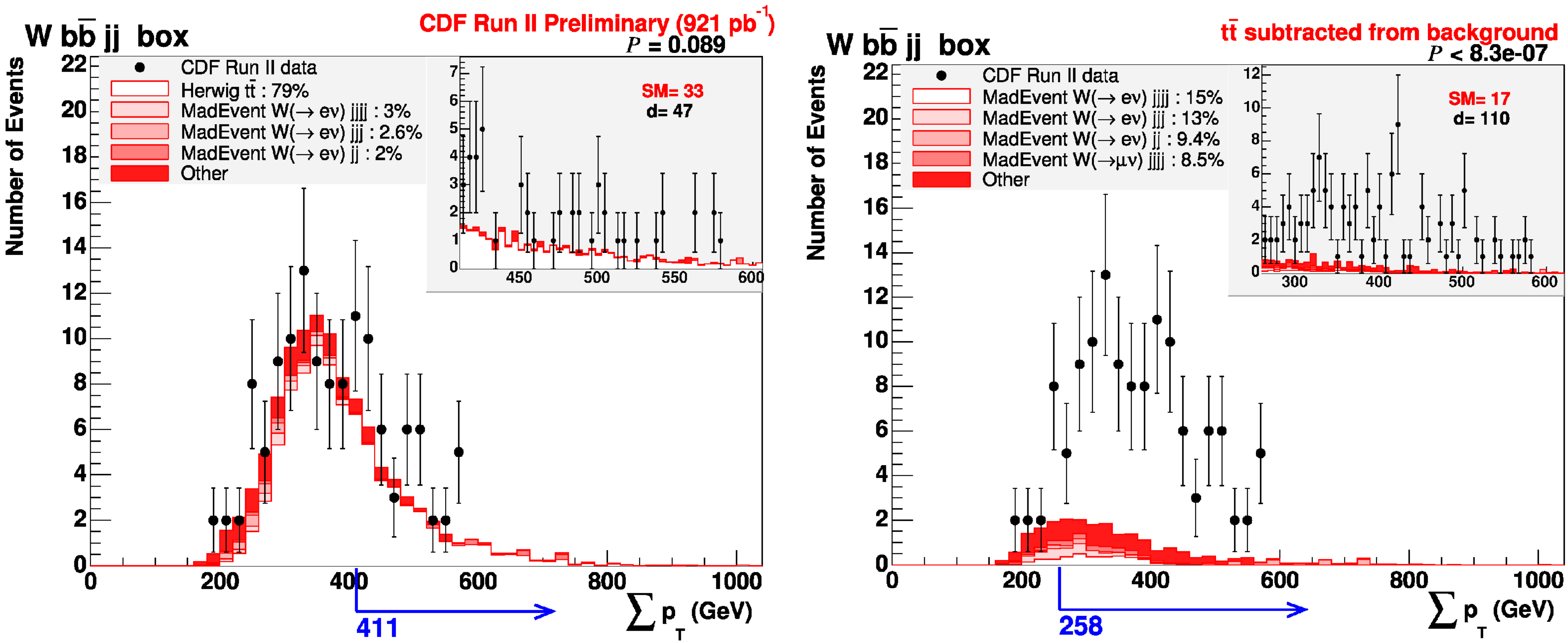
- For each Sleuth final state:
  - scan the Σp_T spectrum
  - select one-sided region with most significant excess of data over SM
- Perform pseudo-experiments to assess the significance

Significance of this region



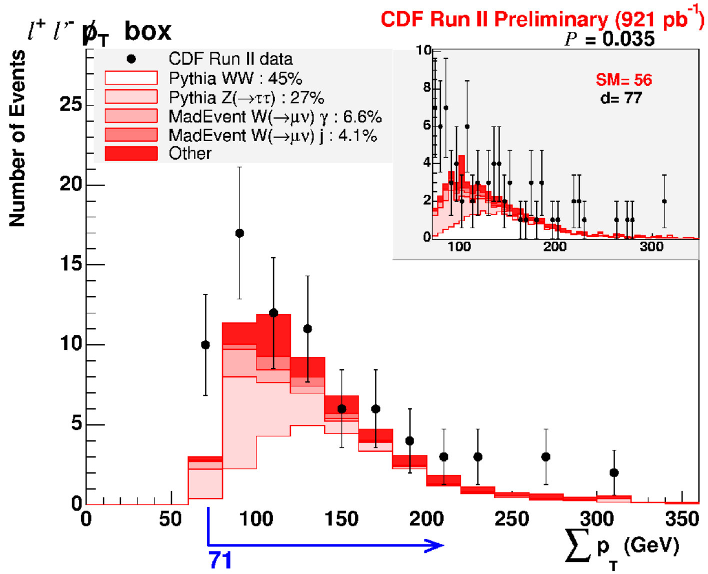
Most interesting region

Would Sleuth Have Found the Top Quark?

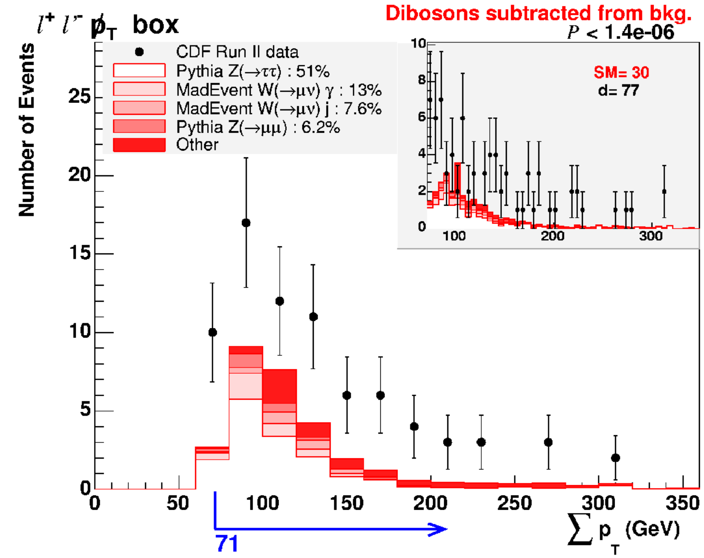


- Remove top quark from SM; refit correction factors
- Sleuth easily finds top in 1 fb^{-1}
- Estimated luminosity for Sleuth discovery ~80 pb^{-1} (Run I discovery = 67 pb^{-1} at $\sqrt{s}$=1.8 TeV)

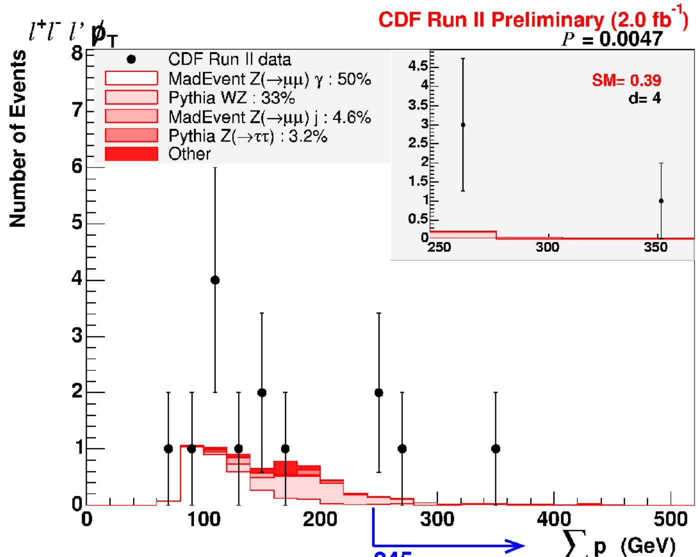
Sleuth Sensitivity to WW and WZ



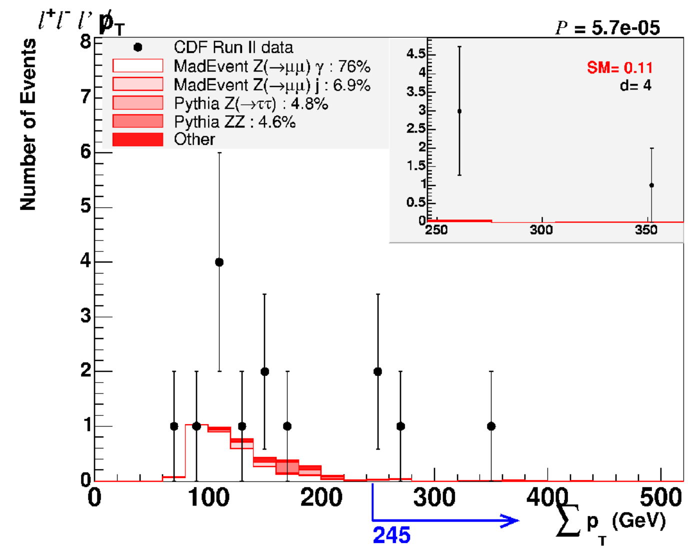
Remove WW



- Sleuth would be sensitive to WW with 1 fb^{-1}
- But not sufficient to claim discovery of WZ, even with 2 fb^{-1}

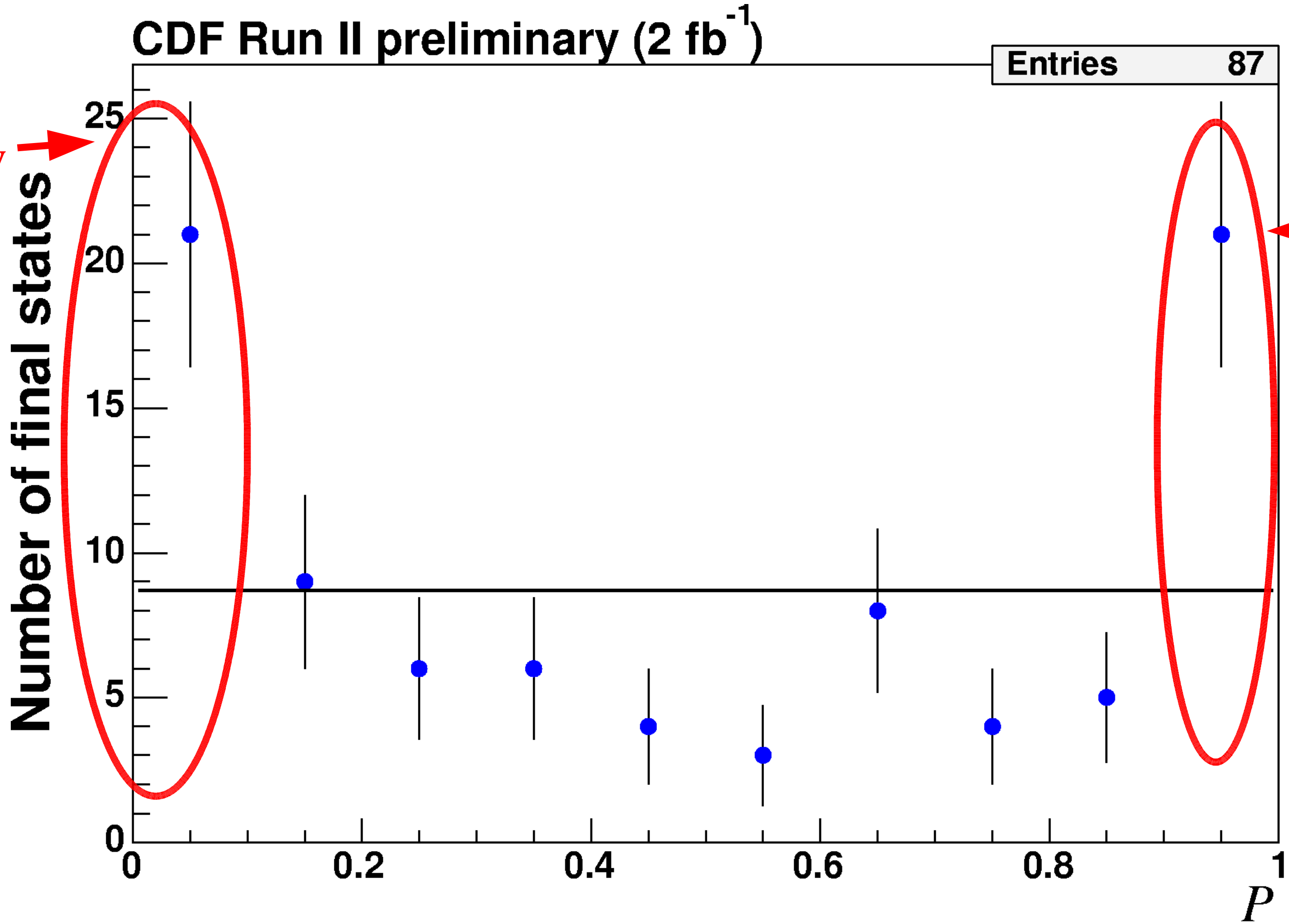


Remove WZ



Sleuth Results Overview

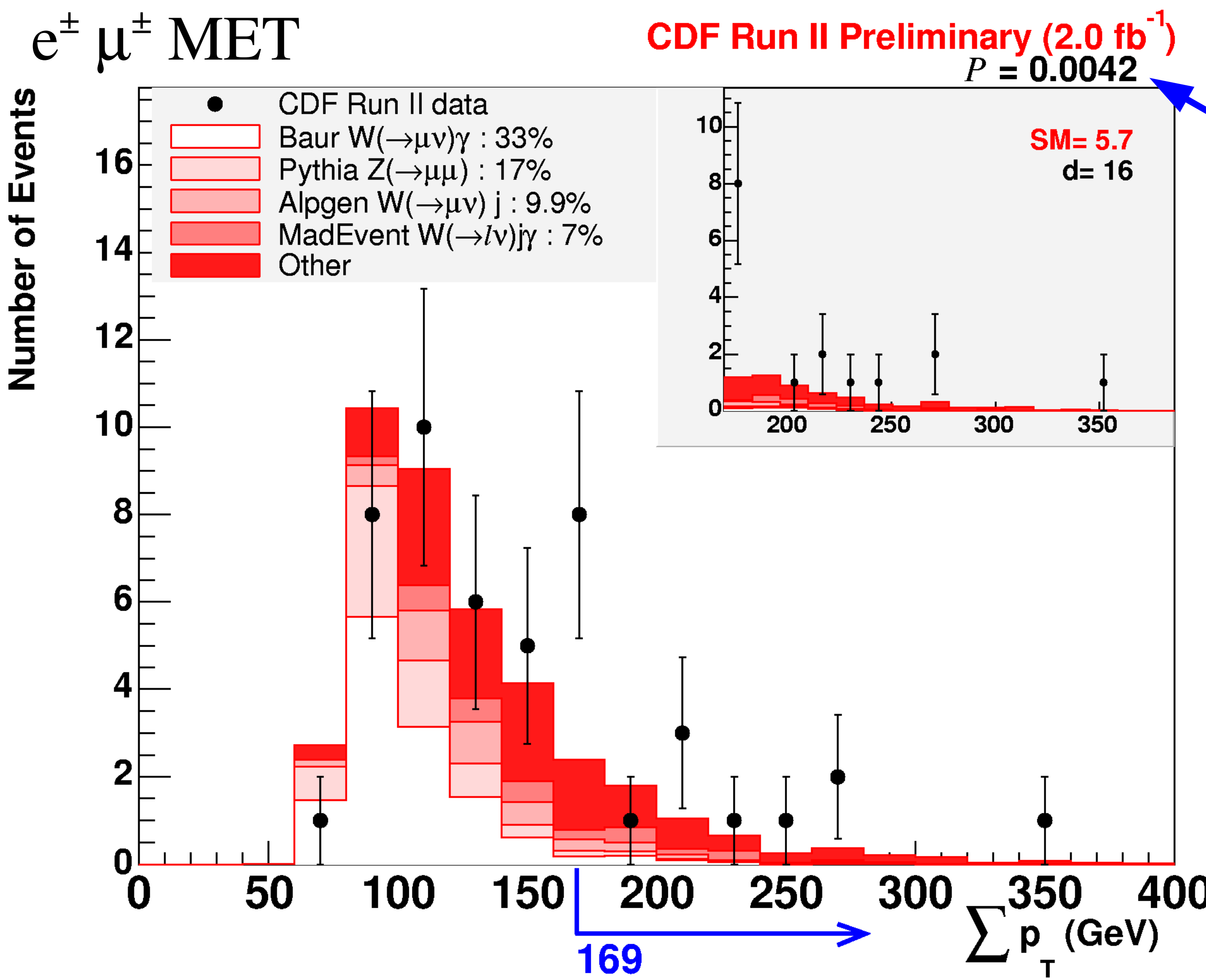
Maybe new physics here? Or just under-estimation of SM?



Probable over-estimation of SM background

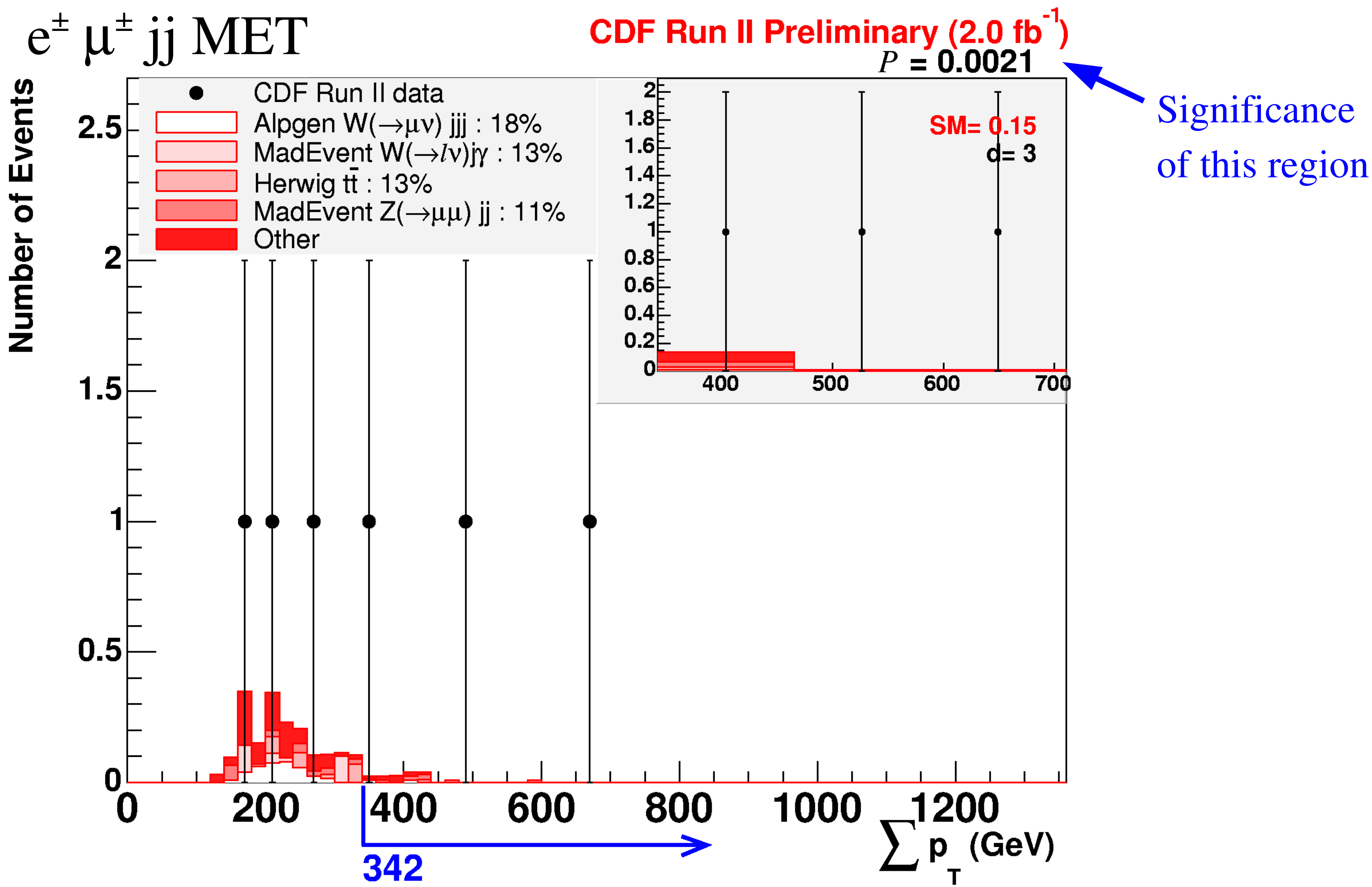
If our simplified Standard Model prediction perfectly represented the data, we would expect this to be a uniform distribution

Sleuth #3 Final State

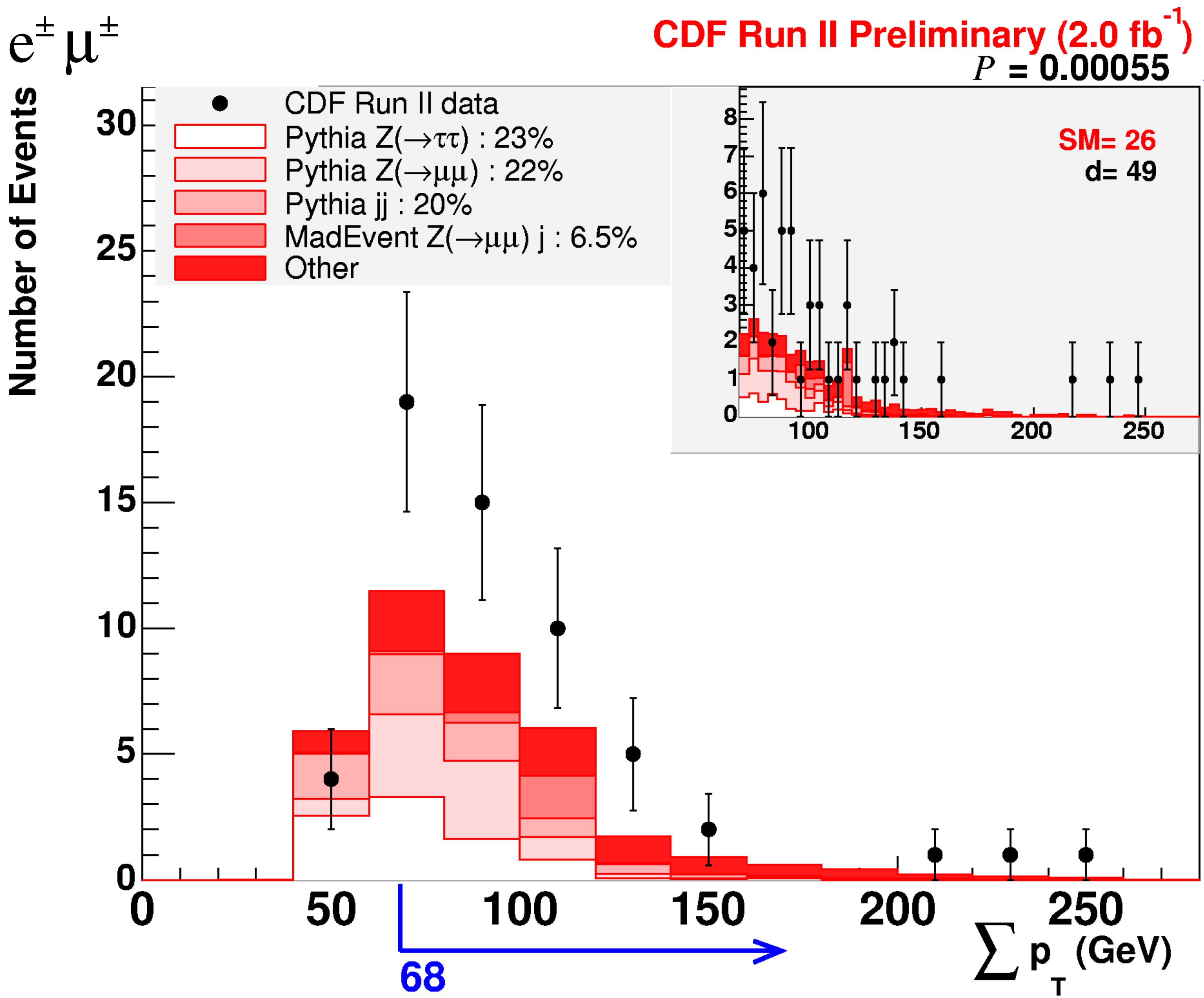


Significance of this region

Sleuth #2 Final State



Sleuth #1 Final State



Significance of this region

Sleuth Results

- Summary of top Sleuth final states:

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

$\ell^+ = e^+, \mu^+$ $\ell'^+ \neq \ell^+$

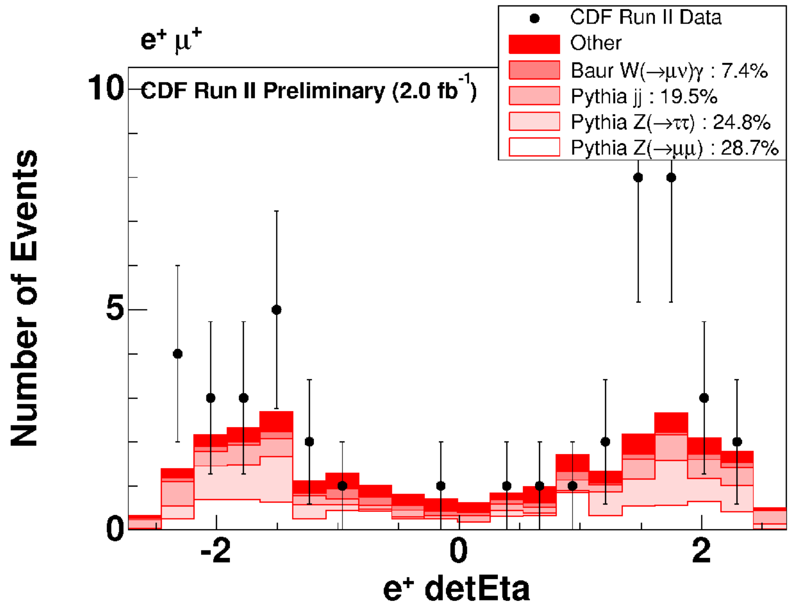
- How significant is the most discrepant excess seen by Sleuth, after accounting for the trials factor?
- Sadly, not very significant:
  - ~8% of hypothetical similar CDF experiments are expected to give a more interesting excess, purely by chance
- There is no discovery claim arising from Sleuth with 2.0 fb^{-1} of data

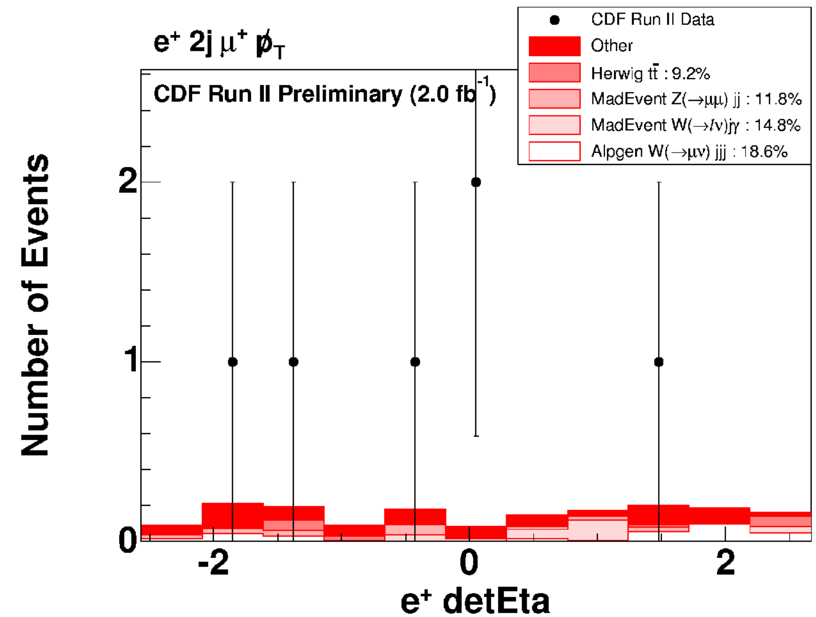
Conclusions

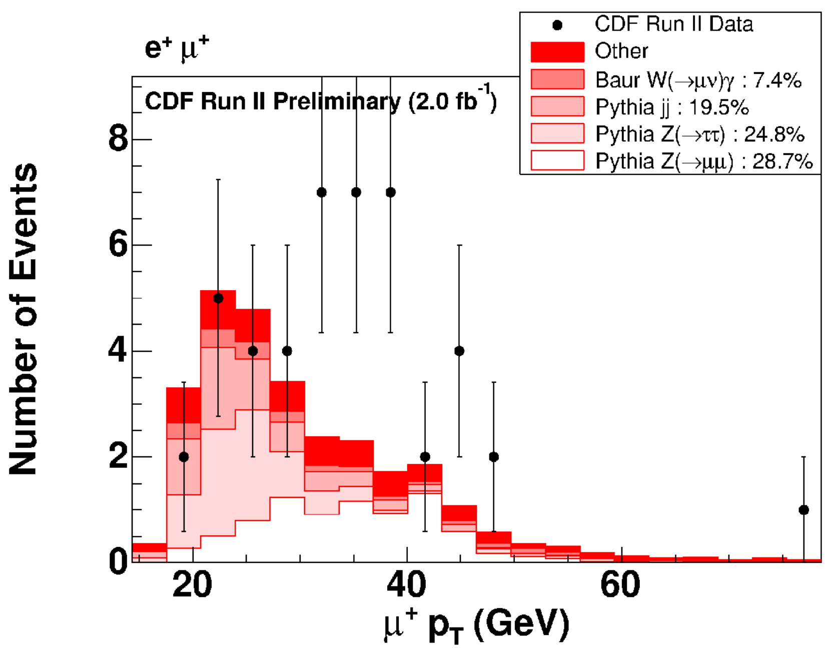
- CDF has performed a model-independent global search for new physics in 2.0 fb^{-1} of data
- Vista considered the bulk features of the high-p_T data: final state populations and shapes of kinematic distributions
- The Bump Hunter searched for narrow resonances in invariant mass distributions
- Sleuth searched for excesses of data at high sum-p_T
- None of these techniques found a significant (~5σ) effect that could motivate a new physics claim
- The hunt for new physics at the Tevatron will continue!

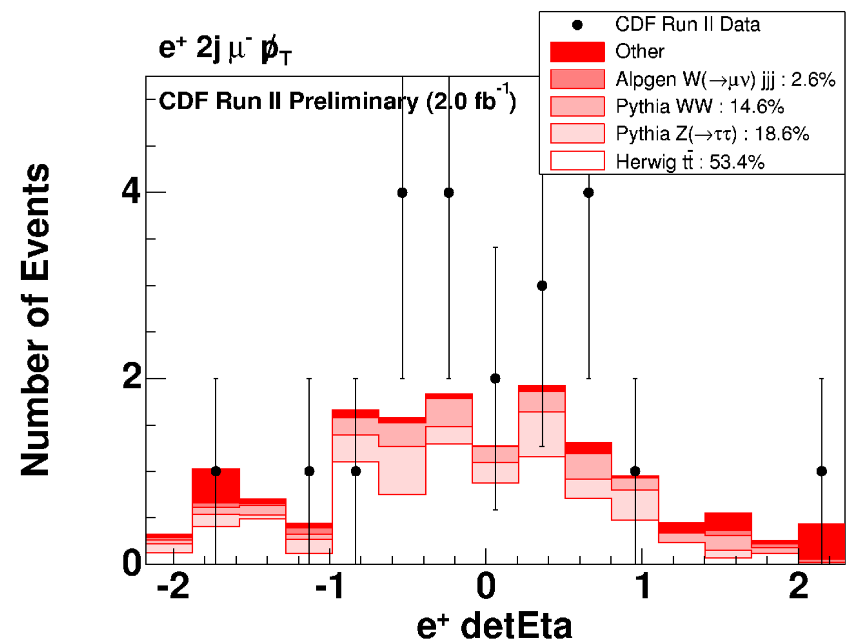
Backups

$e^+ \mu^+$?


e+ μ+
CDF Run II Preliminary (2.0 fb-1)
CDF Run II Data
Other
Baur W(→μν)γ : 7.4%
Pythia jj : 19.5%
Pythia Z(→ττ) : 24.8%
Pythia Z(→μμ) : 28.7%
Number of Events
e+ detEta


e+ 2j μ+ E̸T
CDF Run II Preliminary (2.0 fb-1)
CDF Run II Data
Other
Herwig tt̄ : 9.2%
MadEvent Z(→μμ) jj : 11.8%
MadEvent W(→lν)jγ : 14.8%
Alpgen W(→μν) jjj : 18.6%
Number of Events
e+ detEta


e+ μ+
CDF Run II Preliminary (2.0 fb-1)
CDF Run II Data
Other
Baur W(→μν)γ : 7.4%
Pythia jj : 19.5%
Pythia Z(→ττ) : 24.8%
Pythia Z(→μμ) : 28.7%
Number of Events
μ+ pT (GeV)


e+ 2j μ- E̸T
CDF Run II Preliminary (2.0 fb-1)
CDF Run II Data
Other
Alpgen W(→μν) jjj : 2.6%
Pythia WW : 14.6%
Pythia Z(→ττ) : 18.6%
Herwig tt̄ : 53.4%
Number of Events
e+ detEta

Vista Correction Factors

- The correction factors shown are defined and applicable only within the context of the Vista correction model
- Values and errors are obtained from global fit to data (including constraints)

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

Code	Category	Explanation	Value	Error	Error(%)
0001	luminosity	CDF integrated luminosity	1990	50	2.6
0002	k-factor	cosmic_ph	0.83	0.05	6.0
0003	k-factor	cosmic_j	0.192	0.006	3.1
0004	k-factor	1γ1j photon+jet(s)	0.92	0.04	4.4
0005	k-factor	1γ2j	1.26	0.05	4.0
0006	k-factor	1γ3j	1.61	0.08	5.0
0007	k-factor	1γ4j+	1.94	0.16	8.3
0008	k-factor	2γ0j diphoton(+jets)	1.6	0.08	5.0
0009	k-factor	2γ1j	2.99	0.17	5.7
0010	k-factor	2γ2j+	1.2	0.09	7.5
0011	k-factor	W0j W (+jets)	1.38	0.03	2.2
0012	k-factor	W1j	1.33	0.03	2.3
0013	k-factor	W2j	1.99	0.05	2.5
0014	k-factor	W3j+	2.11	0.09	4.3
0015	k-factor	Z0j Z (+jets)	1.39	0.028	2.0
0016	k-factor	Z1j	1.23	0.04	3.2
0017	k-factor	Z2j+	1.02	0.04	3.9
0018	k-factor	2j $\hat{p}_T$<150 dijet	1.003	0.027	2.7
0019	k-factor	2j 150<$\hat{p}_T$	1.34	0.03	2.2
0020	k-factor	3j $\hat{p}_T$<150 multijet	0.941	0.025	2.7
0021	k-factor	3j 150<$\hat{p}_T$	1.48	0.04	2.7
0022	k-factor	4j $\hat{p}_T$<150	1.06	0.03	2.8
0023	k-factor	4j 150<$\hat{p}_T$	1.93	0.06	3.1
0024	k-factor	5j low	1.33	0.05	3.8
0025	k-factor	1b2j 150<$\hat{p}_T$	2.22	0.11	5.0
0026	k-factor	1b3j 150<$\hat{p}_T$	2.98	0.15	5.0
0027	misId	p(e$\rightarrow$e) central	0.978	0.006	0.6
0028	misId	p(e$\rightarrow$e) plug	0.966	0.007	0.7
0029	misId	p($\mu\rightarrow\mu$) CMUP+CMX	0.888	0.007	0.8
0030	misId	p($\gamma\rightarrow\gamma$) central	0.949	0.018	1.9
0031	misId	p($\gamma\rightarrow\gamma$) plug	0.859	0.016	1.9
0032	misId	p(b$\rightarrow$b) central	0.978	0.021	2.1
0033	misId	p($\gamma\rightarrow$e) plug	0.06	0.003	5.0
0034	misId	p(q$\rightarrow$e) central	7.09×10^{-5}	1.9×10^{-6}	2.7
0035	misId	p(q$\rightarrow$e) plug	0.000766	1.2×10^{-5}	1.6
0036	misId	p(q$\rightarrow\mu$)	1.14×10^{-5}	6×10^{-7}	5.2
0037	misId	p(b$\rightarrow\mu$)	3.3×10^{-5}	1.1×10^{-5}	33.0
0038	misId	p(j$\rightarrow$b) 25<p_T	0.0183	0.0002	1.1
0039	misId	p(q$\rightarrow\tau$)	0.0052	0.0001	1.9
0040	misId	p(q$\rightarrow\gamma$) central	0.000266	1.4×10^{-5}	5.3
0041	misId	p(q$\rightarrow\gamma$) plug	0.00048	6×10^{-5}	12.6
0042	trigger	p(e$\rightarrow$trig) plug, p_T>25	0.86	0.007	0.8
0043	trigger	p($\mu\rightarrow$trig) CMUP+CMX, p_T>25	0.916	0.004	0.4

Constrained Correction Factors

Category	Explanation	
luminosity	CDF integrated luminosity	
k-factor	cosmic_ph	
k-factor	cosmic_j	
k-factor	1ph1j	photon+jet(s)
k-factor	1ph2j	
k-factor	1ph3j	
k-factor	1ph4j+	
k-factor	2ph0j	diphoton(+jets)
k-factor	2ph1j	
k-factor	2ph2j+	
k-factor	W0j	W (+jets)
k-factor	W1j	
k-factor	W2j	
k-factor	W3j+	
k-factor	Z0j	Z (+jets)
k-factor	Z1j	
k-factor	Z2j+	
k-factor	2j pt<150	dijet
k-factor	2j 150<pt	
k-factor	3j pt<150	multijet
k-factor	3j 150<pt	
k-factor	4j pt<150	
k-factor	4j 150<pt	
k-factor	5j+ low	

Category	Explanation	
misId	p(e->e)	central
misId	p(e->e)	plug
misId	p(mu->mu)	CMUP
misId	p(mu->mu)	CMX
misId	p(ph->ph)	central
misId	p(ph->ph)	plug
misId	p(b->b)	central
misId	p(e->ph)	plug
misId	p(q->e)	central
misId	p(q->e)	plug
misId	p(q->mu)	
misId	p(j->b)	25<pt
misId	p(q->tau)	15<pt<60
misId	p(q->tau)	60<pt<200
misId	p(q->ph)	central
misId	p(q->ph)	plug
trigger	p(e->trig)	central, pt>25
trigger	p(e->trig)	plug, pt>25
trigger	p(mu->trig)	CMUP, pt>25
trigger	p(mu->trig)	CMX, pt>25

Has external constraint

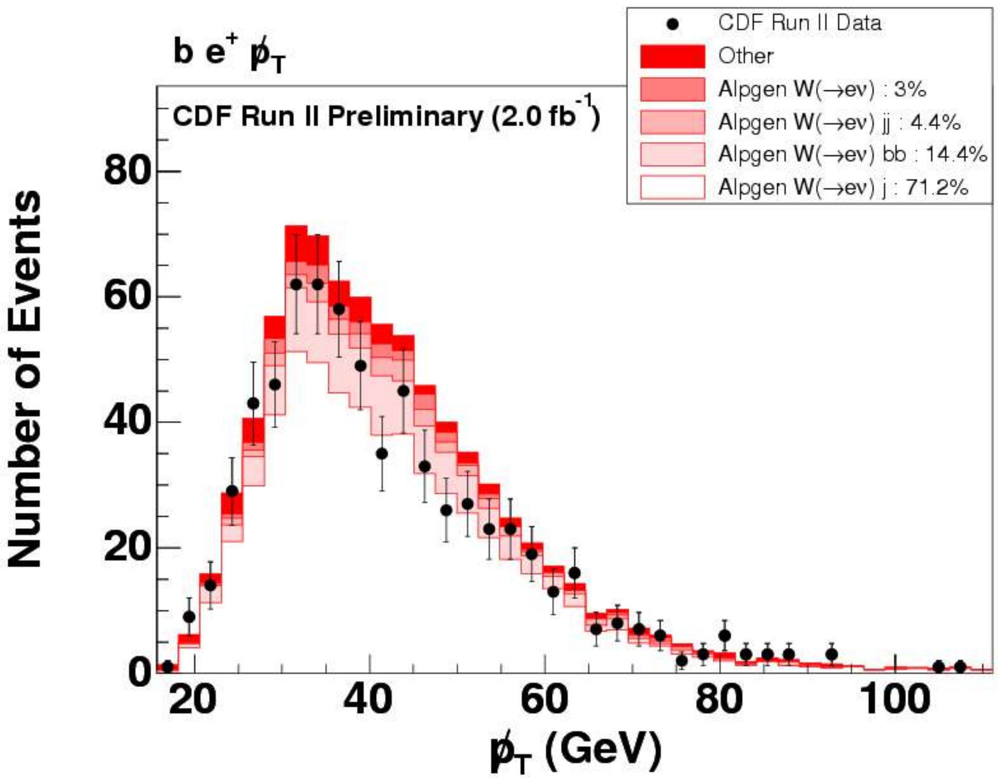
Part of inclusive constraint

Vista Top Final States

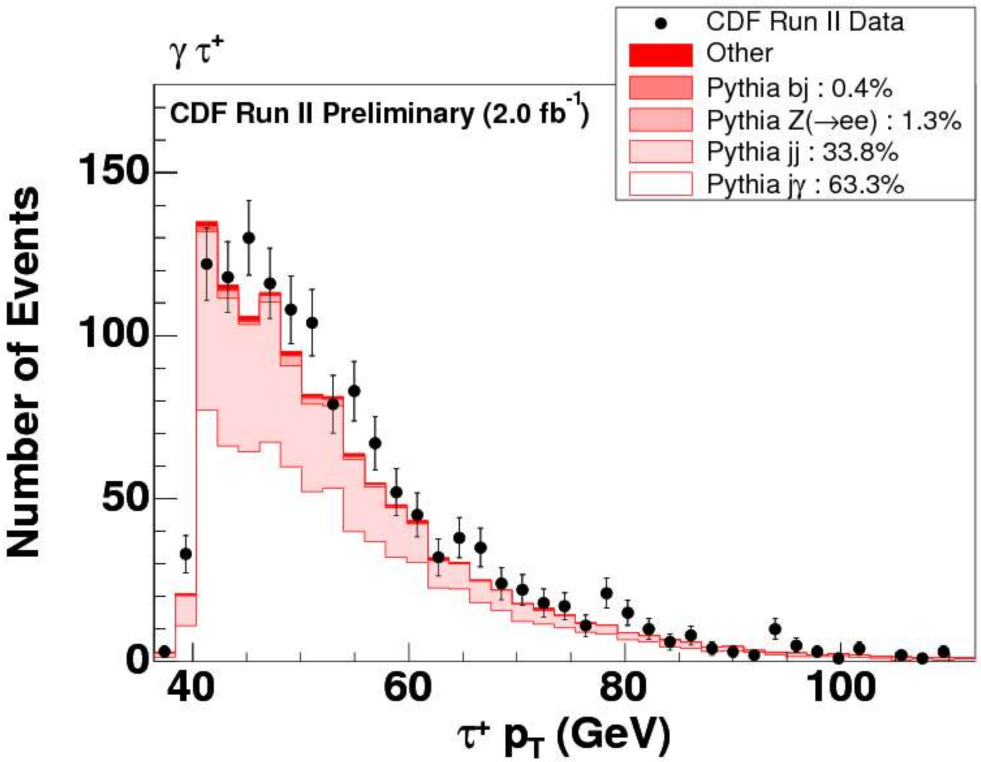
CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

Final State	Data	Background	σ
b$e^{\pm}\not{p}$	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}$2j	256946	249148 ± 2201.5	+1.2
2bj low-Σp_T	279	352.5 ± 11.9	−1.1
j$\tau^{\pm}$ low-Σp_T	1385	1525.8 ± 15	−1.1
2b2j low-Σp_T	108	153.5 ± 6.8	−1
b$\mu^{\pm}\not{p}$	528	613.5 ± 8.7	−0.9
$\mu^{\pm}\gamma\not{p}$	523	611 ± 12.1	−0.8
2bγ	108	70.5 ± 7.9	+0.1

Vista Top Final States

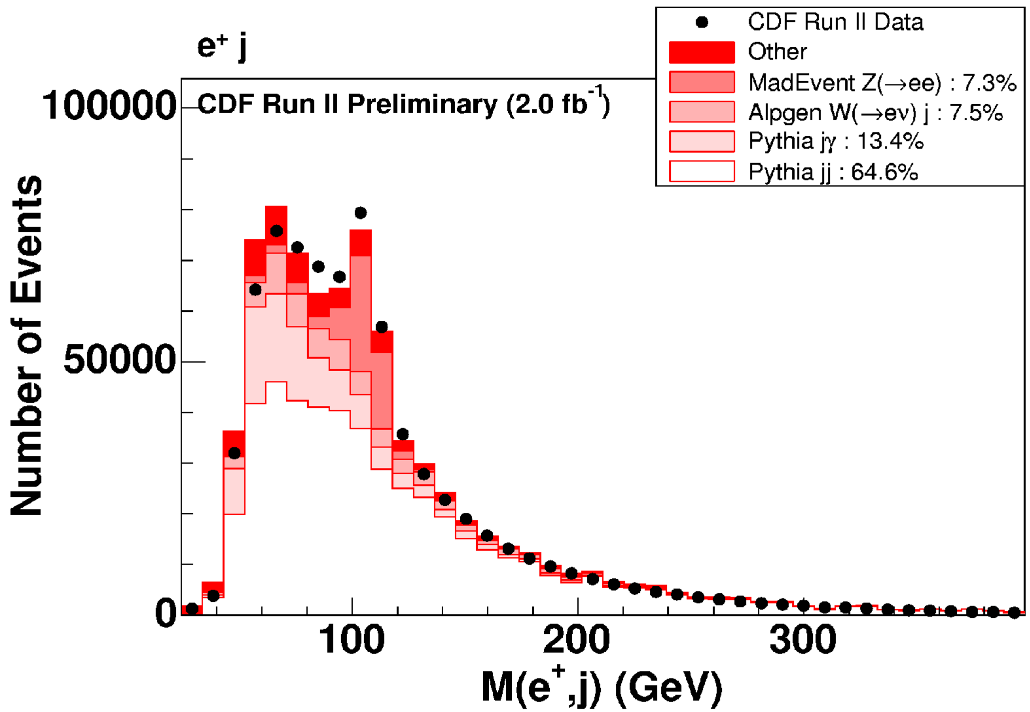


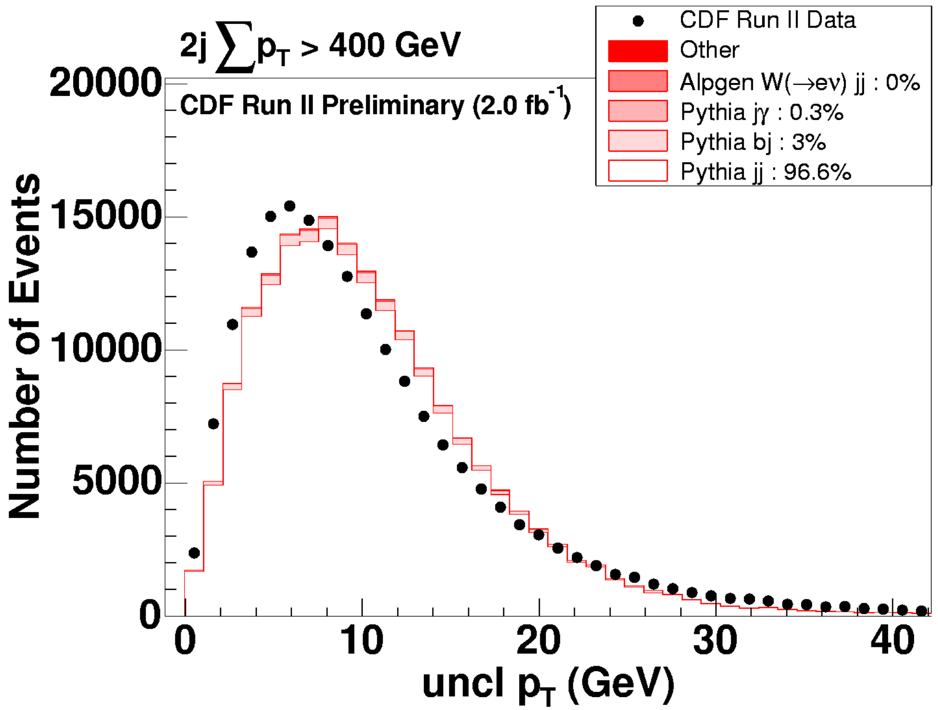
Vista final state with largest deficit of data



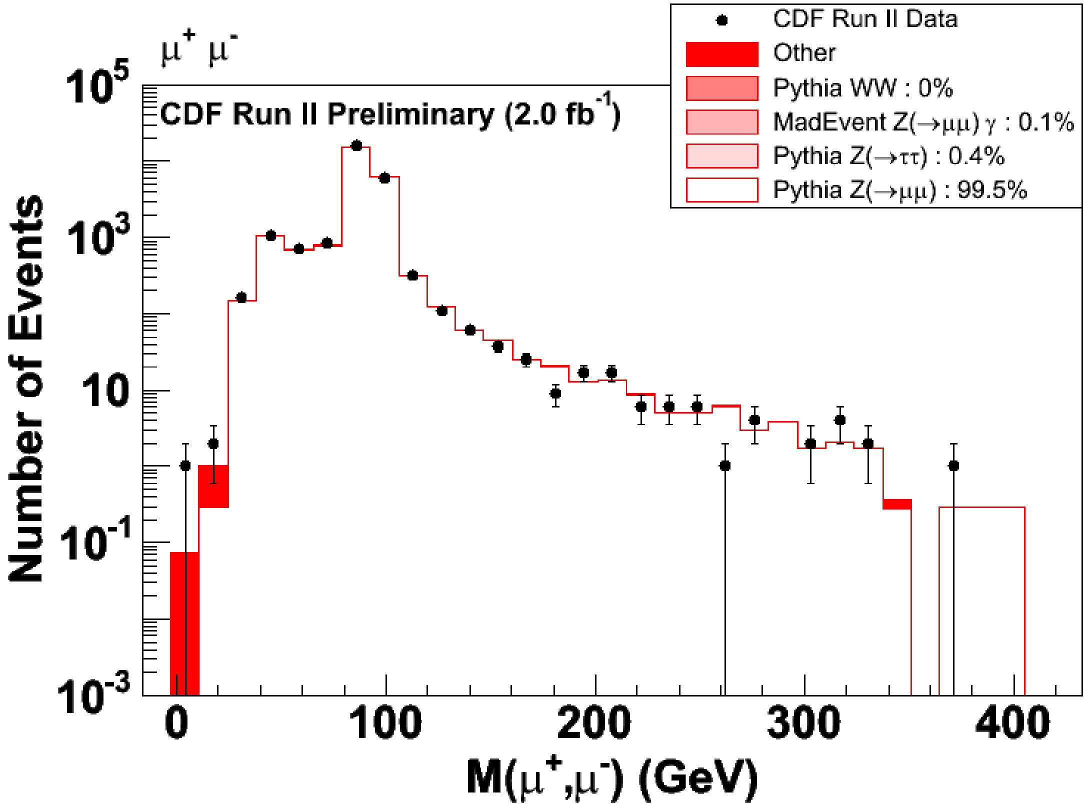
Vista final state with largest excess of data

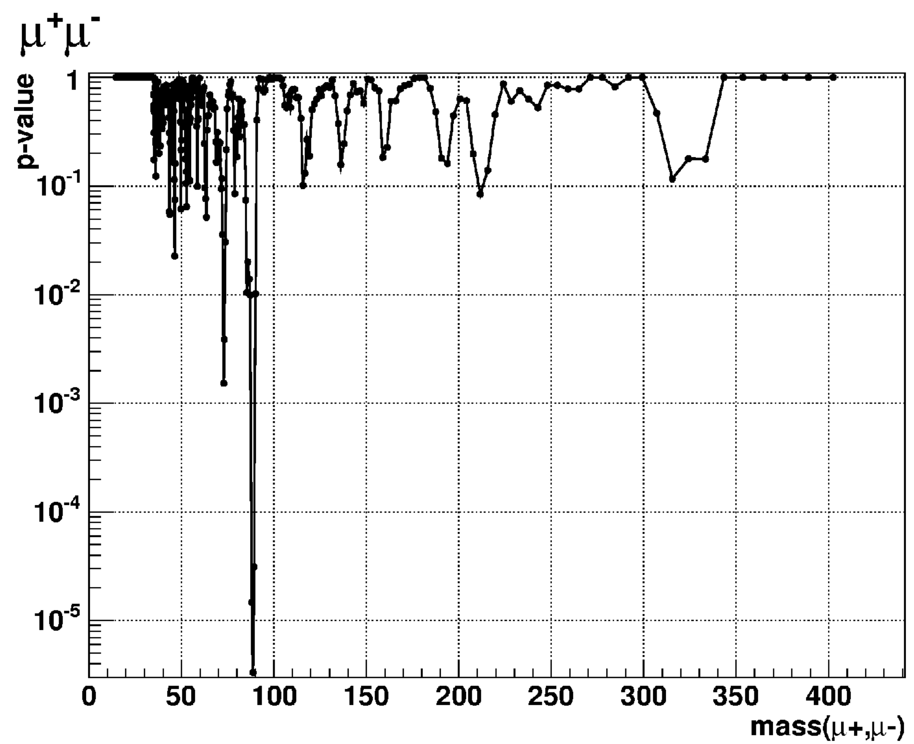
Other Vista Shape Discrepancies





Bump Hunter Study: Dimuons

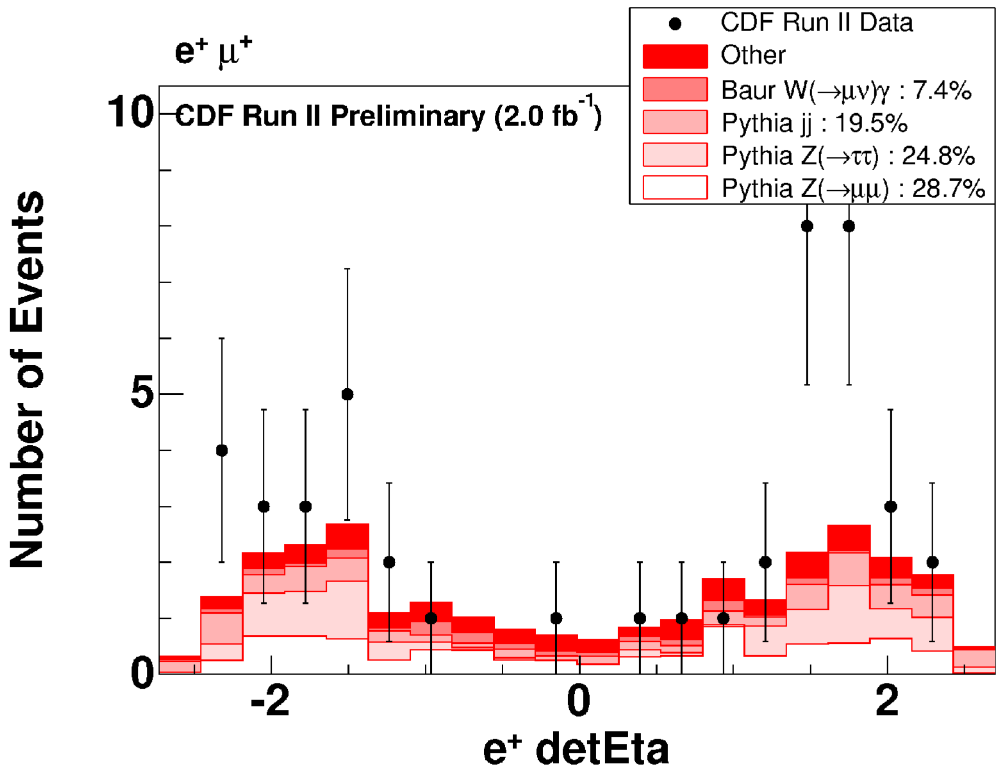


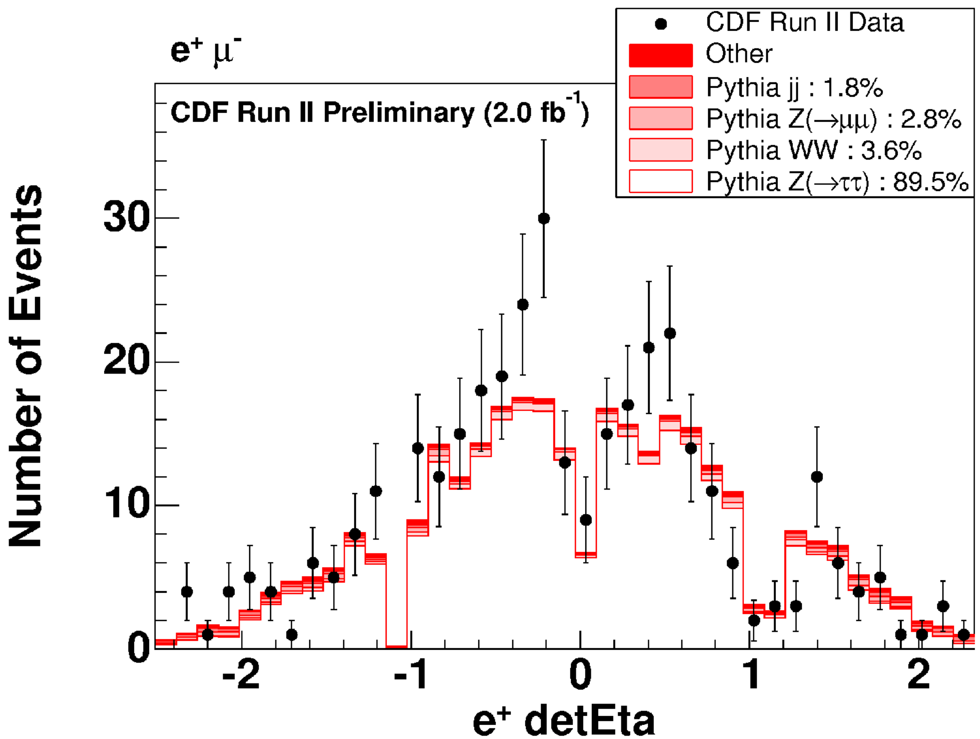


Sleuth Partition Rules

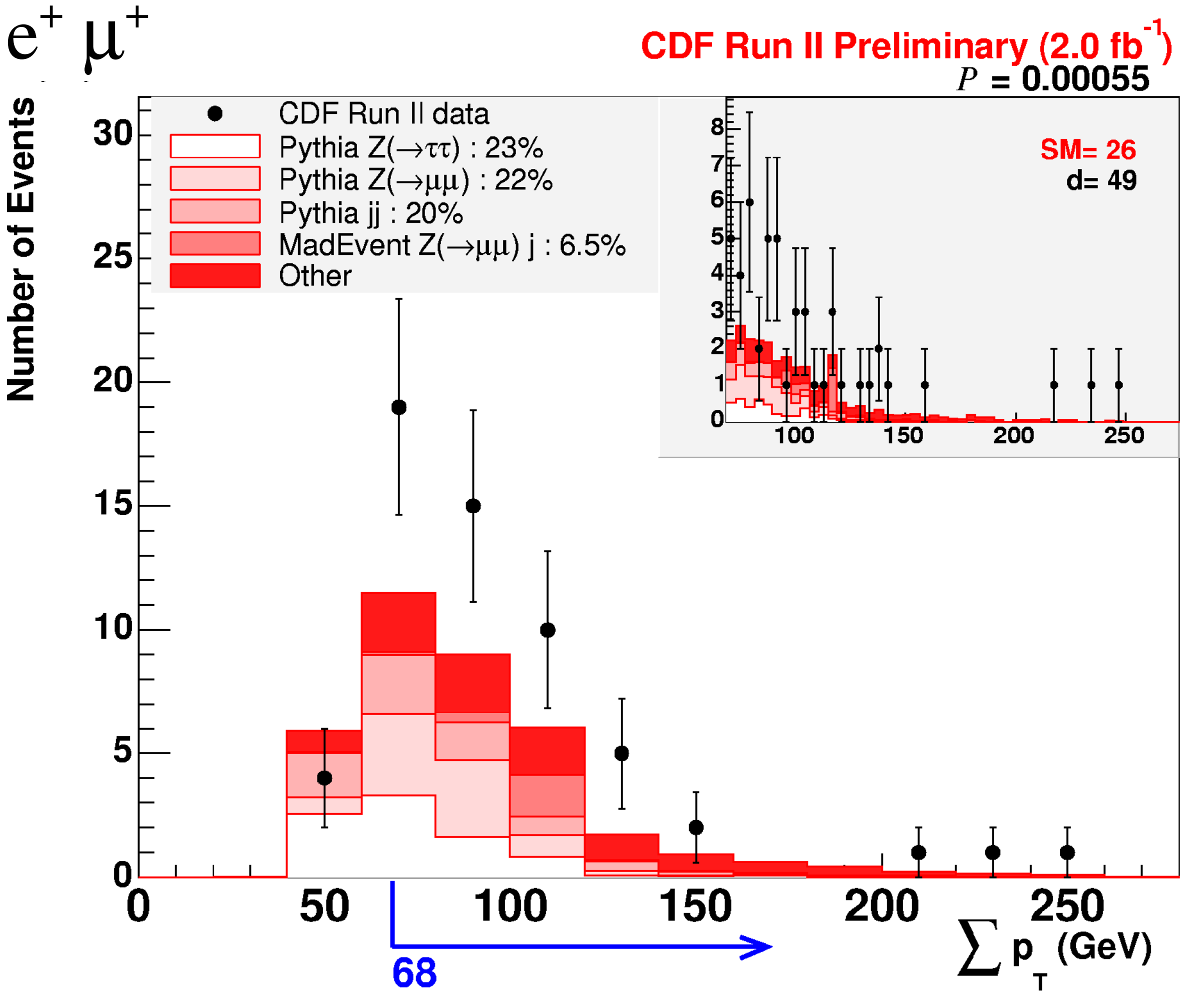
- Vista final states are merged in Sleuth to enhance signal/background
- Assumes that new physics will:
  - treat first 2 generations equivalently
  - be symmetric with respect to global charge conjugation
  - produce jets in pairs
  - conserve lepton flavour number

Regarding Sleuth #1 State





'Other' for Sleuth #1 State

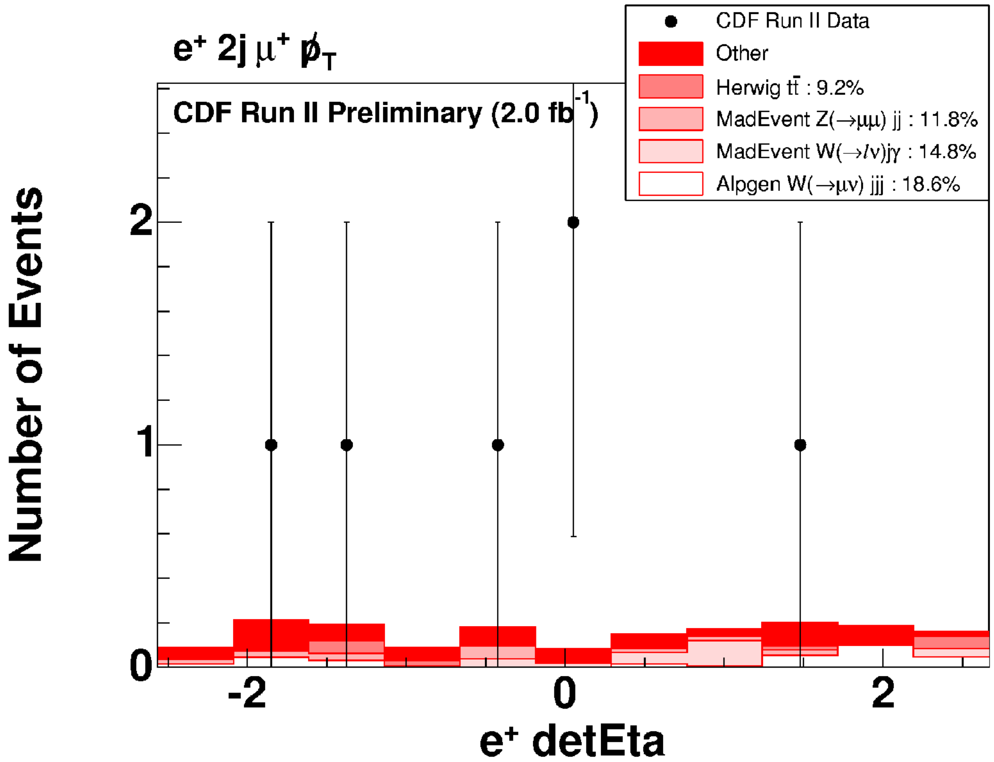


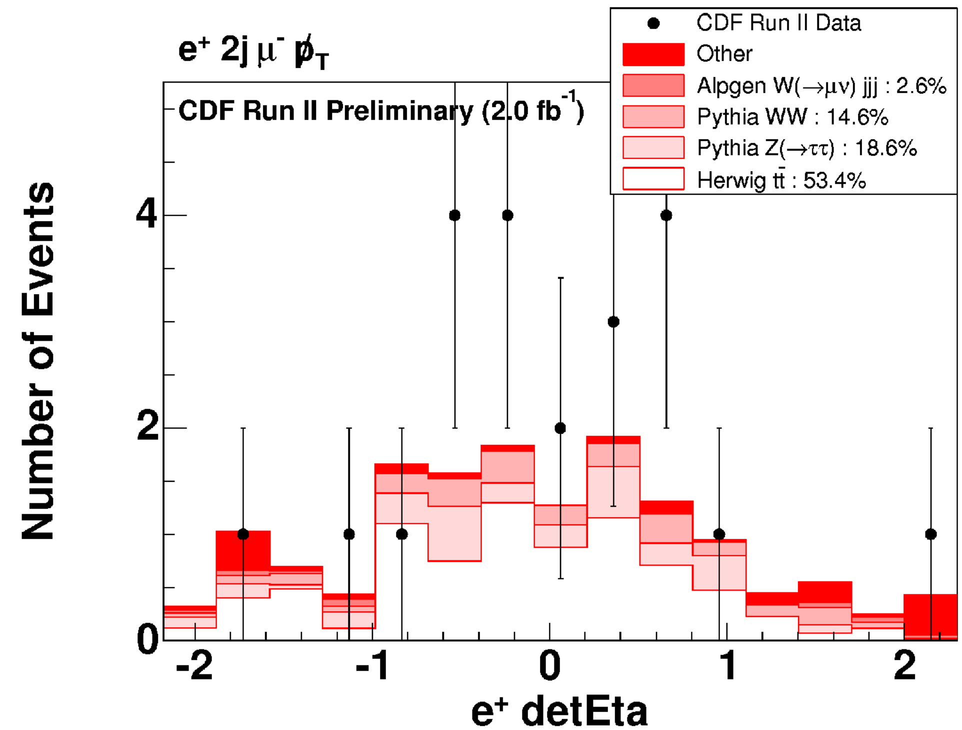
Other contributions:

Baur W(→μν)γ	5.5%
MadEvent Z(→μμ)γ	3.3%
Pythia jγ	3%
MadEvent Wjγ	2%
Alpgen W(→μν)j	2%
Alpgen W(→μν)jj	2%
MadEvent Z(→μμ)jj	2%
Pythia W→μν	2%
Pythia WZ	1%

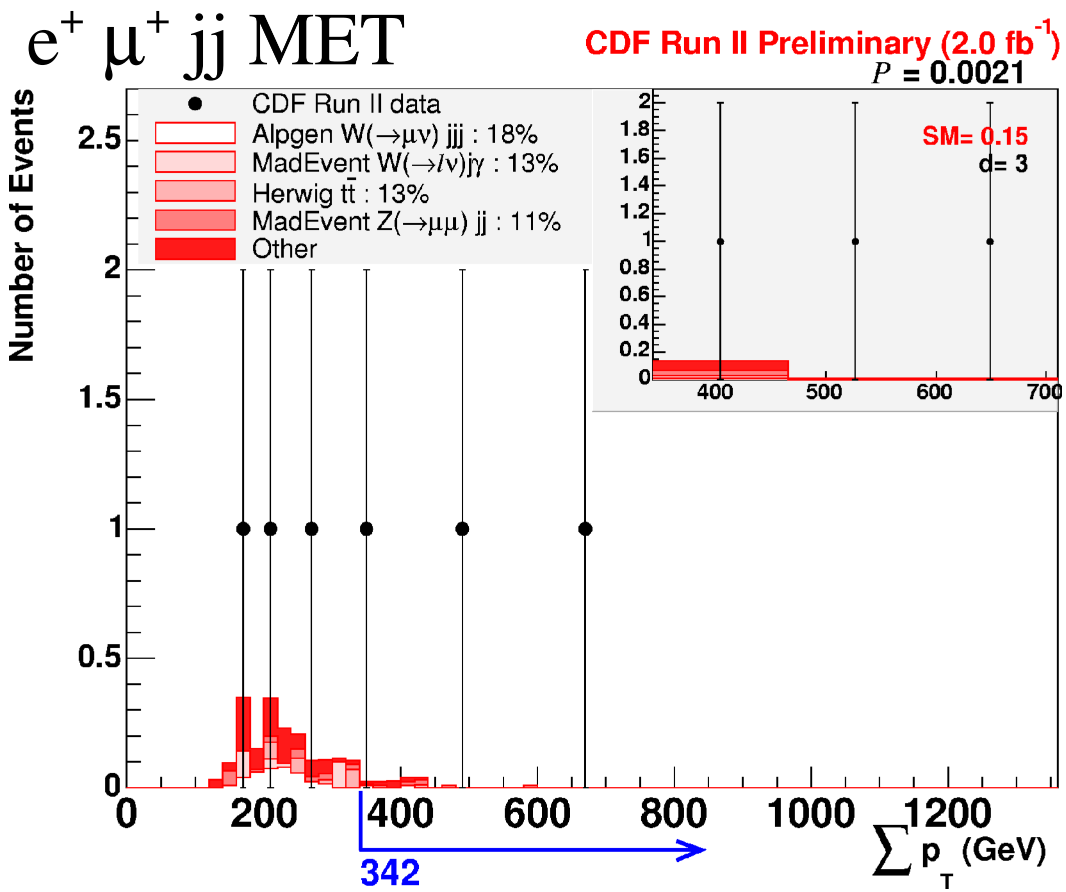
…

Regarding Sleuth #2 State





'Other' for Sleuth #2 State

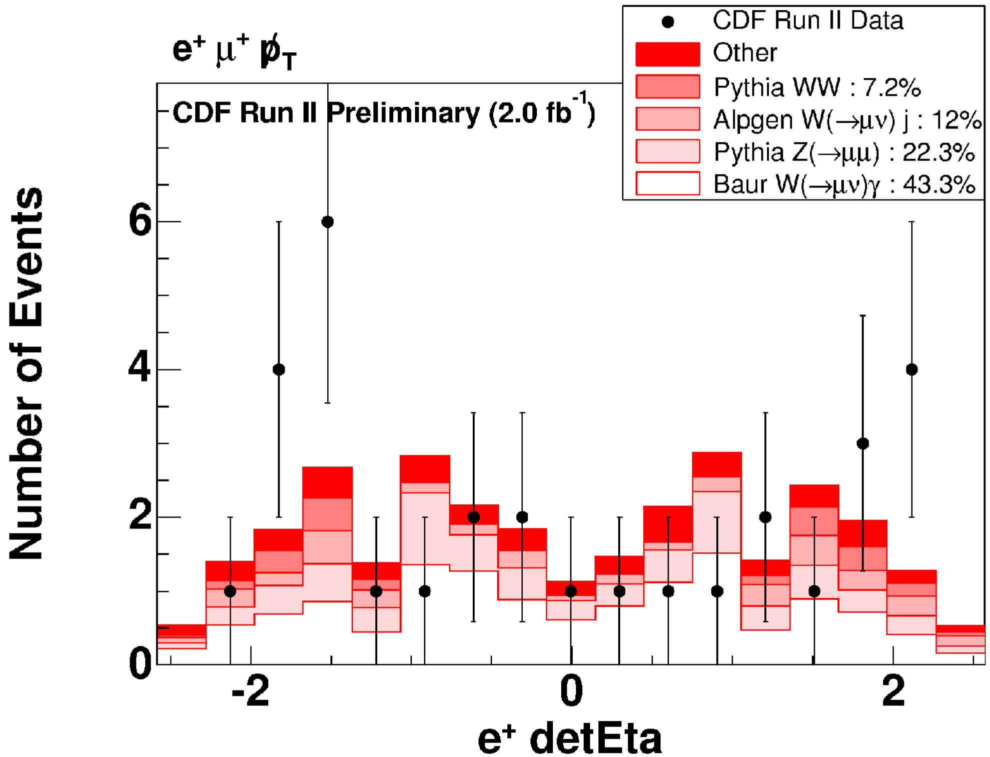


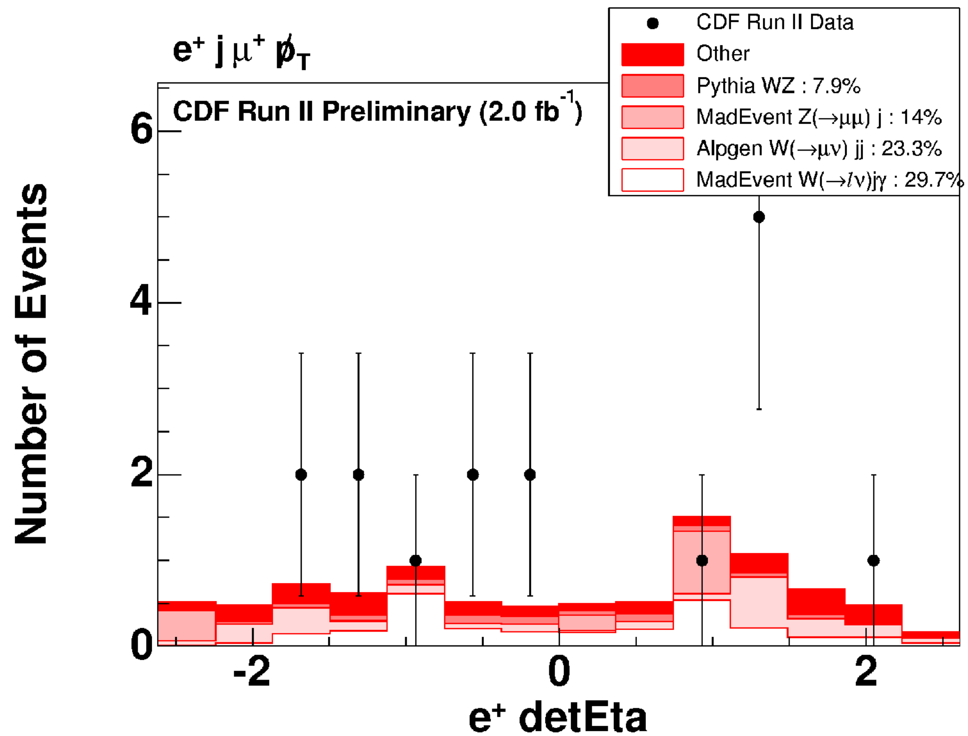
Other contributions:

Alpgen W(→μν)jj	10%
Pythia Z→ττ	7%
Pythia WZ	6%
MadEvent Zjγ	3%
Pythia WW	3%
MadEvent Z(→μμ)jjj	2%
Baur W(→τν)γ	2%
Alpgen W(→μν)bbj	2%
Alpgen W(→eν)bbj	2%

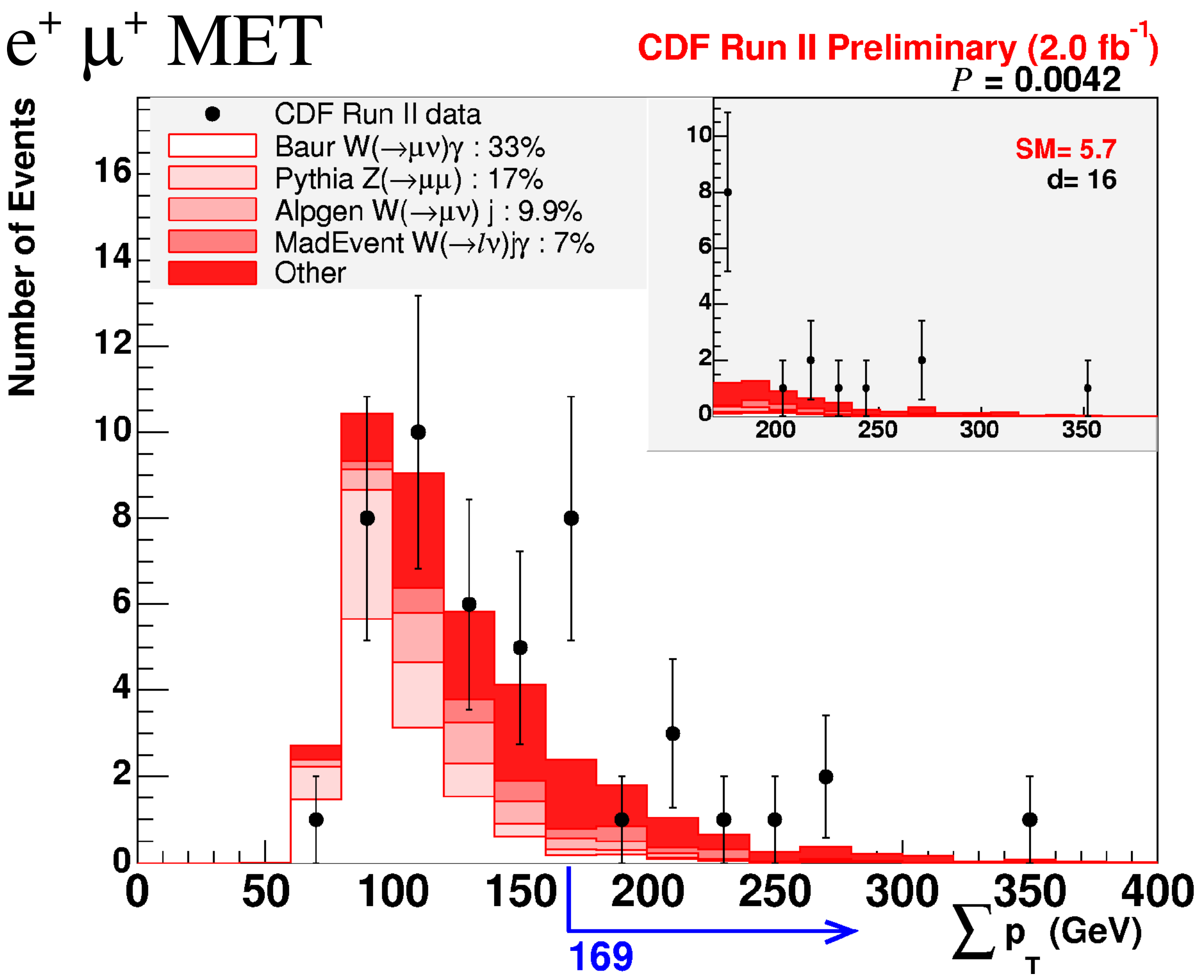
…

Regarding Sleuth #3 State





'Other' for Sleuth #3 State

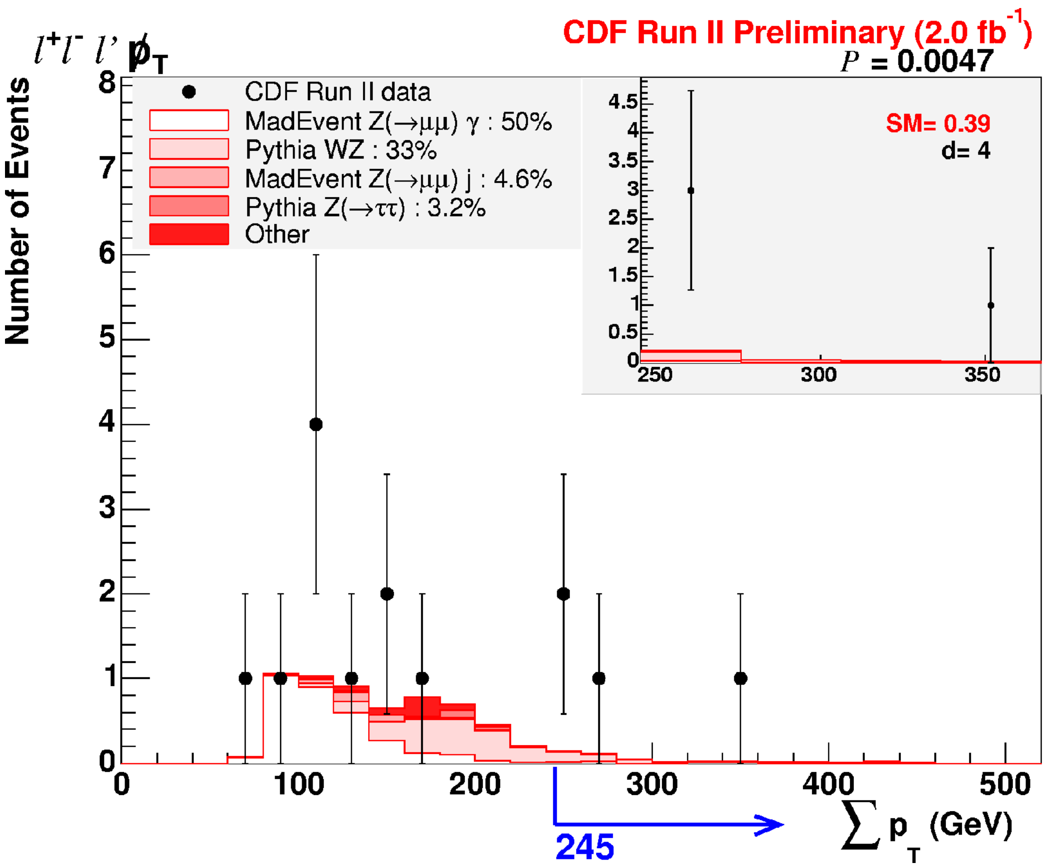


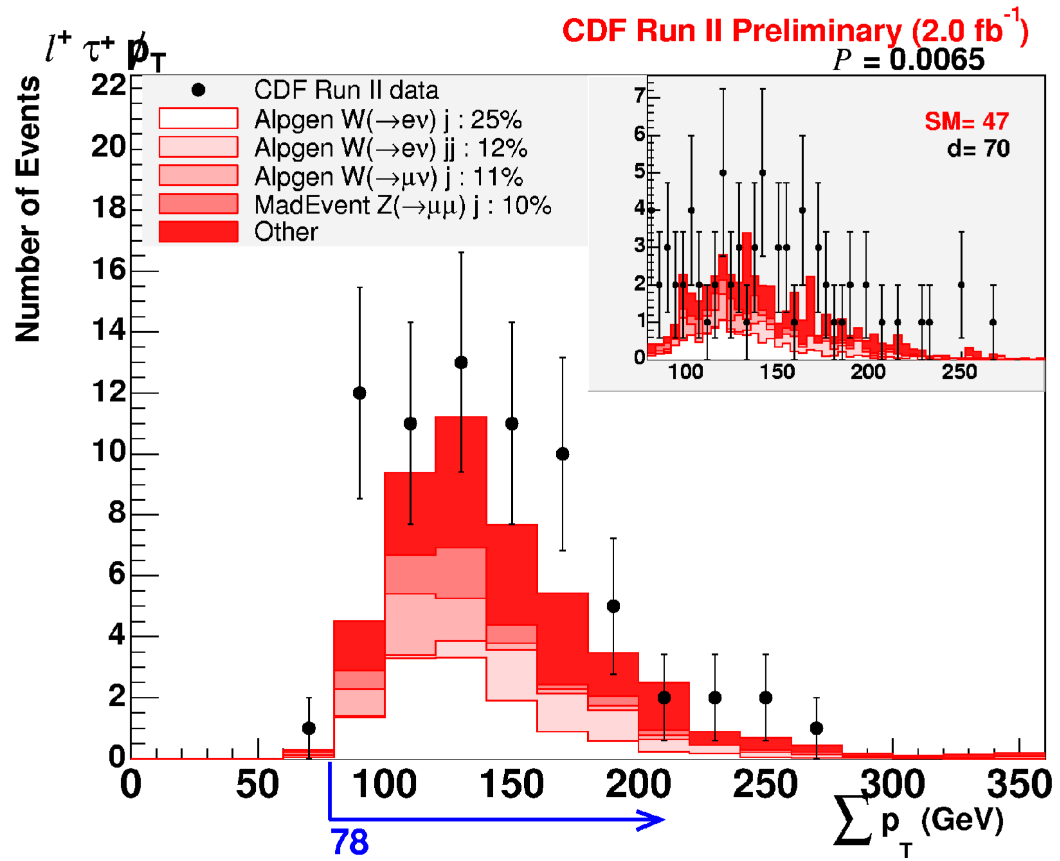
Other contributions:

Pythia WW	7%
Alpgen W(→μν)jj	6%
Pythia WZ	5%
MadEvent Z(→μμ)jj	5%

...

Sleuth's #4 and #5 Final States





Publications

Global Search at CDF on 1.0 fb^{-1}:

arXiv:0712.2534 submitted to Phys Rev Lett.

arXiv:0712.1311 accepted by Phys Rev D

Sleuth previously used in searches at D0 and H1:

D0, Phys. Rev. Lett. 86, 3712 (2001)

D0, Phys. Rev. D 62, 092004 (2000)

D0, Phys. Rev. D 64, 012004 (2001)

H1, Phys. Lett. B 602, 14 (2004)

The CDF Global Search

- Vista: study bulk features of high-p_T data
- Bump Hunter: search for narrow resonances in invariant mass distributions
- Sleuth: search for excesses in high-p_T tails