Mass Measurement at Colliders

Rakhi Mahbubani
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Rencontres de Blois 2012

May 29th 2012

Mass Measurement with MET at Colliders

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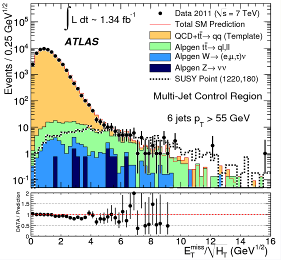
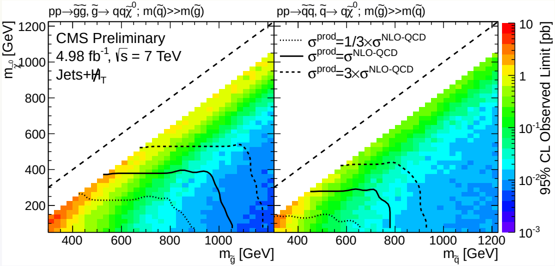
Parameters

WHAT MET?



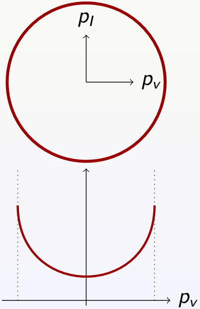


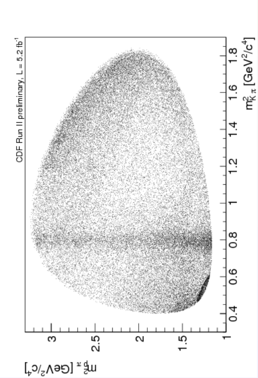
Natural theories with signatures involving large transverse momentum not ruled out. c.f. talks by Csaki, Weiler, ...

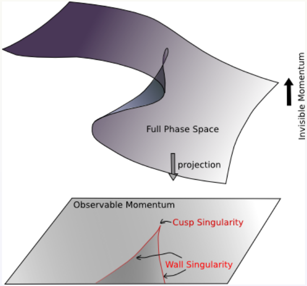
Phase Space

$$\sigma\left(pp \to CD\right) = \sum_{a,b=q,g} \int f_a f_b \int_{\mathrm{PS}} \left|M\left(ab \to CD\right)\right|^2$$

Phase space singularities = edges, endpoints, cusps, ...







Kim 0910.1149

Mass Bound Variables

Barr et al 1105.2977

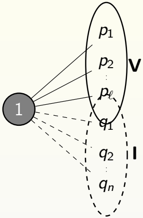
What is best bound for invariant mass of a group of N particles decaying to visibles + invisibles?

$$m_N\left(\not{M}_1, \not{M}_2, \cdots, \not{M}_N\right) = \min_{q_T = \not{p}_T}\left[\max\left(M_1, M_2, \cdots, M_N\right)\right] \leq \max\left(M_1, M_2, \cdots, M_N\right)$$

$$\not{M}_a = \sum_{i=1}^{n_a} m_i$$

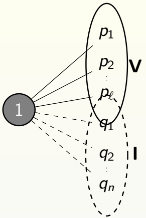
- Gives event-by-event lower bound on maximum parent mass
- Can saturate bound for correct input $\not{M}$

Transverse mass



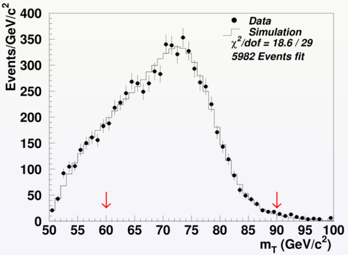
$$m_T\left(\not{M}\right) = m_V^2 + \not{M}^2 + 2\left(\sqrt{\not{p}_T^2 + \not{M}^2}\sqrt{p_T^2 + m_V^2} - \not{p}_T \cdot p_T\right)$$

Transverse mass



$$m_T\,(0) = m_V^2 + 2\left(\sqrt{p_T^2}\sqrt{p_T^2 + m_V^2} + p_T^2\right)$$

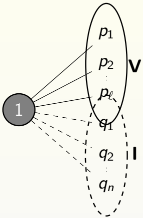
For massless invisibles, no upstream transverse momentum.



CDF 0708.3642

$W \to \ell\nu$

Transverse mass



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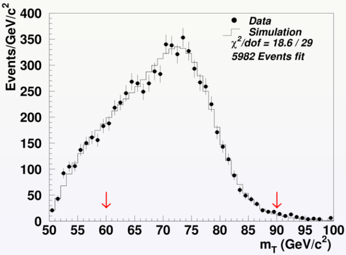


Name depends on context: cluster transverse mass, $m_{T,\text{true}}$, $\sqrt{s}_{\text{min}}$

CDF 0708.3642

$W \to \ell\nu$

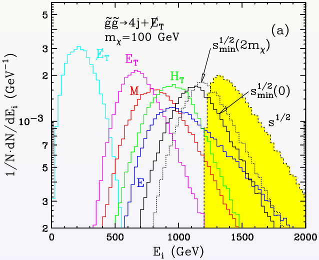
$\sqrt{s}_{min}(0)$

Konar, Kong & Matchev 0812.1042

Correlation between maximum of $\sqrt{s}_{min}(0)$ distribution and sum of parent masses.

Independent of:

- process
- topology
- combinatorics



$\sqrt{s}_{min}(0)$

Konar, Kong & Matchev 0812.1042

Correlation between maximum of $\sqrt{s}_{min}(0)$ distribution and sum of parent masses.

Independent of:

- process
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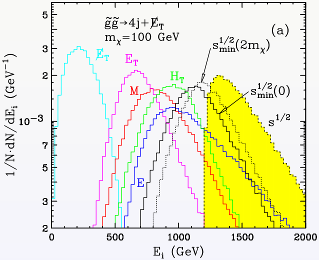
- combinatorics

Caution: correlation dependent on $\not{M}$ and number of invisibles

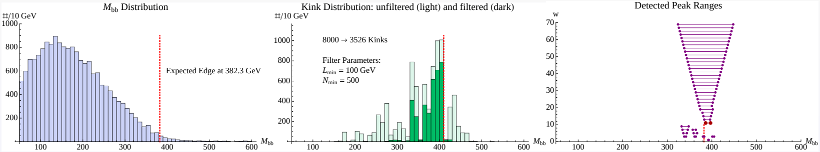


Determining Endpoints

Curtin 1112.1095

Systematic way to automatically extract endpoint position.
Procedure:

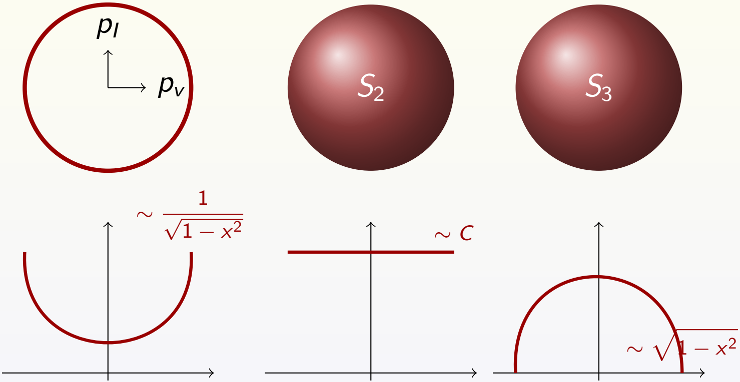
- Fit linear kink distribution to random domains within distribution
- Obtain kink distribution (with filters)
- Detect peaks in kink distribution (bump-hunting) for intervals of varying width w. Real peaks are upside-down growing cones



Code can be found at:
http://insti.physics.sunysb.edu/ curtin/edgefinder/

Counting Invisibles

Giudice, Gripaios, RM 1108.1180



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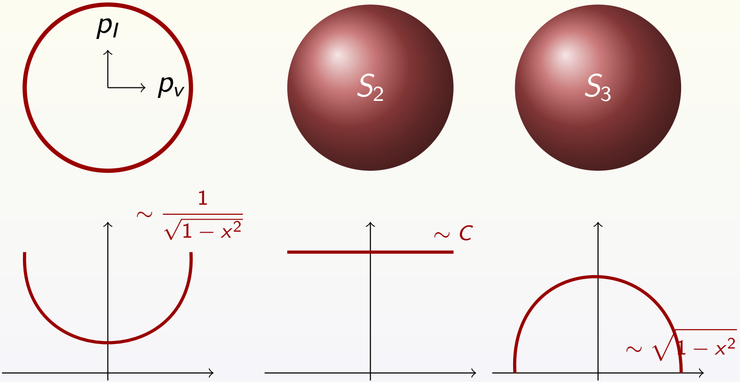
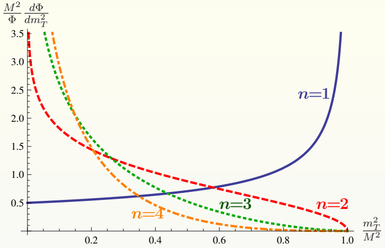
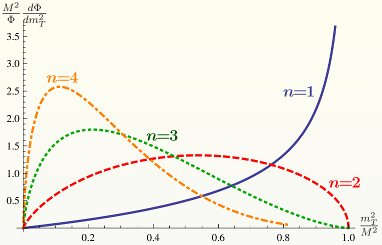


Study near-endpoint behaviour to extract number of invisibles

Single Production



$M \to W + nX$

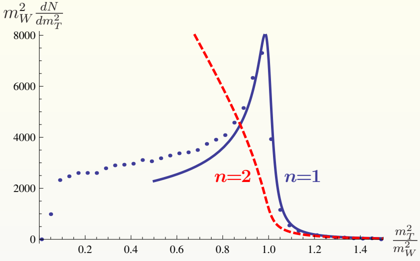


$M \to 2W + nX$

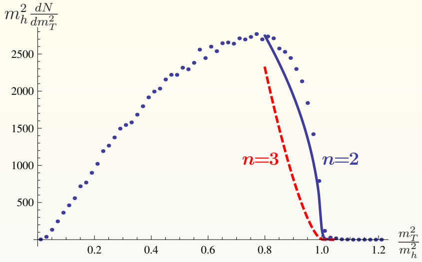
$$\frac{d\Phi}{dm_T^2} \propto \left(1 - \frac{m_T^2}{M^2}\right)^{n-\frac{3}{2}}$$

- Large difference between $n = 1$ and $n > 1$
- Distinguishing between different $n \geq 2$ more difficult
- Near-universal behaviour

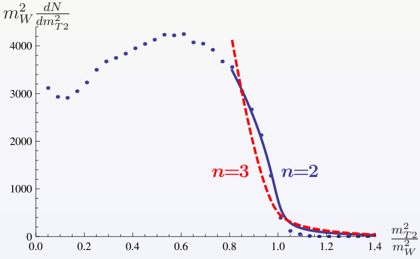
Standard Model Examples



Tevatron, $W \to \ell\nu$



LHC $h \to WW \to \ell\nu\ell\nu$, $m_h = 180$ GeV



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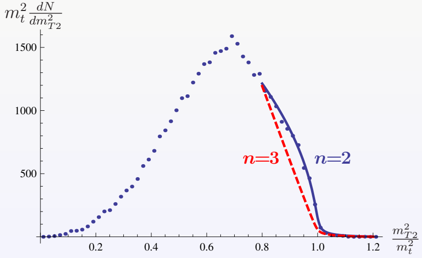
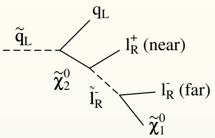
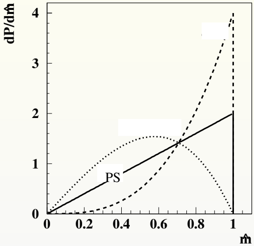


LHC $t\bar{t} \to b\bar{b}WW \to b\bar{b}\ell\nu\ell\nu$

SUSY Example

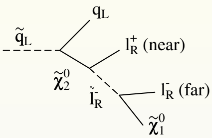




Barr hep-ph/0405052

	$\tilde{u}_L$	χ_2^0	$\tilde{e}_R^-$	χ_1^0
mass (GeV)	631	231	153	116

SUSY Example



m_X / GeV	R-squared $\left(m^2_{T2}\right)$ $n=2$	$n=3$	$n=4$	R-squared $\left(m^2_{V1}\right)$ $k=1$	$k=2$
0	0.947	0.992	0.899	0.992	0.855
100	0.998	0.889	0.822	0.993	0.921
450	0.859	0.991	0.870	0.987	0.911

Barr hep-ph/0405052