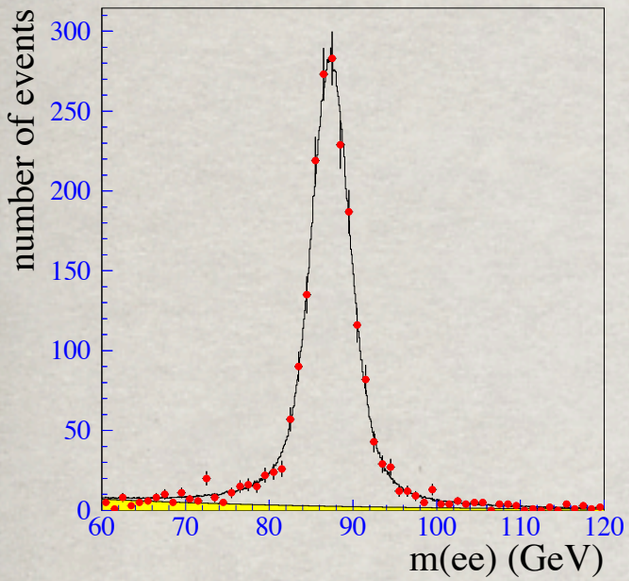
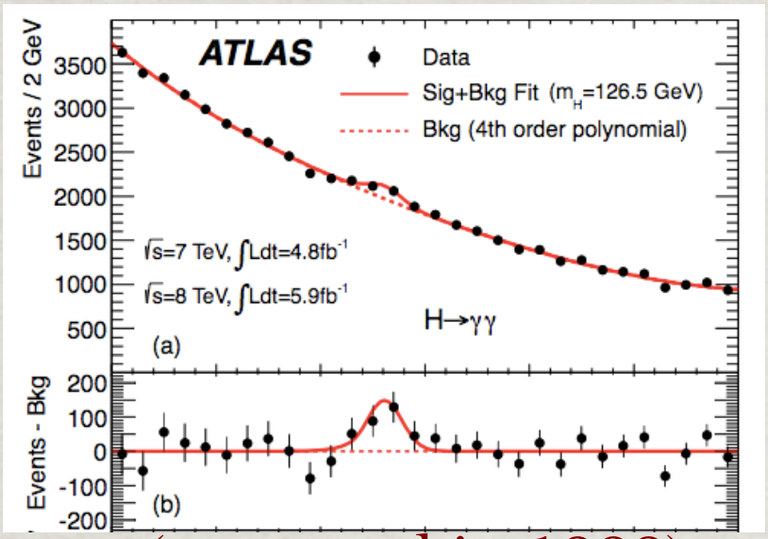
Discovery:
Theory & Experiments hand in hand

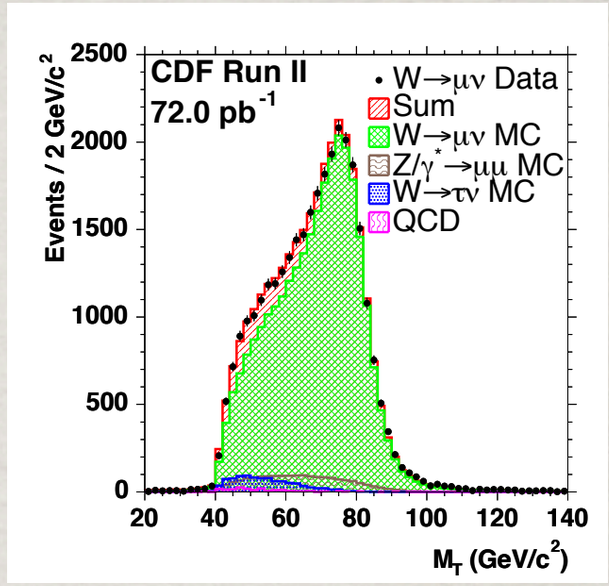
My favorite examples (and work):

From Kinematics to Dynamics

Ex 1: mass & missing mass







proposed in 1983

(proposed in 1988)

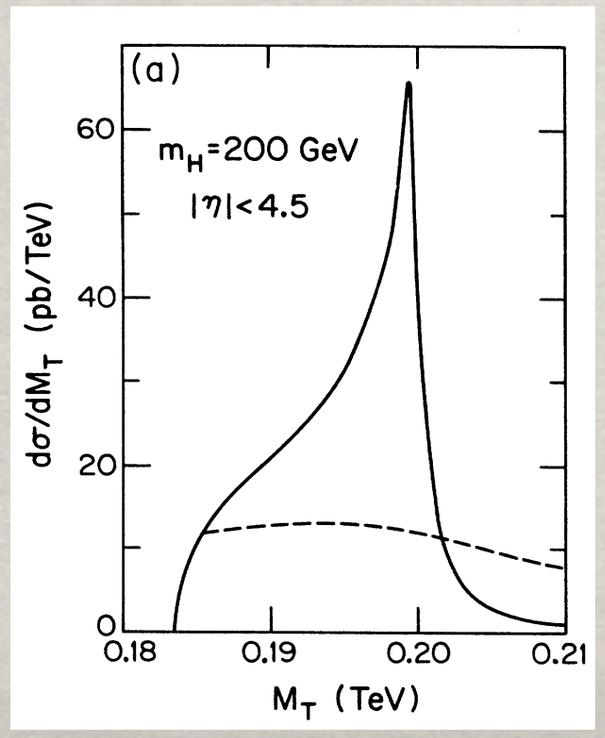
$$\mathrm{m}^2(ab) = 2p_a p_b(1-\cos\theta_{ab}) \qquad \mathrm{m}_T^2(e\nu) = E^2 - p_T^2 = 2p_T^e p_T^\nu(1-\cos\phi_{e\nu})$$

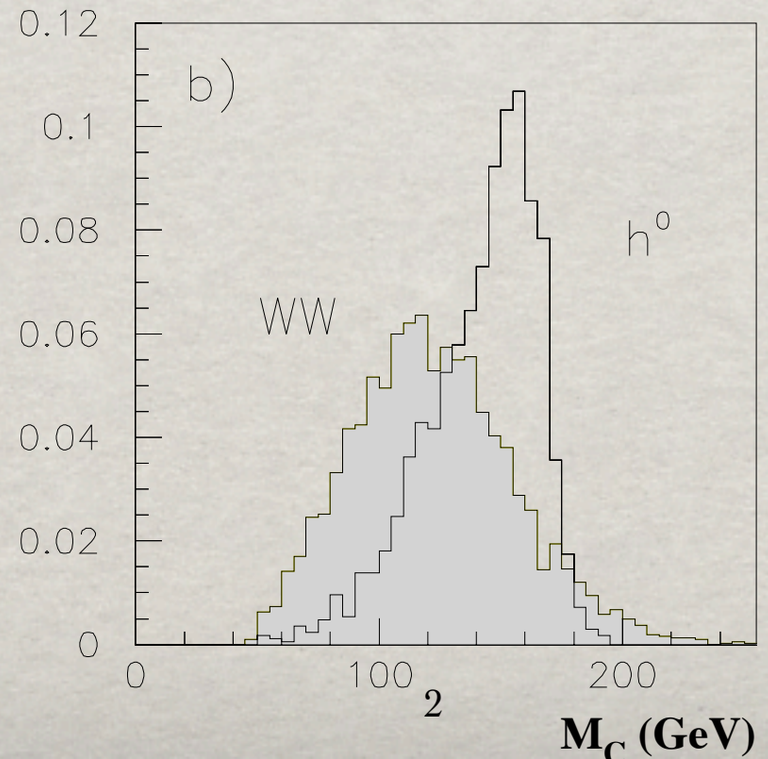
$$h \to ZZ^* \to \ell^+\ell^-\ \nu\bar{\nu}$$

What about

$$\to WW^* \to \ell^+\ell^-\ \nu\bar{\nu}$$

$$m_T^2(cluster) = (E_{T\ell\ell} + E_{Tmiss})^2 - (\vec{p}_{T\ell\ell} + \vec{p}_{Tmis})^2$$





ZZ* mode sharper than WW* mode

proposed in 1987

Now, $pp \to X + \chi^0\chi^0 \to X + E_T(miss)$ very hard to get the mass!

$pp \to X + \chi^0\chi^0 \to 1\ jet\ + E_T(miss)$ hopeless!

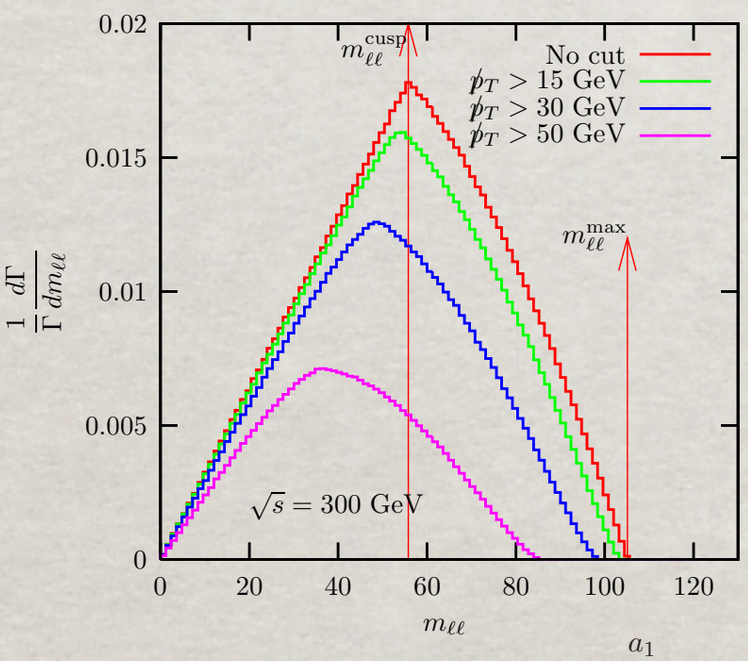
$pp \to \tilde{f}f^* \to f\bar{f}\ \chi^0\chi^0 \to 2\ \text{“}jet\text{”}\ + E_T(miss)$

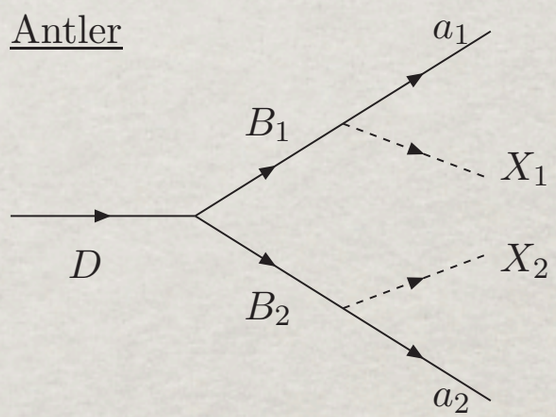
Energy end-point, M_{T2} , … proposed in 1997, 1999

If, $pp \to Z' \to \tilde{f}f^* \to 2\ \text{“}jet\text{”}\ + E_T(miss)$ and knowing $M_{Z'}$

$e^+e^- \to \tilde{f}f^* \to 2\ \text{“}jet\text{”}\ + E_T(miss)$

“Antler kinematics”: proposed in 2009

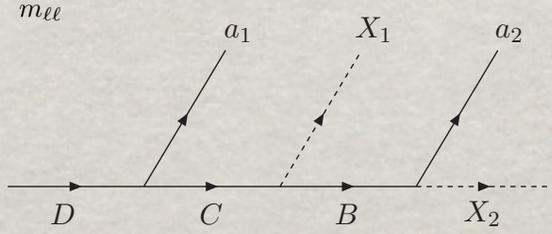




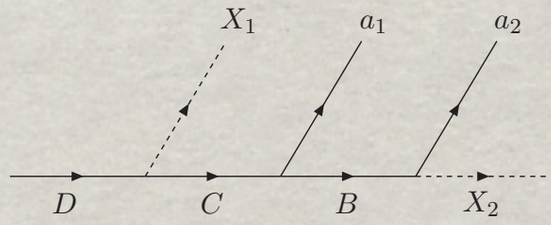
$$M_{aa}^{\rm max} = m_B\left(1 - \frac{m_X^2}{m_B^2}\right)e^{\eta}$$

$$M_{aa}^{\rm cusp} = m_B\left(1 - \frac{m_X^2}{m_B^2}\right)e^{-\eta}.$$

Cascade decays:



Cascade Type I



Cascade Type II

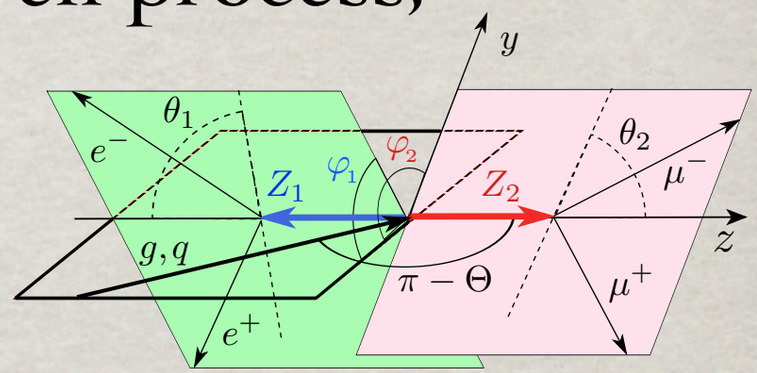
Ex 2: Asymmetries

LHC (unlike Tevatron) has symmetric beams,
so it is not simple to define an asymmetry.

For forward-backward asymmetry (parity property),
we can define the quark along the boost direction. $y \sim \frac{1}{2} \ln \frac{x_1}{x_2}$

For CP asymmetry, it should be compared with $\bar{p}\bar{p}$ collider!

This is avoided if we can identify a CP-even process,
and define a CP-old variable:



$h \to ZZ^* \to e^+e^- \ \mu^+\mu^-$ proposed in 1993

$A_{CP} \sim (\vec{p}_- \times \vec{p}_+ \cdot \vec{k}_-)[(\vec{p}_- \times \vec{p}_+) \cdot (\vec{k}_- \times \vec{k}_+)].$

What about $q\bar{q} \to W^+W^-, \ \chi^+\chi^- \to \mu^+\mu^- + E_T(miss)$

$(\vec{p}_f \times \vec{p}_{\bar{f}}) \cdot \vec{p}_q.$ $\quad (\vec{p}_f \times \vec{p}_{\bar{f}}) \cdot \hat{p}_q \ \mathrm{sgn}((\vec{p}_f - \vec{p}_{\bar{f}}) \cdot \hat{p}_q).$ proposed in 2009

What about $q\bar{q} \to \tilde{t}\tilde{t}^* \to b\bar{b} + \ell^+\ell^- + E_T(miss)$

In anticipation of discovery, a lot theory work to do!