A new CP violating observable for the LHC

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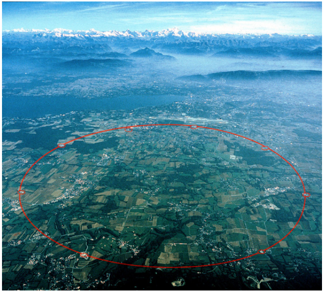
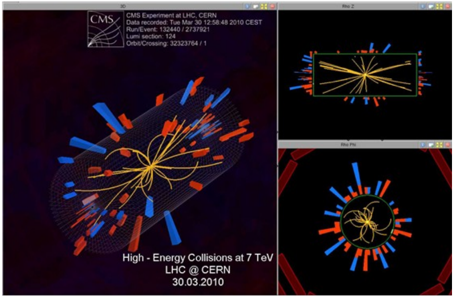
The LHC era has begun!





After discovery:

1. Identify new states
2. Measure masses and spins
3. Measure couplings, flavor structure, CP-violation

Seeing CP-violation

$$\mathcal{A}_{\mathrm{CP}} = \frac{\Gamma(i \to f) - \Gamma(\bar{i} \to \bar{f})}{\Gamma(i \to f) + \Gamma(\bar{i} \to \bar{f})} \neq 0$$

Requirements:

1. Two interfering amplitudes a_1, a_2
2. Different weak (CP-odd) phases ϕ_1, ϕ_2
3. Different strong (CP-even) phases δ_1, δ_2

$$\mathcal{A}_{\mathrm{CP}} \propto |a_1||a_2| \sin(\phi_1 - \phi_2) \sin(\delta_1 - \delta_2)$$

How can we get a calculable strong phase?

A new calculable strong phase

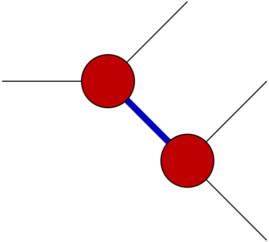
Requirements:

1. Heavy Majorana fermion
2. Three-body decay
3. On-shell charged resonance

Result:

CP-asymmetry in Dalitz plot

Strong phase from the propagator



$$= \mathcal{M}_1 \frac{1}{q^2 - m^2 + i\Gamma m} \mathcal{M}_2$$

Strong phase from intermediate particle:

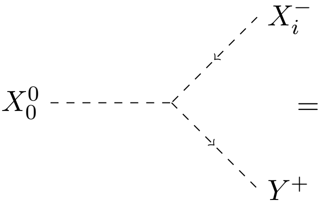
1. Different **particles**
2. Different **virtuality**

A toy model

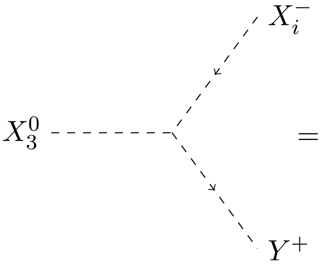
Heavy neutral particle: X_0^0

Charged resonance: $Y^{\pm}$

Lighter particles: $X_{1,2}^{\pm}$, X_3^0



$= -iae^{i\varphi_a}$

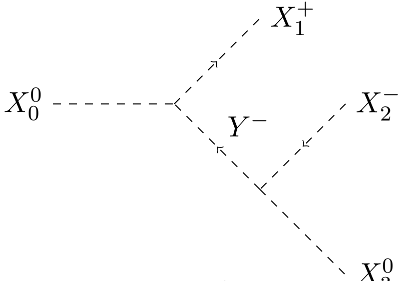


$= -ibe^{i\varphi_b}$

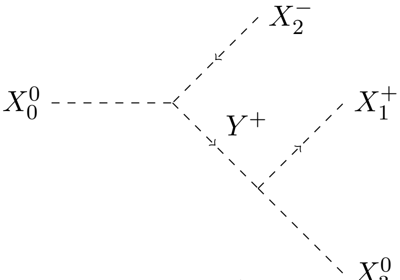
One weak phase: $\varphi = \varphi_b - \varphi_a$

Toy model decays

Relevant decay: $X_0^0 \to X_1^+ X_2^- X_3^0$



$$= e^{i\varphi} \frac{1}{q_{23}^2 - m_Y^2 + i m_Y \Gamma_Y}$$



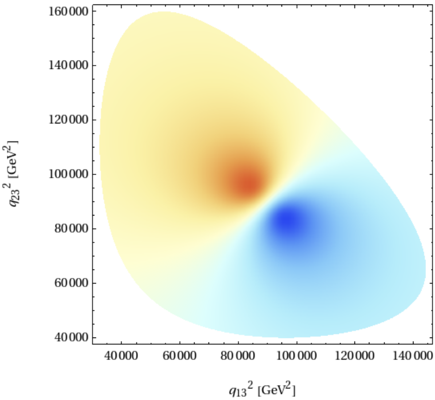
$$= e^{-i\varphi} \frac{1}{q_{12}^2 - m_Y^2 + i m_Y \Gamma_Y}$$

Two diagrams, different weak phase, different strong phase

$$\mathcal{A}_{\mathrm{CP}}^{\mathrm{diff}} \propto \sin 2\varphi (q_{13}^2 - q_{23}^2) \Gamma_Y m_Y$$

Source of strong phase

$$\mathcal{A}_{\mathrm{CP}}^{\mathrm{diff}} \propto \sin 2\varphi (q_{13}^2 - q_{23}^2)\Gamma_Y m_Y$$



$\mathcal{A}_{\mathrm{CP}}^{\mathrm{diff}} = 0$ if

- $\varphi = 0$
- $\Gamma_Y = 0$ or $q_{13}^2 = q_{23}^2$

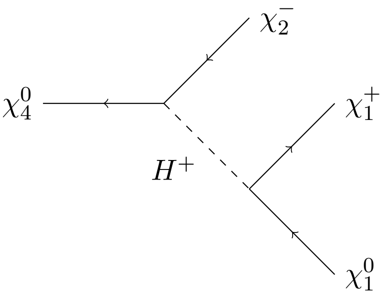
$\mathcal{A}_{\mathrm{CP}}^{\mathrm{diff}}$ maximal $\Gamma_Y m_Y$ from m_Y^2

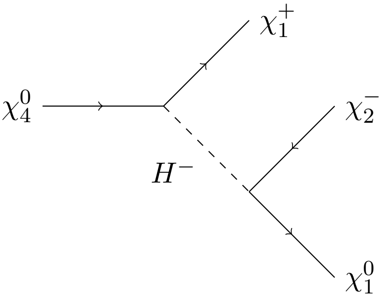
An MSSM example

Heavy neutral particle: χ_4^0 ($\tilde{B}$)

Charged resonance: $H^\pm$

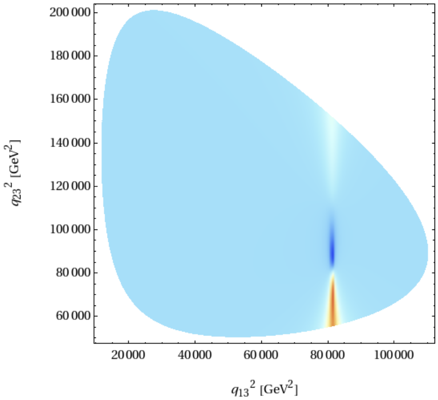
Lighter particles: $\chi_{1,2}^\pm$, χ_1^0





One weak phase: $\arg(\mu b^* M_2)$

MSSM results



Suppressed integrated asymmetry:

$$\mathcal{A}_{\mathrm{CP}}^{\mathrm{int}} \propto \frac{|\mu M_2|\Gamma_{H^\pm}\Delta m_{\chi^\pm}}{M_1^3 m_{H^\pm}} = -3.5\times 10^{-5}$$

Using phase space weighting:

$$\mathcal{A}_{\mathrm{CP}}^{\mathrm{wgt}} = -6.5\times 10^{-4}$$

The ingredients

Recipe for Dalitz plot asymmetry:

- Heavy Majorana particle
- Three-body decay
- On-shell charged resonance

Looking for an ideal candidate!