Symmetry tests using η(‘) mesons

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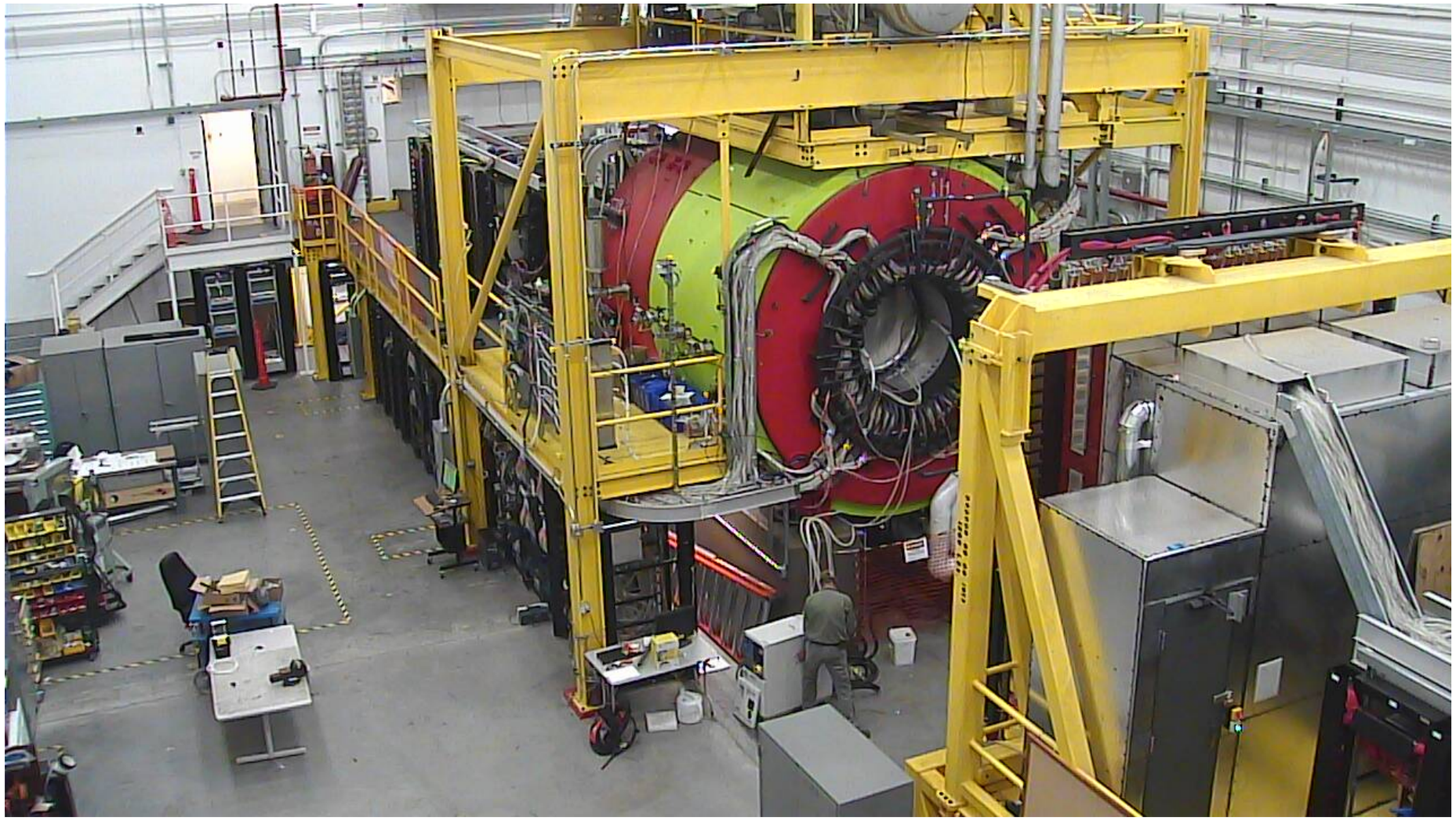
Introduction

Disclaimer: I've just very recently starting thinking about this topic, so excuse me if I've missed something obvious interesting ... or listed something as interesting that obviously isn't.



GlueX was designed to search for "hybrid mesons" which requires good efficiency/PID for many-body final states containing both charged and neutral particles ... what else can we do with it?

Yields

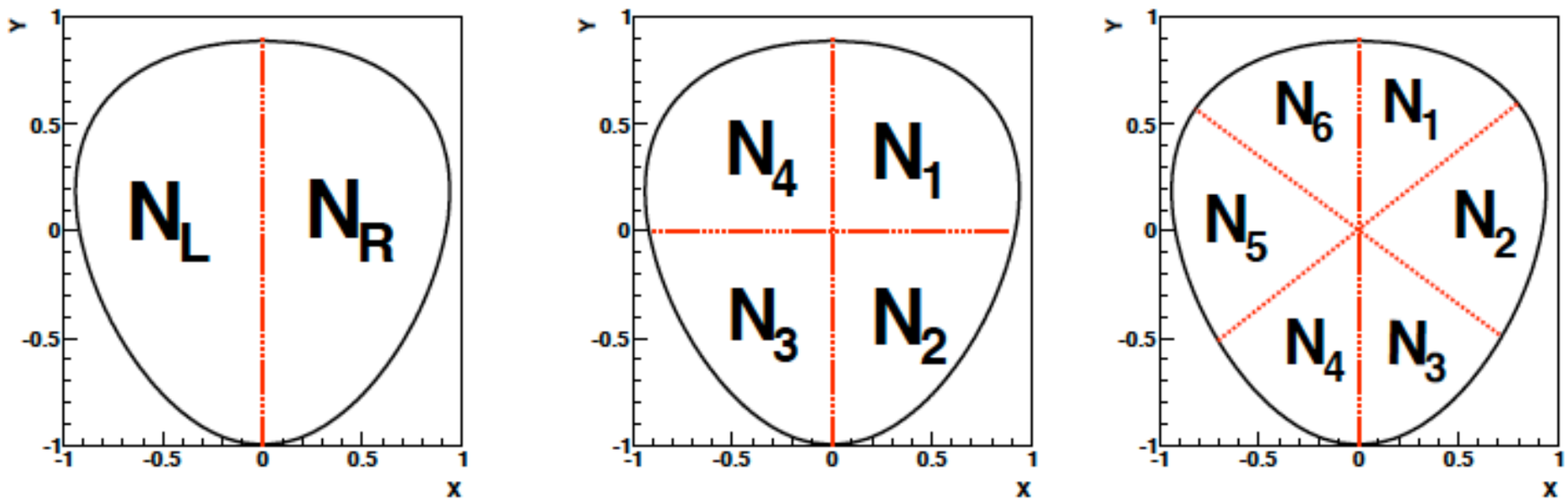
The yields expected to produced in GlueX during its ~4-year run are:

- $O(10^{10})$ η(X) and $O(10^{9})$ η'(X);
- X fully reconstructible for $O(10^{8})$ η(X) and $O(10^{7})$ η'(X);
- many η(') decays possible to fully reconstruct;
- resolution is better with fully reconstructed final state and backgrounds will be lower ... will assume here that we need to fully reconstruct the final state.

Let's look at some ideas of studies that could (most likely) be done at GlueX, starting first with the "baseline" detector (pre-JEF).

η→πππ

Can search for C violation in η→3π. Past searches all seem to use X,Y parametrization instead of standard Dalitz variables. Search for C violation has involved fitting moments of XY or the following asymmetries are reported:



$$A_{LR} = \frac{N_R - N_L}{N_R + N_L}$$

$$A_Q = \frac{N_1 + N_3 - N_2 - N_4}{N_1 + N_2 + N_3 + N_4}$$

$$A_S = \frac{N_1 + N_3 + N_5 - N_2 - N_4 - N_6}{N_1 + N_2 + N_3 + N_4 + N_5 + N_6}$$

Largest stats "competitor" is KLOE with 5M; KLOE-2 should get ~13M. KLOE resolution on X,Y ~ 0.02.

GlueX: ~15M with σ(X,Y) ~ 0.03, and ~20k η'→3π.

C(P)V Searches

Can search for C(P)V in model-independent way without fitting. This is essentially a "2 sample test". The most powerful one I've used is the "energy test" which constructs:

Aslan & Zech, SCS 75 (2004)
MW, JINST 5 (2010) [1006:3019]

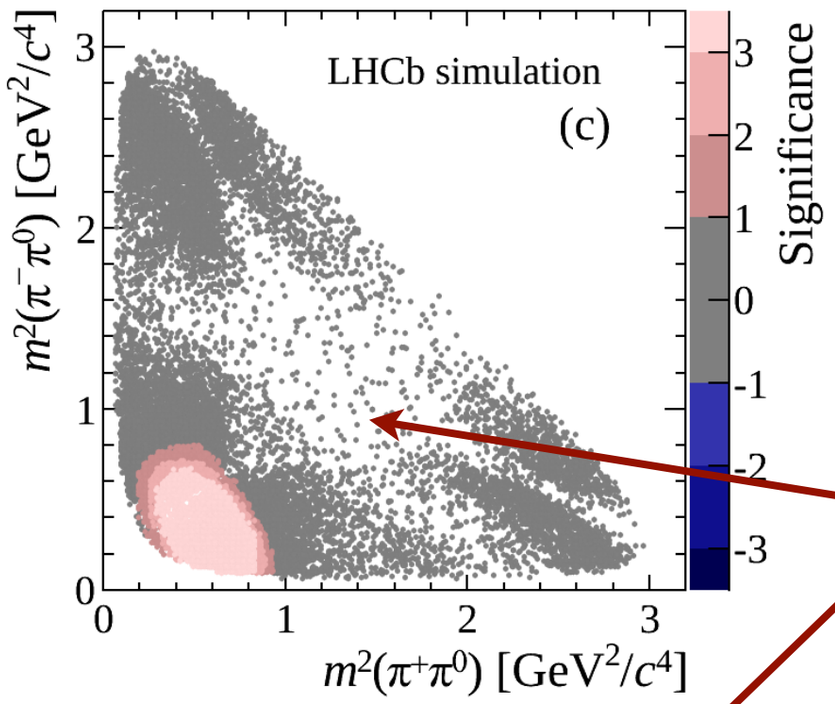
$$
\begin{aligned}
T &= \frac{1}{2}\int\int \left(f(\vec{x}) - \bar{f}(\vec{x})\right)\left(f(\vec{x}') - \bar{f}(\vec{x}')\right) \\
&\qquad \times\psi(|\vec{x}-\vec{x}'|)d\vec{x}d\vec{x}' \\
&= \frac{1}{2}\int\int \left[f(\vec{x})f(\vec{x}') + \bar{f}(\vec{x})\bar{f}(\vec{x}') - 2f(\vec{x})\bar{f}(\vec{x}')\right] \\
&\qquad \times\psi(|\vec{x}-\vec{x}'|)d\vec{x}d\vec{x}' \qquad \approx \frac{1}{n(n-1)}\sum_{i,j>i}^{n}\psi(\Delta\vec{x}_{ij}) \\
&\qquad + \frac{1}{\bar{n}(\bar{n}-1)}\sum_{i,j>i}^{\bar{n}}\psi(\Delta\vec{x}_{ij}) - \frac{1}{n\bar{n}}\sum_{i,j}^{n,\bar{n}}\psi(\Delta\vec{x}_{ij}),
\end{aligned}
$$

Can use this on any multivariate samples provided you do C(P) conjugation then simply feed the test. I developed some nice visualization for this.

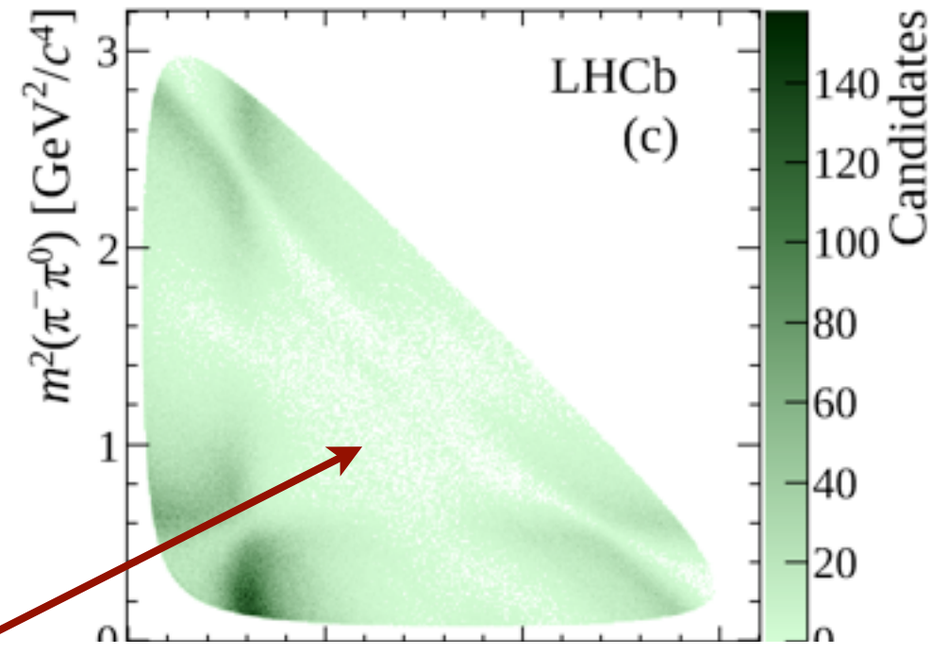
MW, PRD 84, 054015 (2011) [1105:5338]

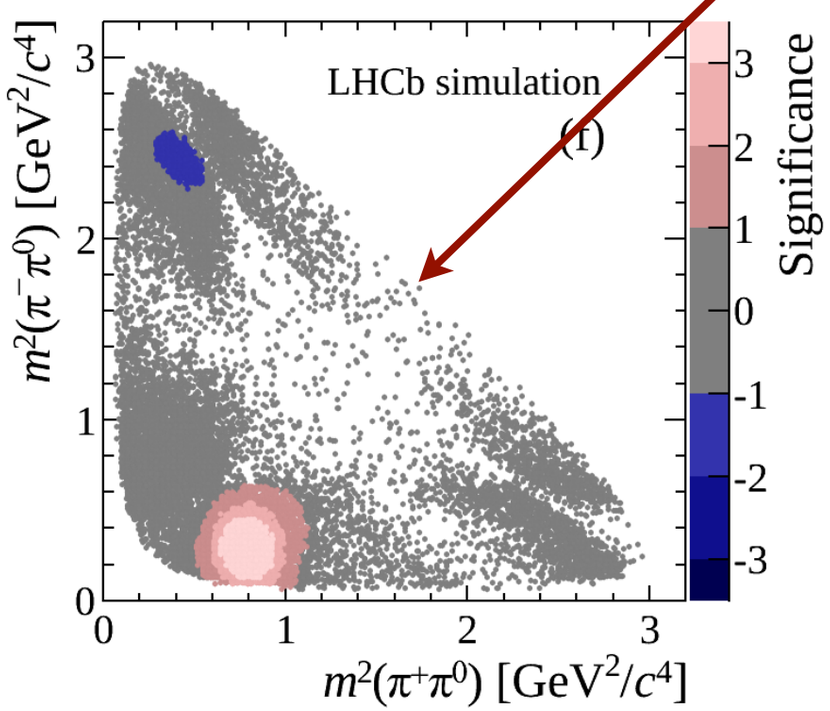
Use@LHCb

Search for CPV in ~700k tagged D0→3π decays.

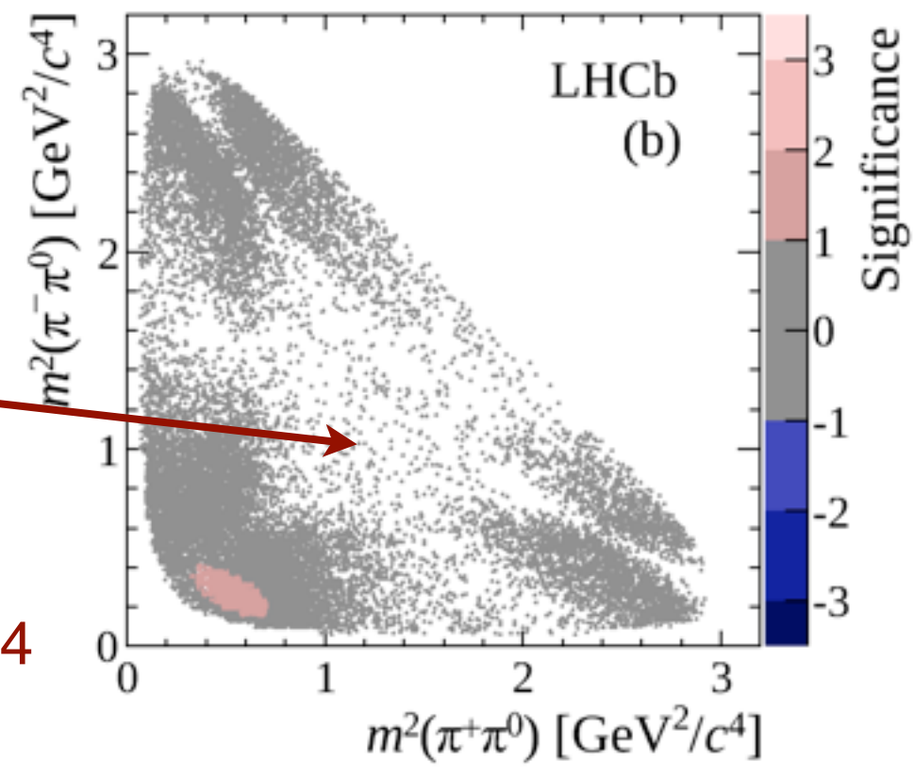


Simulated events with "injected" CPV of different types.





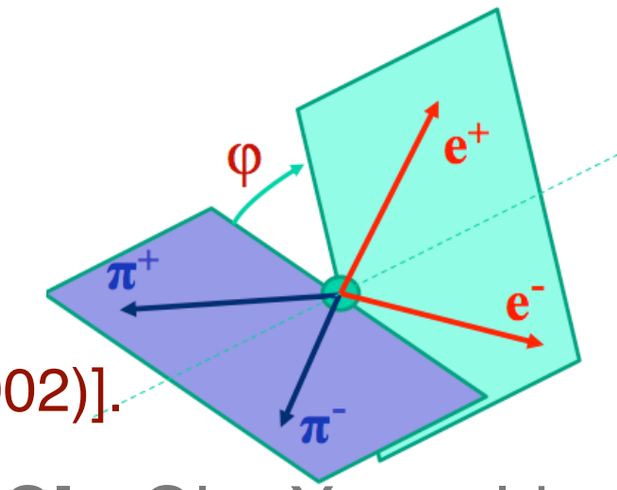
Real data ... no evidence for CPV; global p-value ~2%.



LHCb-PAPER-2014-054
[1410:4170]

More Decays

- Could play same game with $\eta' \to \pi\pi\eta$. BESIII has ~200k events with $\sigma(X,Y) \sim 0.03$. GlueX expects to collect ~4M with $\sigma(X,Y) \sim 0.03$.



- CPV in $\eta \to \pi\pi ee$: ~20k (c.f. KLOE2 ~5k); $\eta' \to \pi\pi ee$: ~40k.

  Probe CPV flavor-conserving ssuu-type operators [Gao, MPLA17(2002)].

- CPV $B(\eta \to \pi\pi) < 10^{-5}$ [PDG], $B(\eta' \to \pi\pi) < 6\times10^{-5}$ [PDG]. GlueX could improve these by factors of O(100).

  Any possible "well motivated" way this isn't ruled out by EDMs?

- CV $B(\eta \to \pi^0 ee) < 4\times10^{-5}$ [PDG], $B(\eta' \to \pi^0 ee) < 10^{-3}$ [PDG]. GlueX could improve by factor O(100) and O(1000), respectively.

- CV $B(\eta' \to \eta ee) < 2\times10^{-3}$ [PDG]. GlueX could improve by factor O(1000).

*Assuming e ID works well at GlueX (being worked on now).

Summary

- Baseline GlueX η and η' yields for many C(P)V modes much larger than previous experiments.

- Are there "well motivated" reasons to expect to see something in any of these modes given constraints from EDMs etc?

- With JEF CALO, modes with many neutrals come into play, e.g., $\eta \to 3\gamma$.

- What did I miss?