INFN - Sezione di Ferrara

Università degli Studi di Ferrara

Inclusive Measurements of $h_c(^1P_1)$ in $\Psi(2S)$ Decay

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Outline:

- **The Goal of The Analysis**;
- **General Information**;
- **General Selection Criteria**;
- **Event Selection**:
  - **Inclusive**;
  - **E1 Tagged**;
- **Next Steps**.

The Goal of The Analysis

Measure M and Γ of the $h_c(^1P_1)$ with higher precision wrt Phys. Rev. Lett. 104, 132002 (2010) [BAM-00001]:

$\underline{M(h_c) = 3525.40 \pm 0.13 \pm 0.18 \text{ MeV}}$
$\underline{\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28 \text{ MeV}}$

Measurements of branching ratios ($\Psi' \longrightarrow \pi^0 h_c$, $h_c \longrightarrow \gamma \eta_c$) will be performed too.

<u>Previous Analysis: 106M of Ψ(2S) events</u>
<u>This Analysis: 500M of Ψ(2S) events</u>

Enhancement in the knowledge of $M(h_c)$ could lead to better knowledge in the hyperfine (spin-spin) mass splitting among $\chi(1\ ^3P_1)$ and h_c:

> From <u>https://arxiv.org/pdf/1508.02178.pdf</u> (T. Kawanai & S. Sasaki): "In the current experiments, however, the splitting $M_{hyp}(^1P) = M(1\ ^3P_1) - M(h_c)$ for 1P -charmonium states is not appreciably observed within experimental error" .

$\underline{\Delta M_{hyp} \equiv M(1\ ^3P_1) - M(h_c) = -0.10 \pm 0.13 \pm 0.18 \text{ MeV}}$

General Informations

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Decay Psi(2S)
1.0000 h_c π_0 PHSP;

Decay h_c
1.0000 $\gamma\eta_c$ PHSP;

****

- **Signal MC** Run;
- 80000 events;
- Release: 6.6.4.p03 .

Inclusive Decay: $\Psi' \longrightarrow \pi^0 h_c$

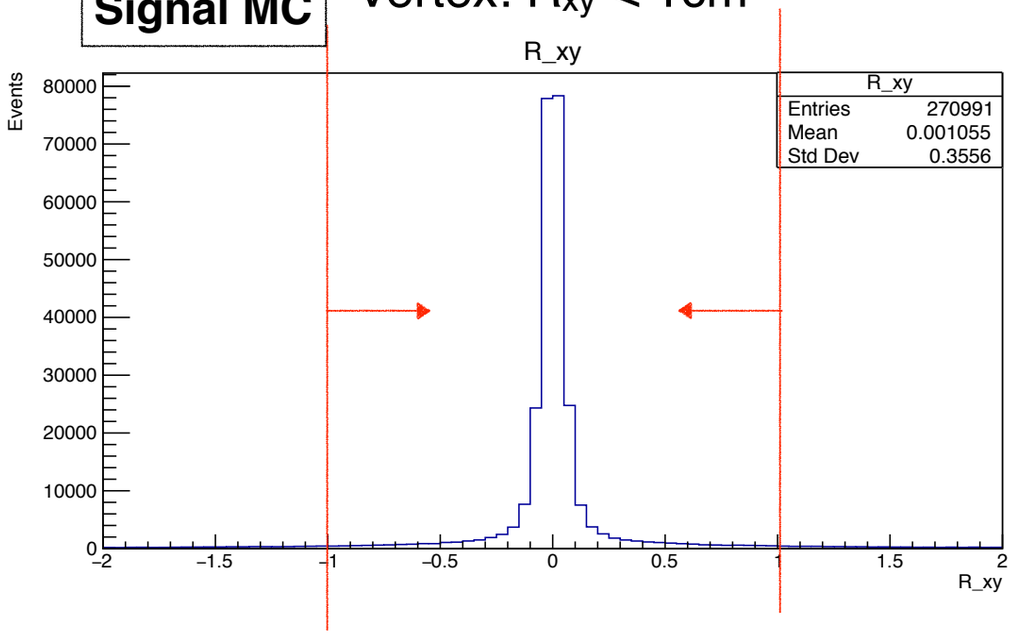
E1 Tagged Decay: $h_c \longrightarrow \gamma \eta_c$

General Selection Criteria

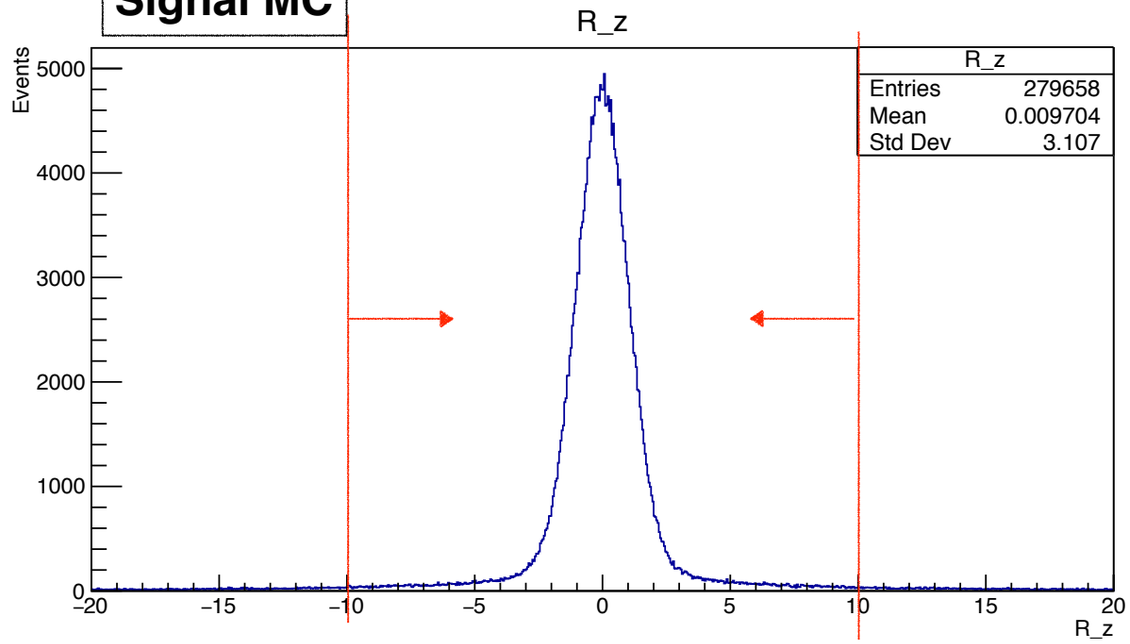
Charged Tracks

At least 2 charged tracks with at least 1 good

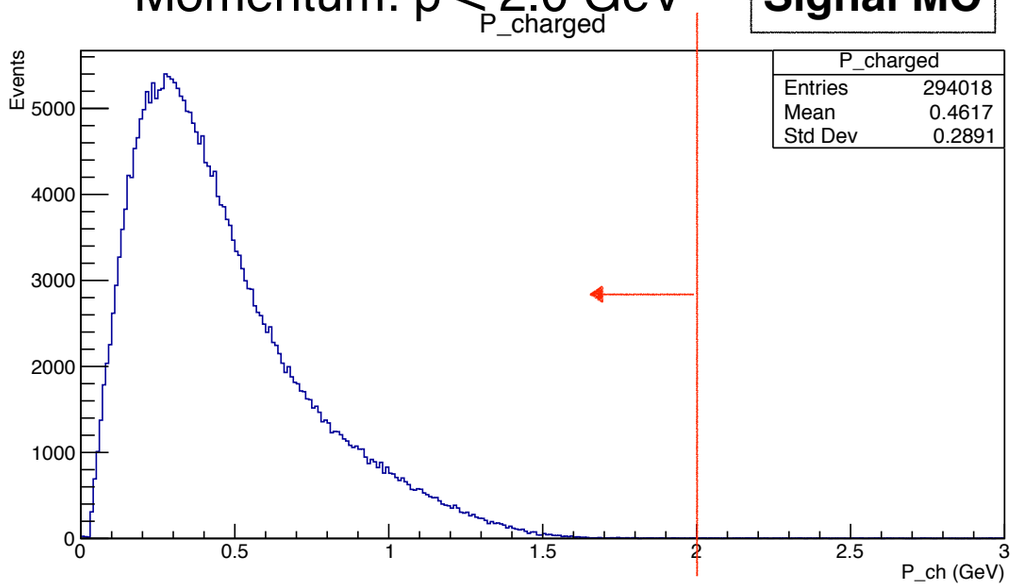
Signal MC Vertex: $R_{xy} < 1$cm



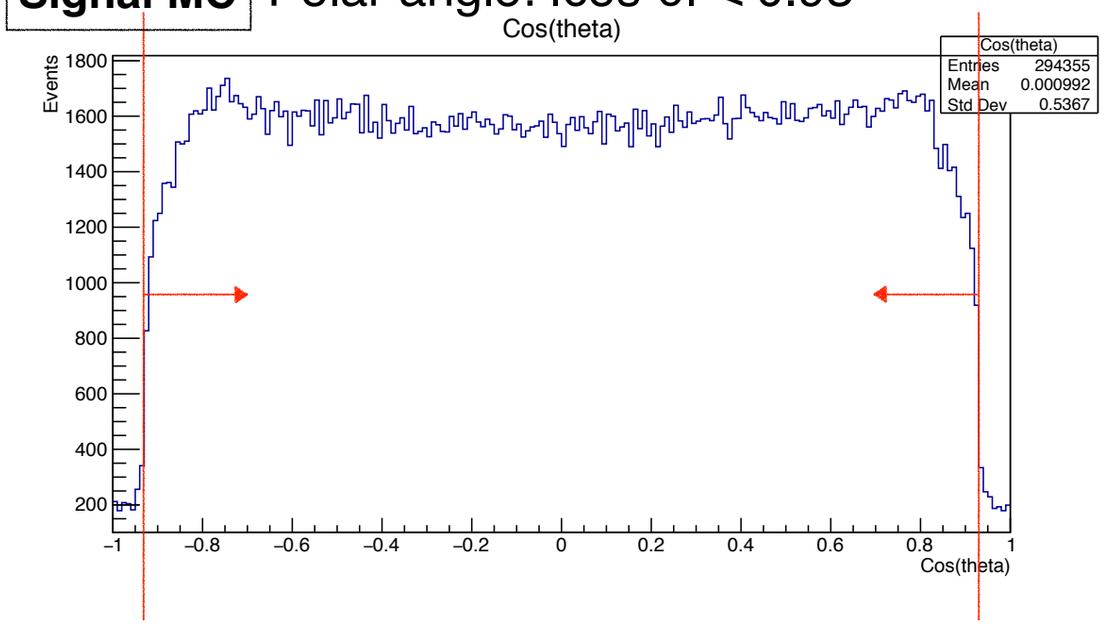
Signal MC $R_z < 10$ cm



Momentum: $p < 2.0$ GeV **Signal MC**



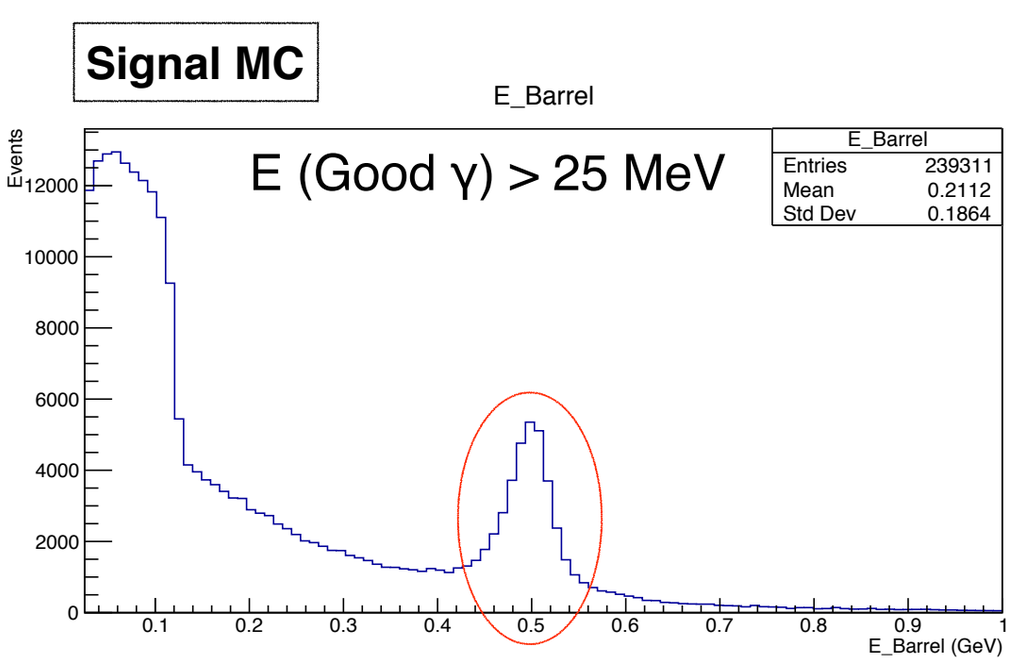
Signal MC Polar angle: $|\cos\theta| < 0.93$

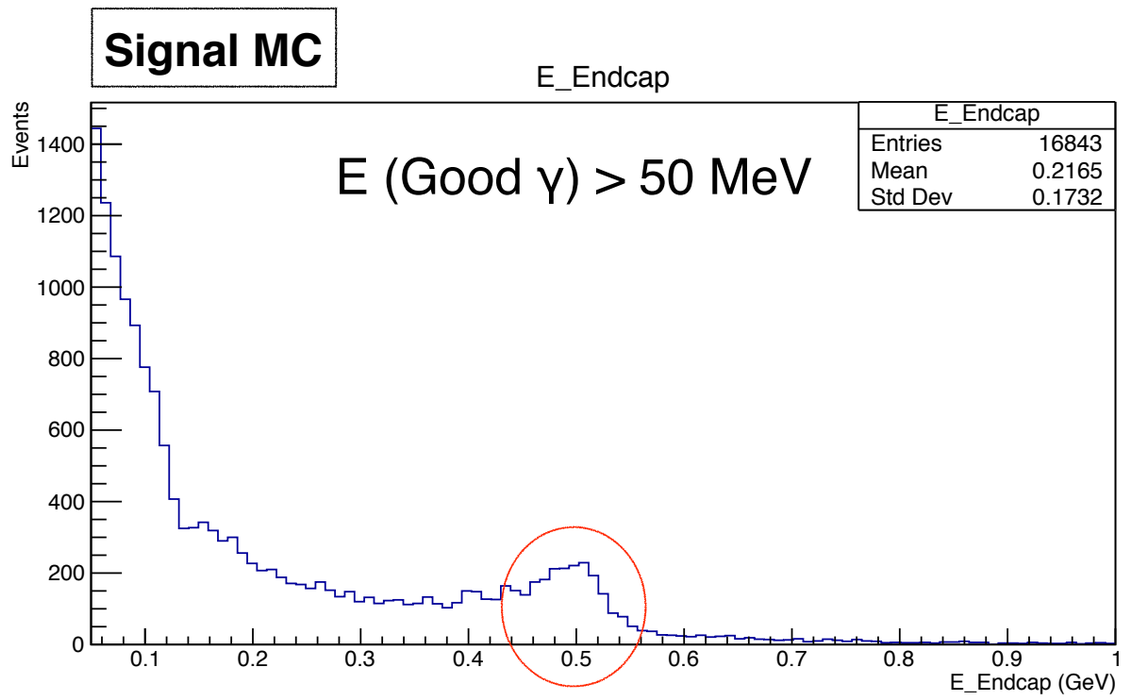


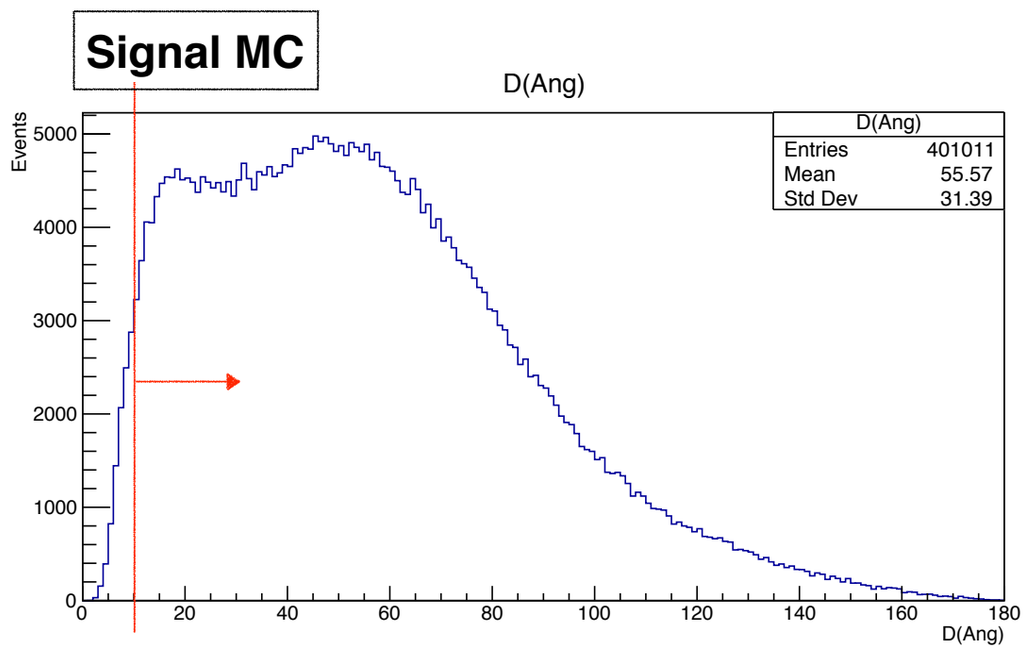
General Selection Criteria

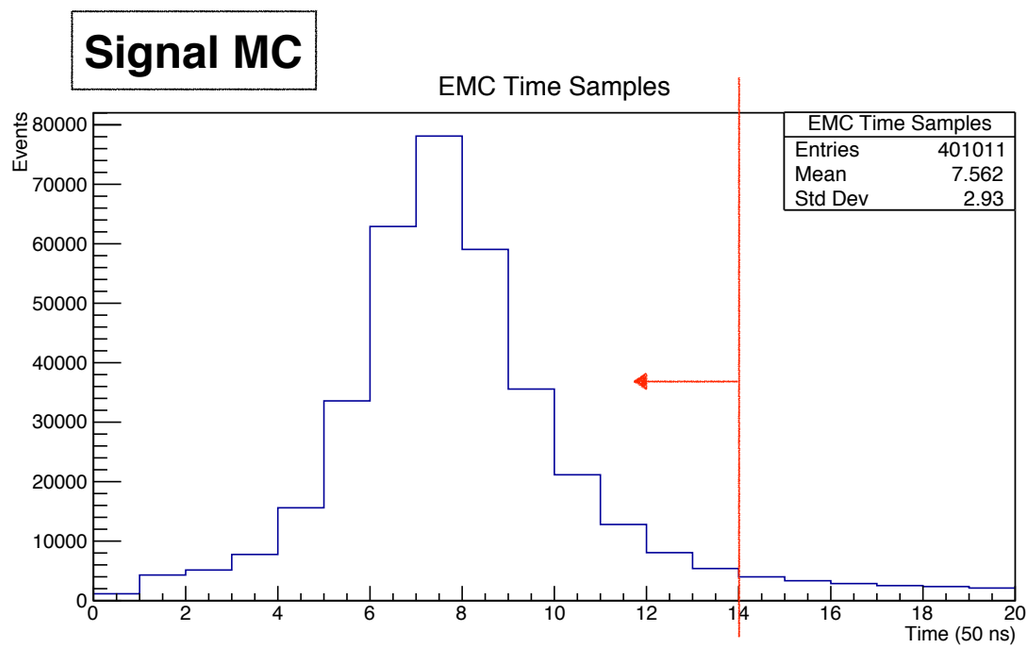
Photons

At least 2 good photons for $\psi(2S) \rightarrow \pi_0 h_c$
At least 3 good photons for $\psi(2S) \rightarrow \pi_0 h_c$, $h_c \rightarrow \gamma \eta_c$.



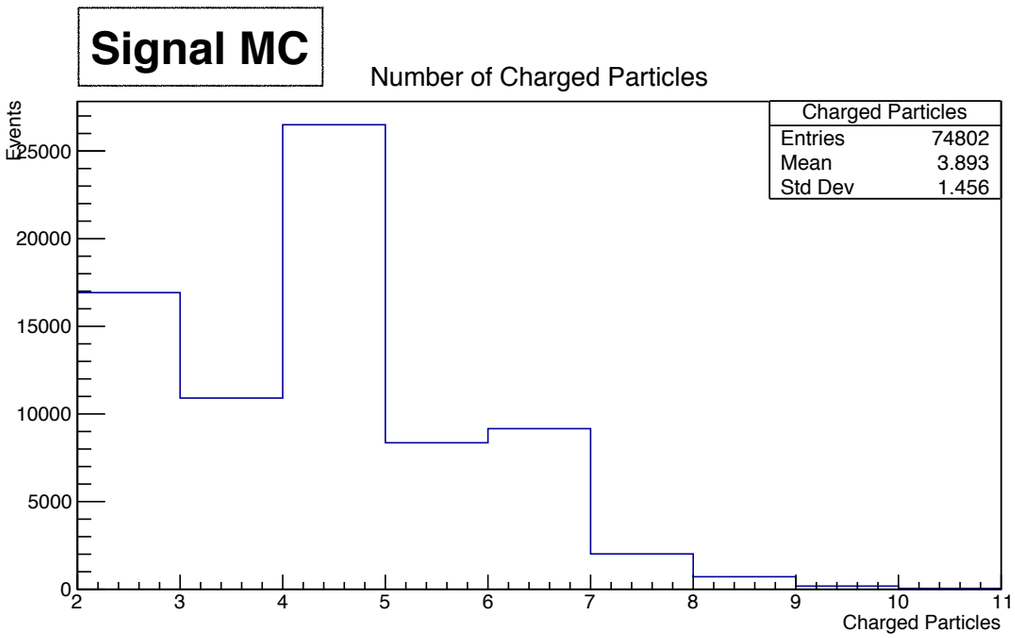


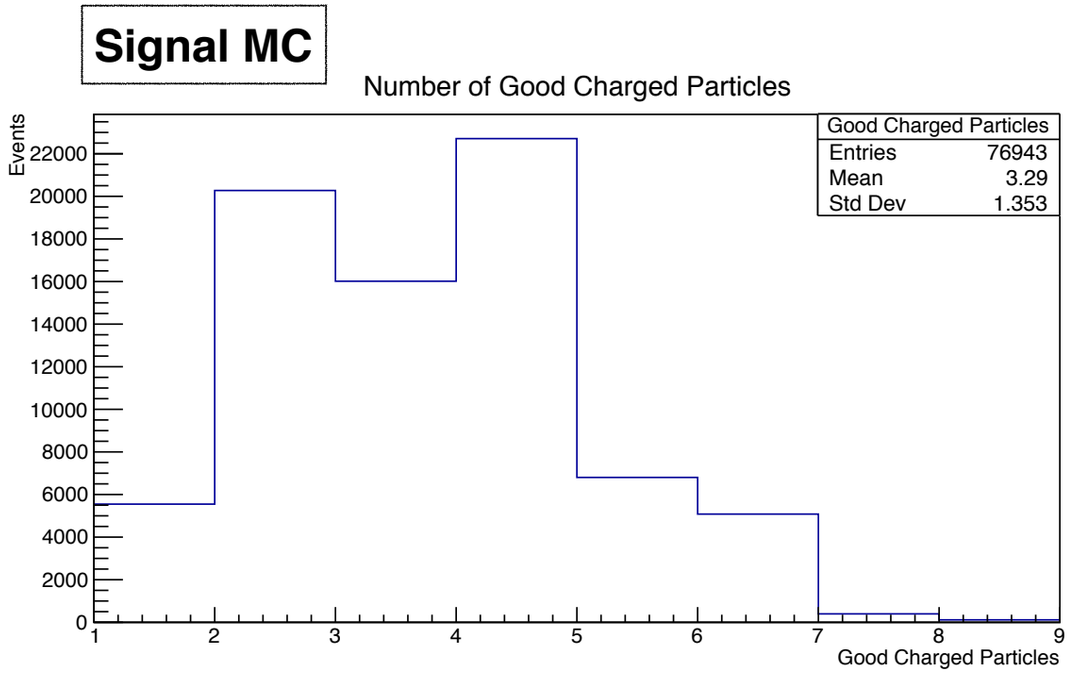


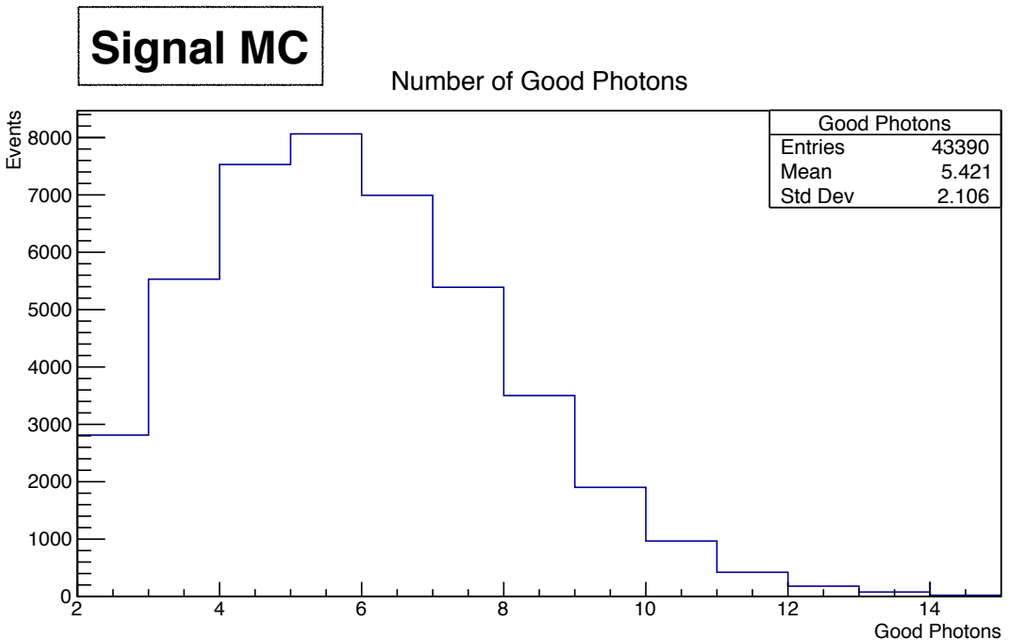


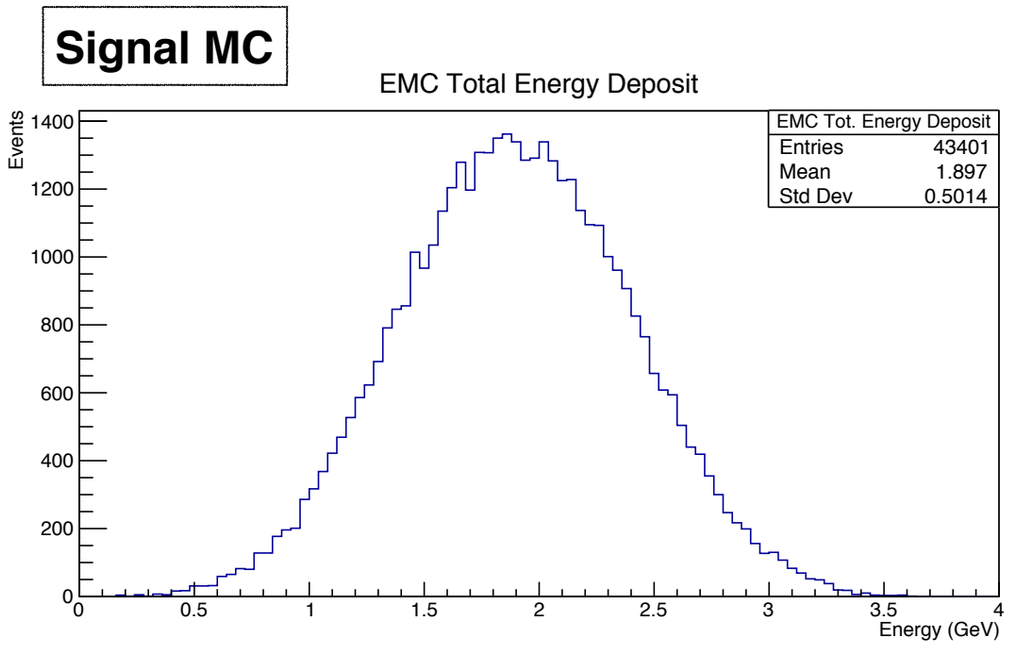
Event Selection

Inclusive Analysis









Event Selection

Cuts in a nutshell

Charged Tracks

Vertex: $R_{xy} < 1$cm & $R_z < 10$ cm;

Polar angle: $|\cos\theta| < 0.93$;

Momentum: $p < 2.0$ GeV;

At least 2 with at least 1 good.

Photons

γ-charged track angle > 10°;

EMC Time Cut: $T \leq 14$;

$E(\gamma) > 25$ MeV in the Barrel;

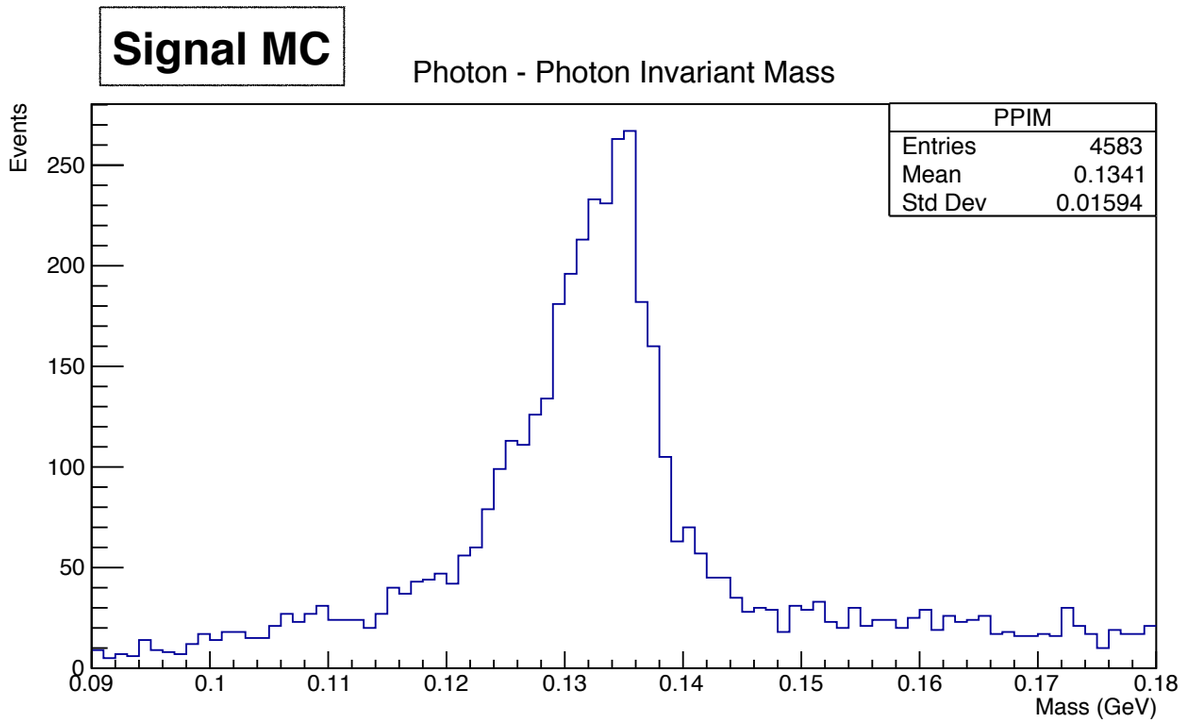
$E(\gamma) > 50$ MeV in the Endcaps;

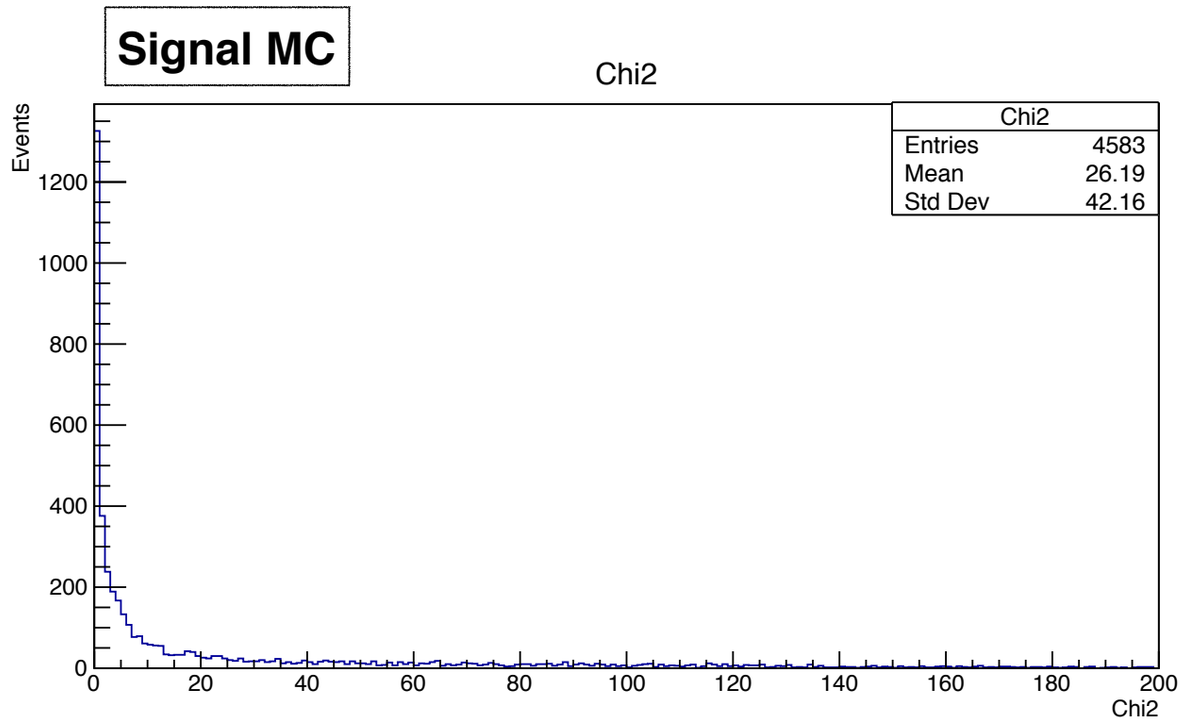
$\psi(2S) \rightarrow \pi^0 h_c$: At least 2 good;
$h_c \rightarrow \gamma\eta_c$: At least 3 good.

Event Selection

Inclusive Analysis

- Eγ(π0) > 40 MeV;
- 90 MeV < Mγγ < 180 MeV;
- The two photons in the barrel;
- Daughter photons from the signal should not belong to other π0;(**e.g.** photon from the signal can combined with another good photon—> **BAD)**
- Invariant mass constrained to the π0 nominal mass by a 1-C kinematic fit; no χ2 cut .





Event Selection

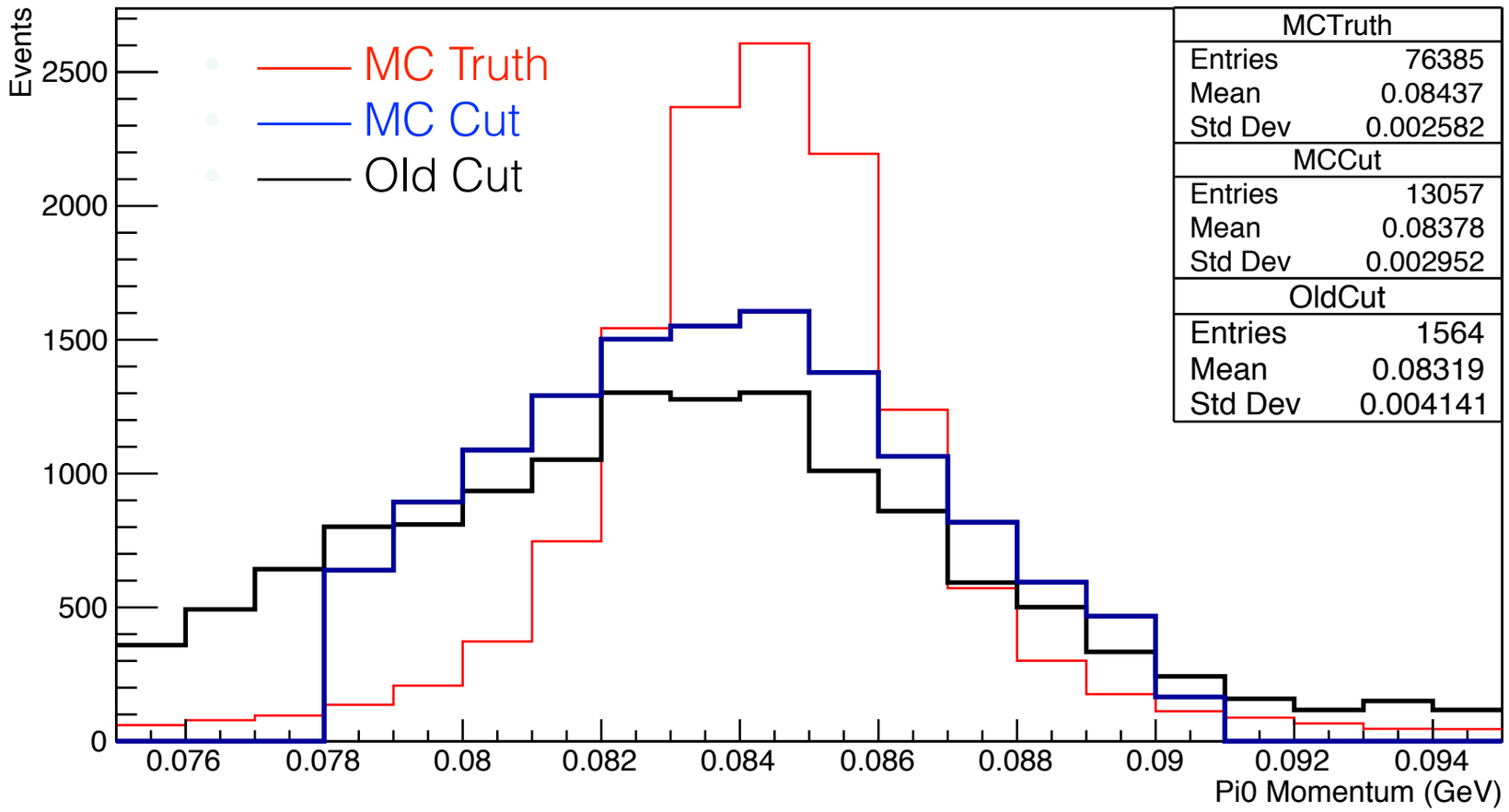
Inclusive Analysis

What if we loosen the π^0 constraint?

Daughter photons from the signal should not belong to other π0

- $\psi(2S) \rightarrow \pi_0 h_c$ is a 2B Decay which means $P(\pi_0)$ is determined;
- From MC —> $P(\pi_0)$;
- For each event select the γ couple whose invariant P nearest to $\langle P_{MC}(\pi_0) \rangle$.

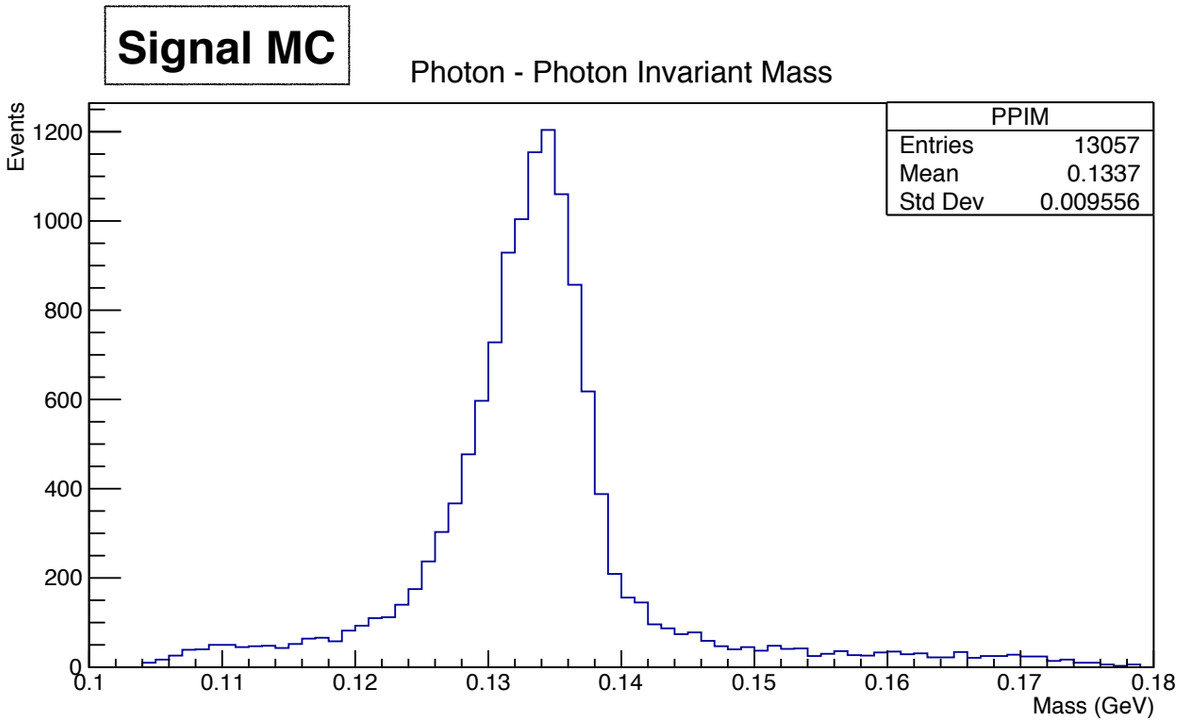
Signal MC MC Truth (Red) - MC Cut (Blue) - Old Cut (Black)

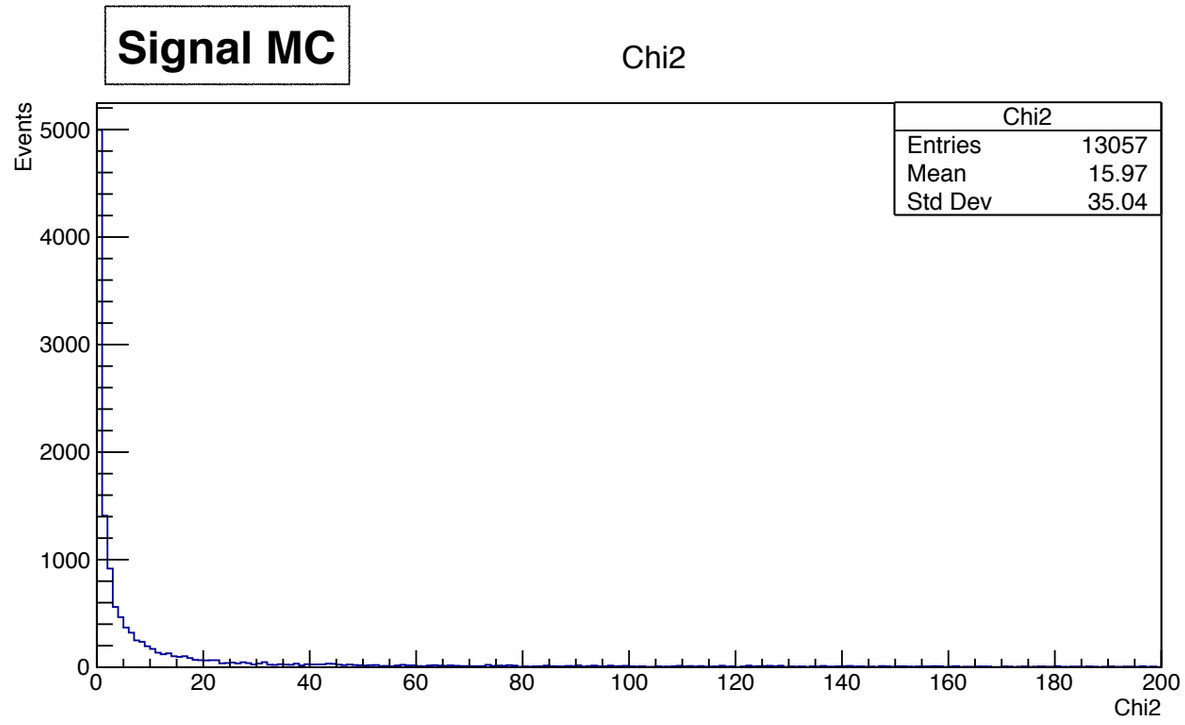


Event Selection

Inclusive Analysis

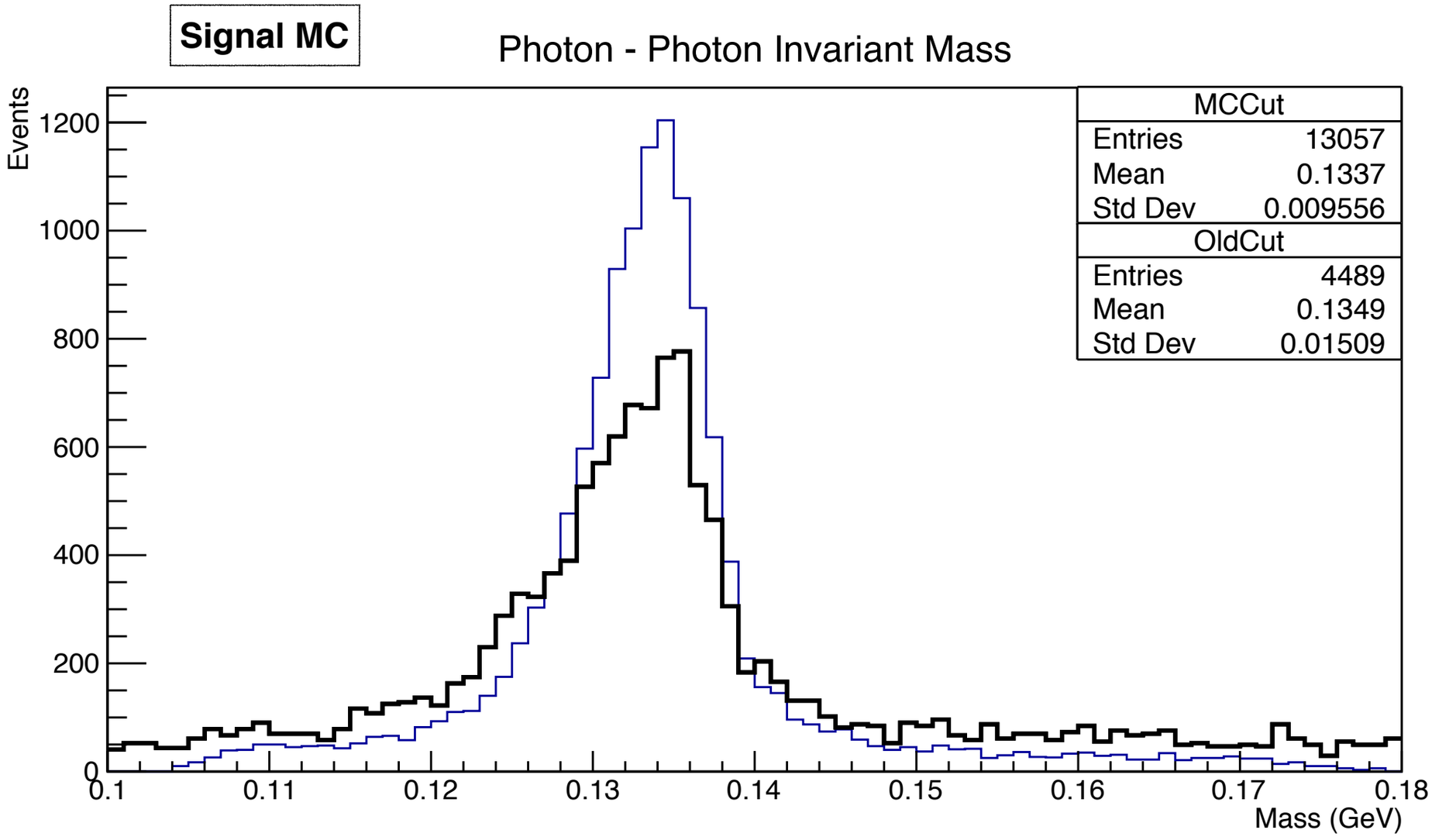
- Eγ(π0) > 40 MeV;
- 90 MeV < Mγγ < 180 MeV;
- The two photons in the barrel;
- MC cut;
- Invariant mass constrained to the π0 nominal mass by a 1-C kinematic fit; no χ2 cut .





Event Selection

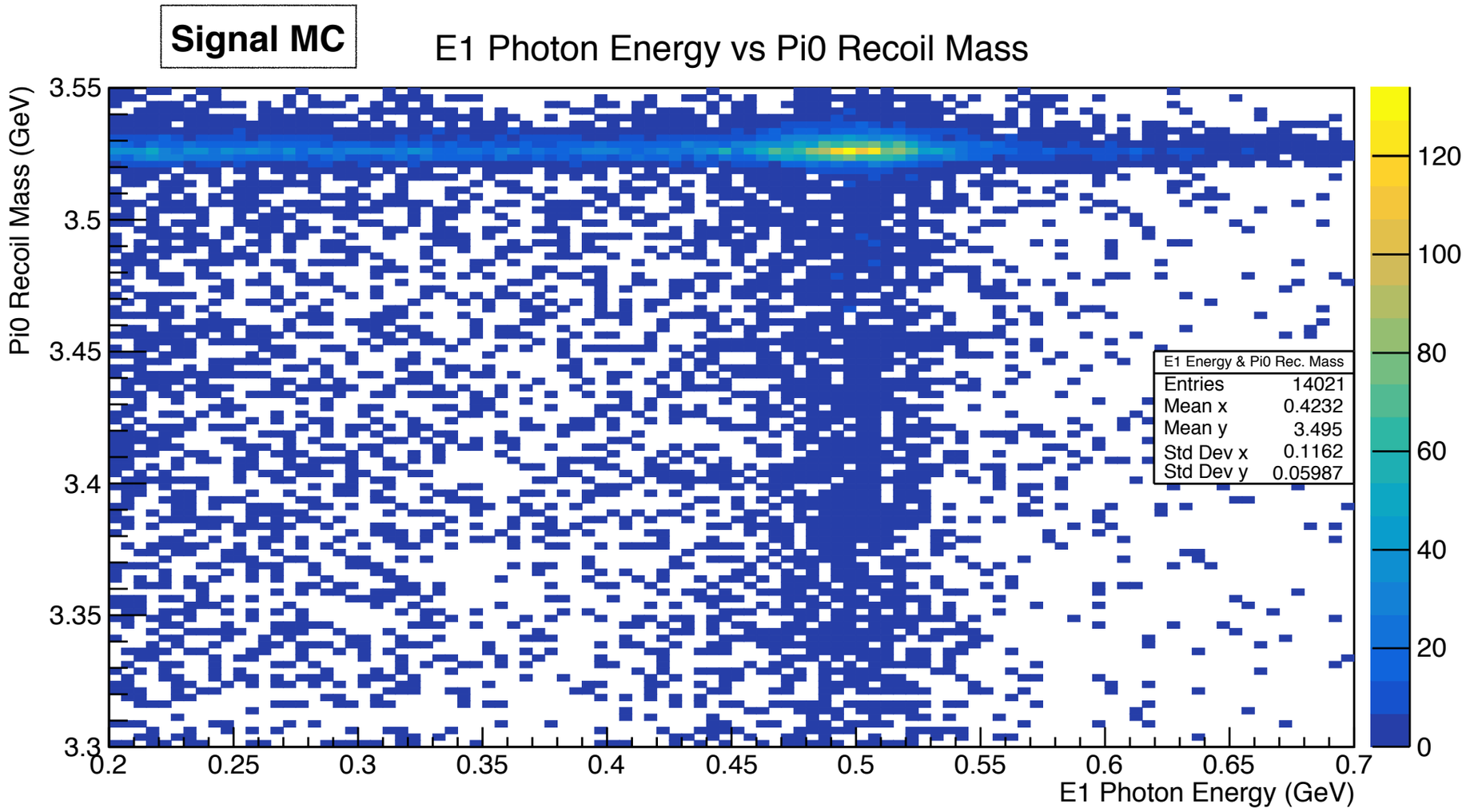
Comparison



Event Selection

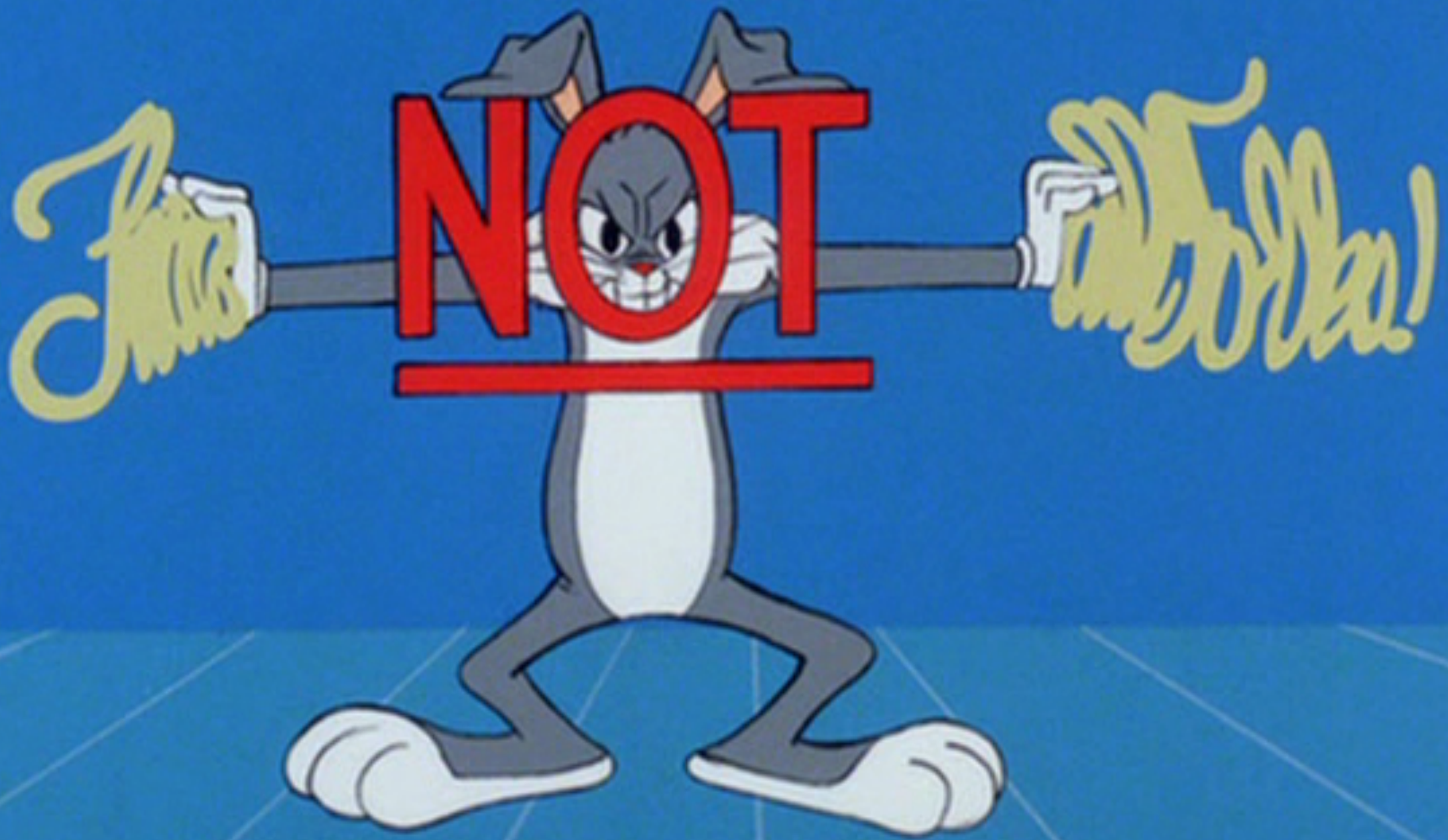
E1 Tagged Analysis

- At least three good photons (other criteria same to the inclusive);
- If the daughter photon of one π0 can combine more than one π0, minimum χ2 is selected;
- If invariant mass of E1 photon and any other good photon is compatible with a π0, the E1 photon candidate is rejected.



Next Steps

- Run on Inclusive & Data (Workshop at Guangzhou);
- Run on Continuum;
- Re-check the cuts (especially the new one proposed) with $S/\sqrt{(S+B)}$ as a FoM;
- Background suppression:
  - $\pi+ \ \pi- \ J/\psi$;
  - $\pi0 \ \pi0 \ J/\psi$.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