5γ+1γ analysis with Barrels & Study of Barrels with 1γ

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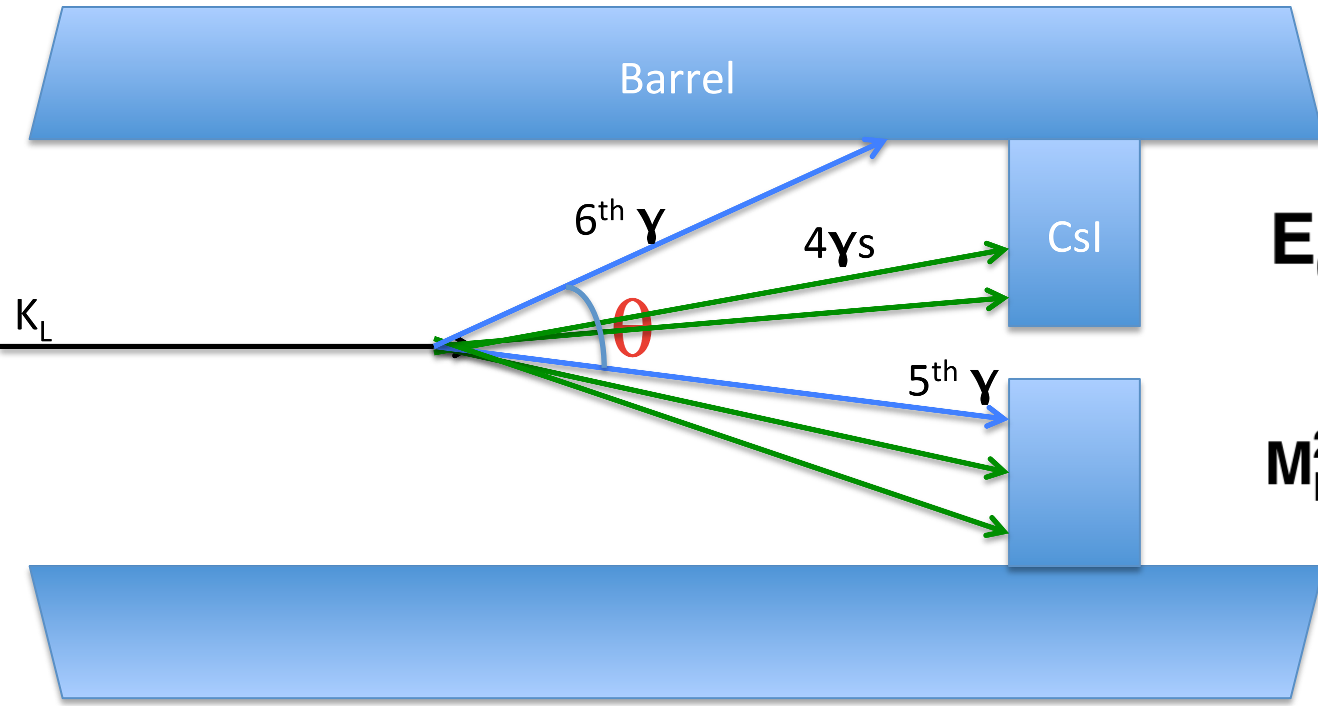
$K_L \to \pi^0\pi^0\pi^0$ Reconstruction Using 5γ on CsI and 1γ on Barrel



$$E_6 = \frac{M_\pi^2}{2E_5(1-\cos\theta)}$$

$$M_{K_L}^2 = \left(\sum_{i=1}^{6} E_i\right)^2 - \left(\sum_{i=1}^{6} \vec{p}_i\right)^2$$

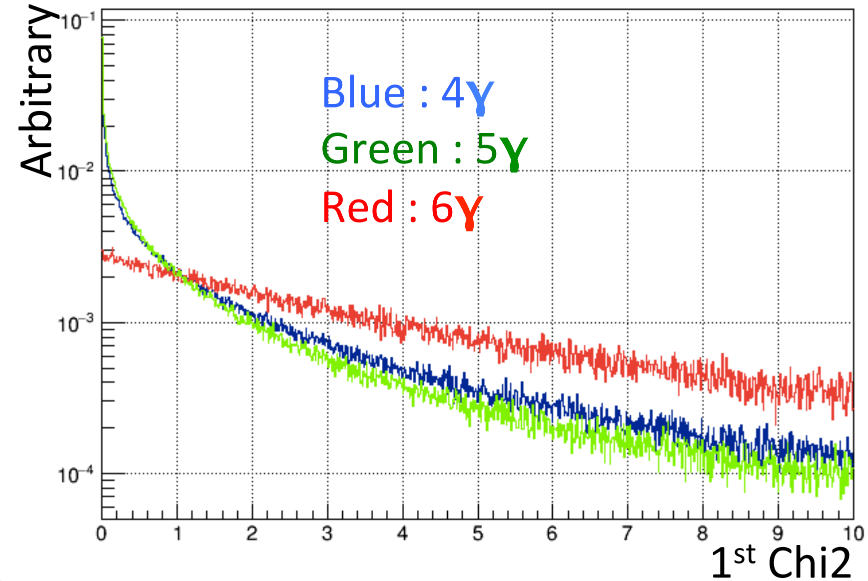
- $K_L \to \pi^0\pi^0\pi^0$ decay samples with 5γs on CsI and 1γ on Barrel
- Reconstruction of $2\pi^0$ from 4γs on CsI
- 1γ Reconstruction from hit information of Barrel (timing and Module ID)
- Reconstruction of the last π^0 from 1γ on CsI and 1γ on Barrel

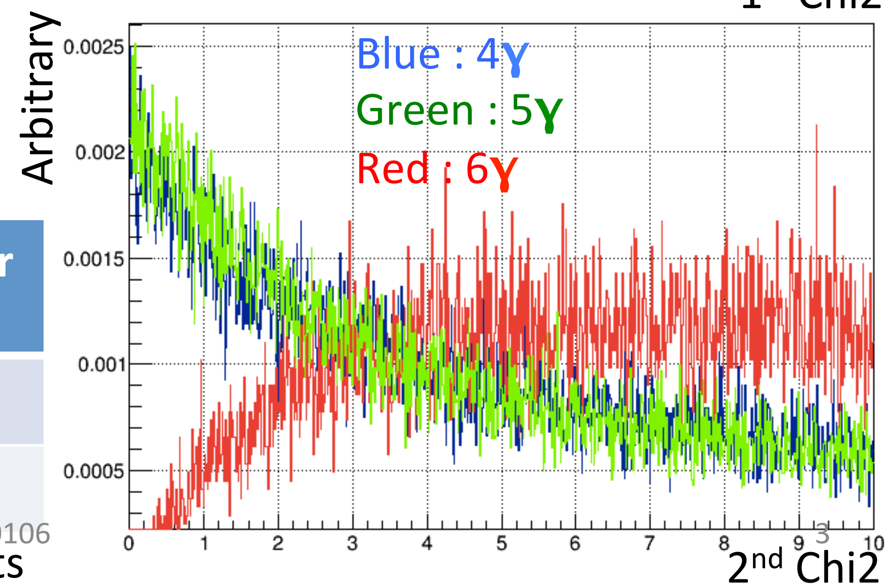
Vertex estimation from $2\pi^0$ Reconstruction

- Behavior of Vertex Chi2 of 5**γ** is same as g4
- Chi2 Cut of 5**γ** is not so effective as g4
  - 90% Wrong pair with 5^{th} **γ**

	Wrong pair ratio without chi2 cut	Wrong pair ratio after 1^{st} chi2 cut(<4)
4ϒ	20%	11%
5ϒ	50%	47%

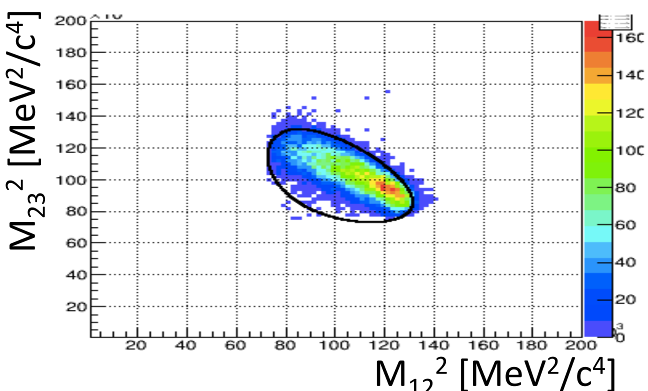
Without unknown 20% events

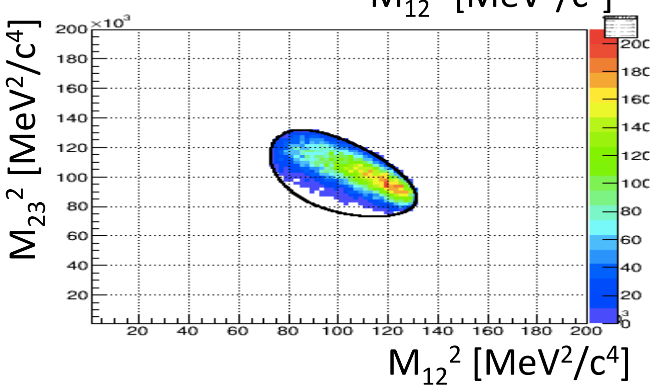




Cuts

- Dalitz Cut
  - Graphical cut about phase space of three body decay



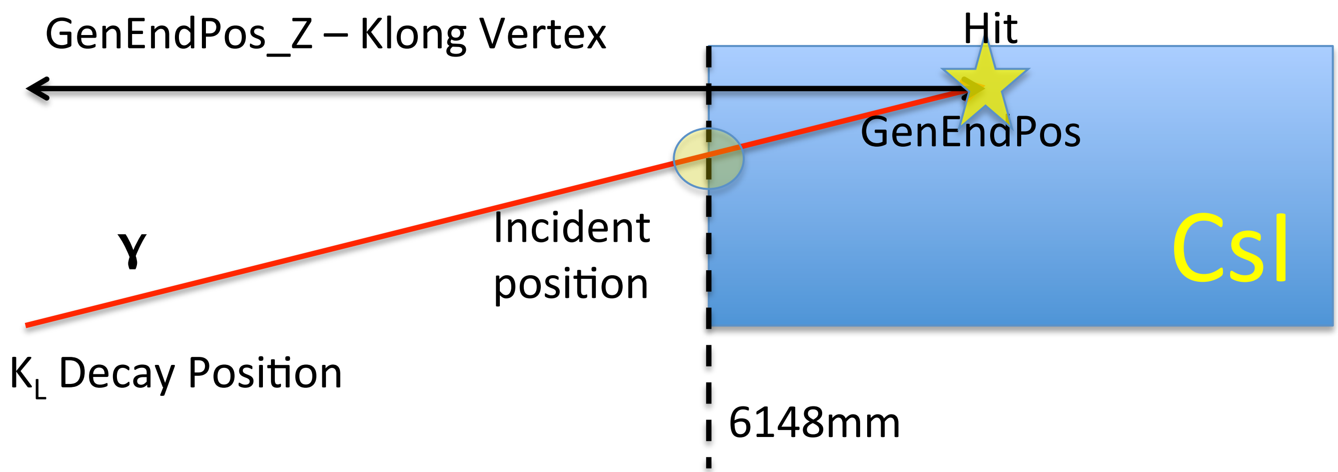


Cut applied

Cut Variables	Selected region
Klong Vertex	2500<VTZ<5000 [mm]
Gamma Energy on CSI	100<e<2000 [MeV]
Distances btw gammas	D>175 [mm]
Fiducial distance	150<r<900[mm]
Chi2_1st	Chi2<4
Chi2_2nd	Chi2>10
ShapeChi2	Chi2<10
Pi0 mass	Mass difference<5MeV
Difference btw 2pi0 mass	Mass difference<5MeV
Klong Pt	Pt<40[MeV/c]
Dalitz Cut	

Minimum Cut

Match of ϒ



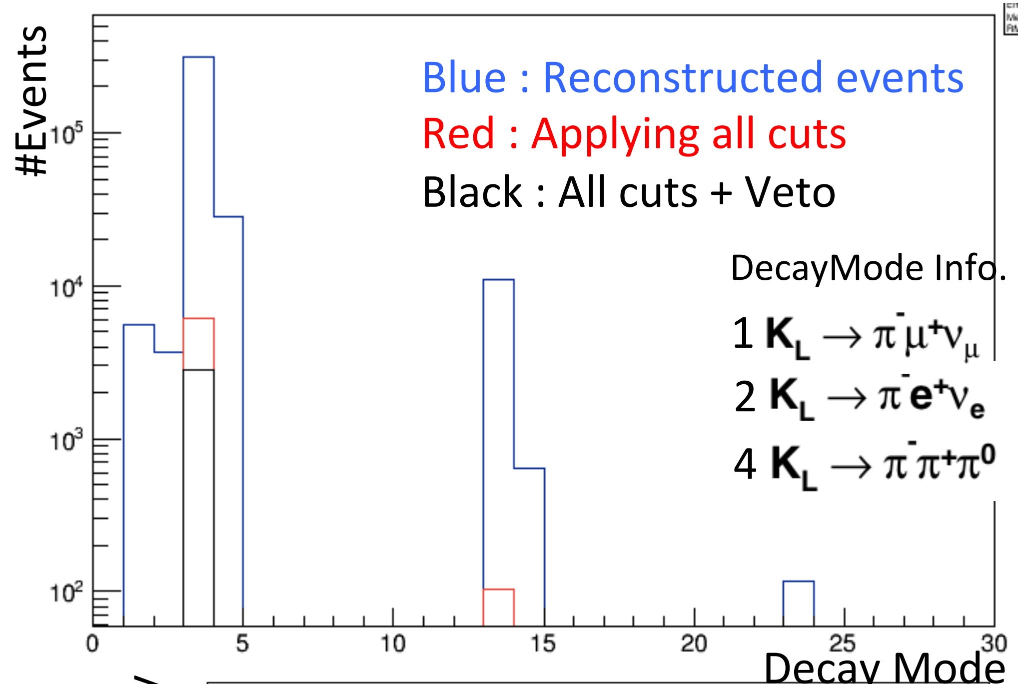
- Calculation of incident position of γs
  - IncidentPosition – GammaPos
- One to one match for 5γ
  - Match Ratio
  - Match for checking status of π^0 pairing

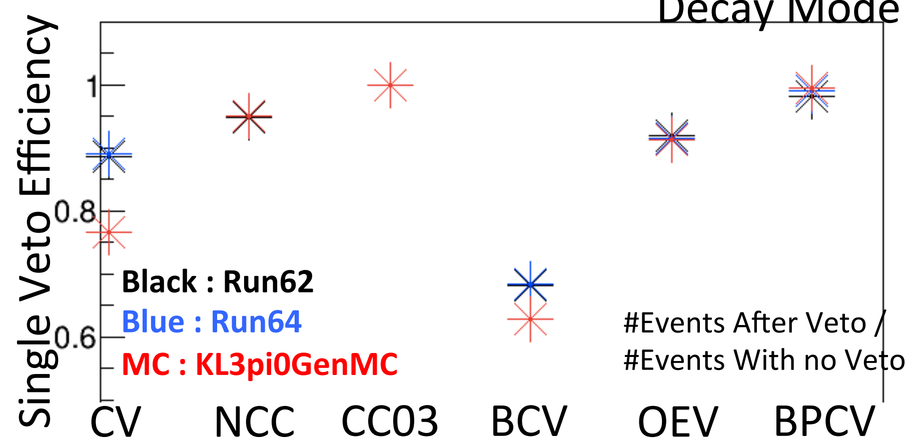
Conditions	Match Ratio	Wrong Pair
No cut	79%	50%
Minimum Cut	97.7%	35%
Min. Cut + Pt	98.0%	23%
All Cuts	98.2%	6%

Veto Detectors

Veto Conditions

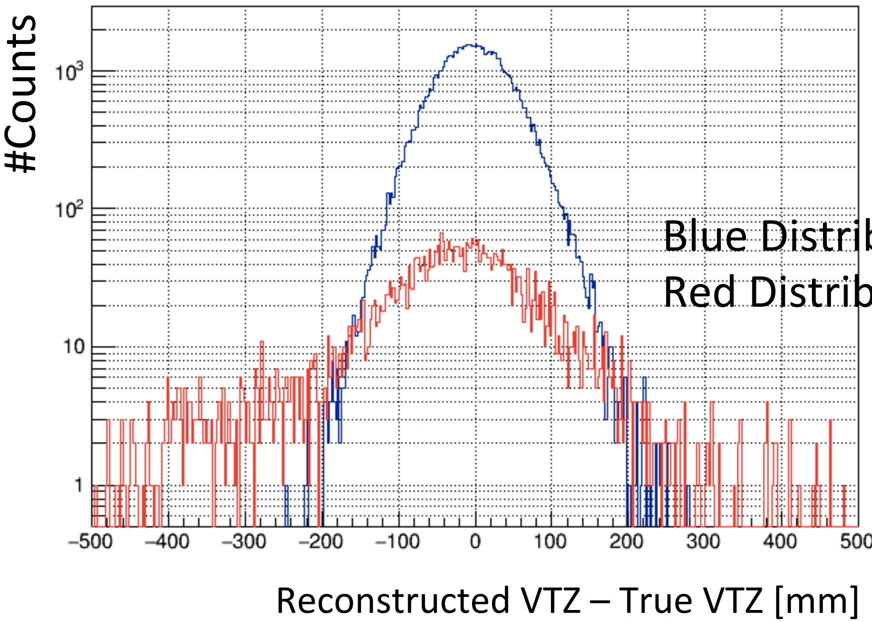
Detector	Time window	threshold
CV	30ns	0.25 [MeV]
NCC	40ns	2 [MeV]
CC03	40ns	3 [MeV]
BCV	50ns	0.5 [MeV]
OEV	70ns	2 [MeV]
BPCV	30ns	2 [MeV]

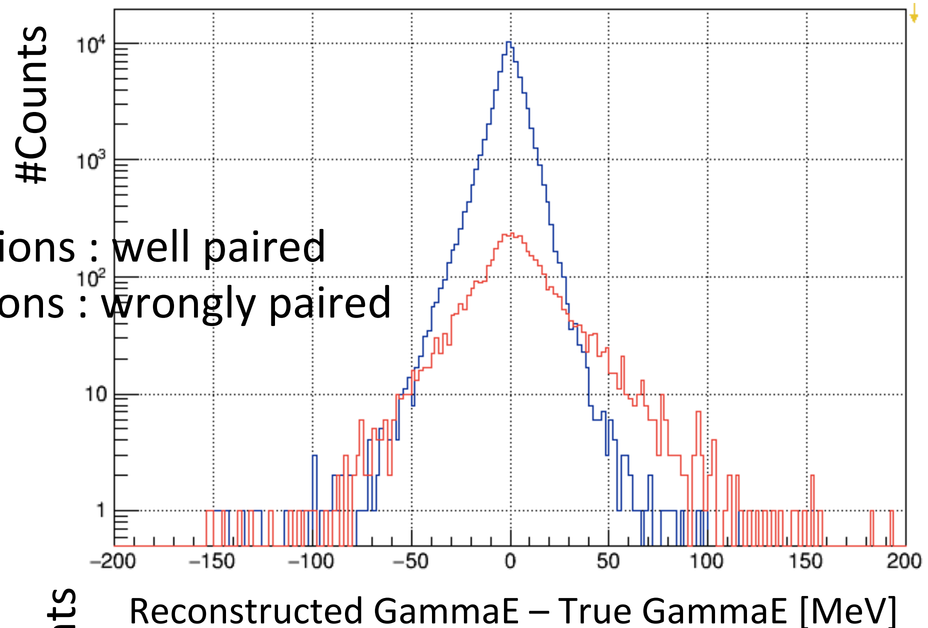




- After applying all Cuts,
  - ~1% Dalitz Decay Event from $K_L \to \pi^0\pi^0\pi^0$ remain.
- After using Detector Veto,
  - Only $K_L \to \pi^0\pi^0\pi^0$ events remain. (Decay Mode = 3)

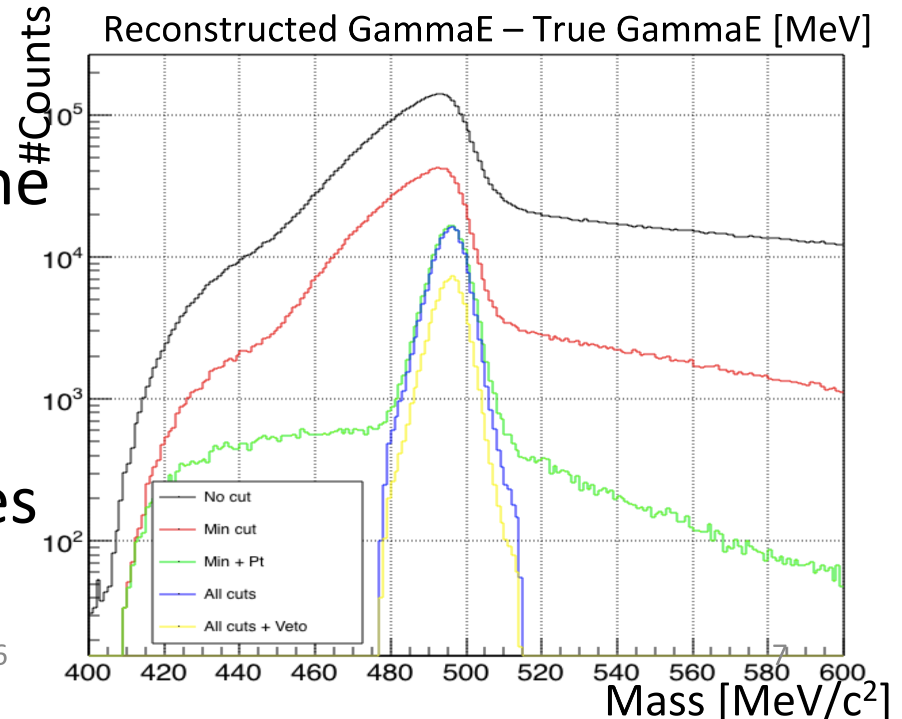
Variables after all cut & veto



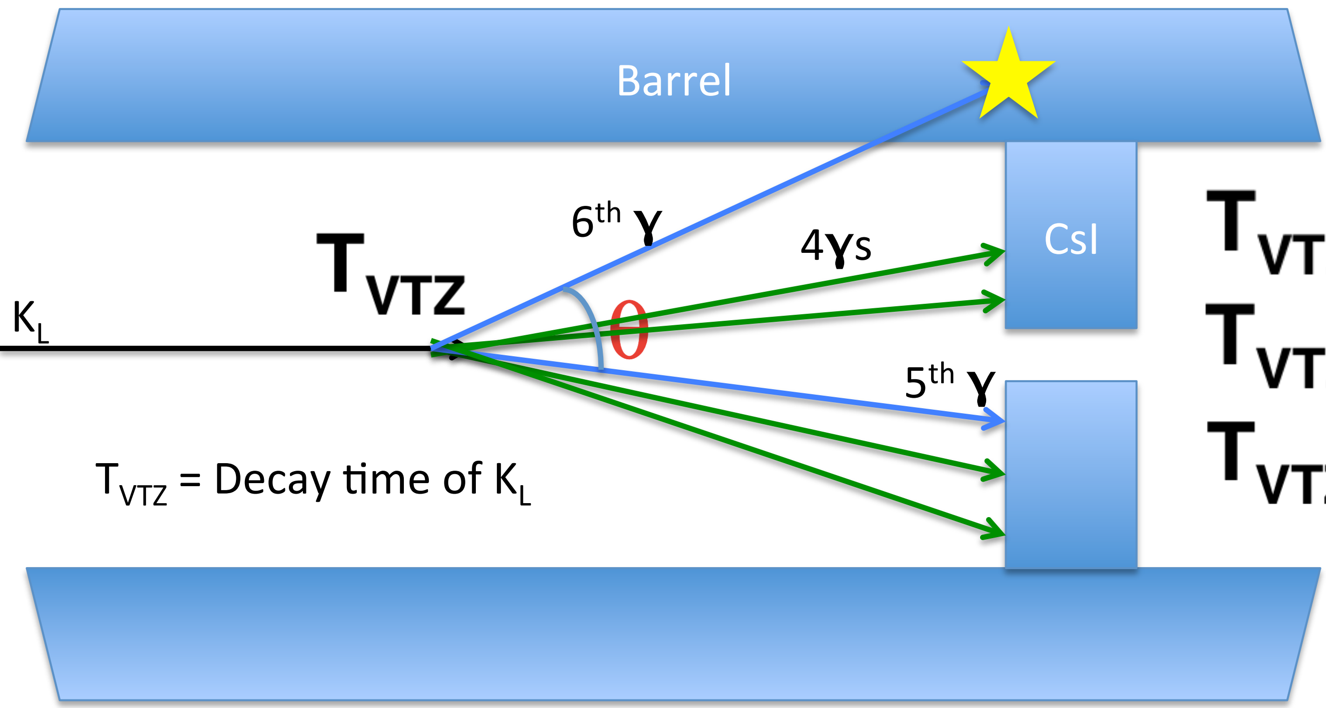


Blue Distributions : well paired
Red Distributions : wrongly paired

- Reduced wrong pair ratio to the 6% level.
  - With ignored 1.8% data
- Clean Mass distribution
- Clean selection of **γ** which goes to Barrel



K_L Vertex Time



T_{VTZ} = Decay time of K_L

$$ToF = \frac{L}{c}$$

L : path length of photons

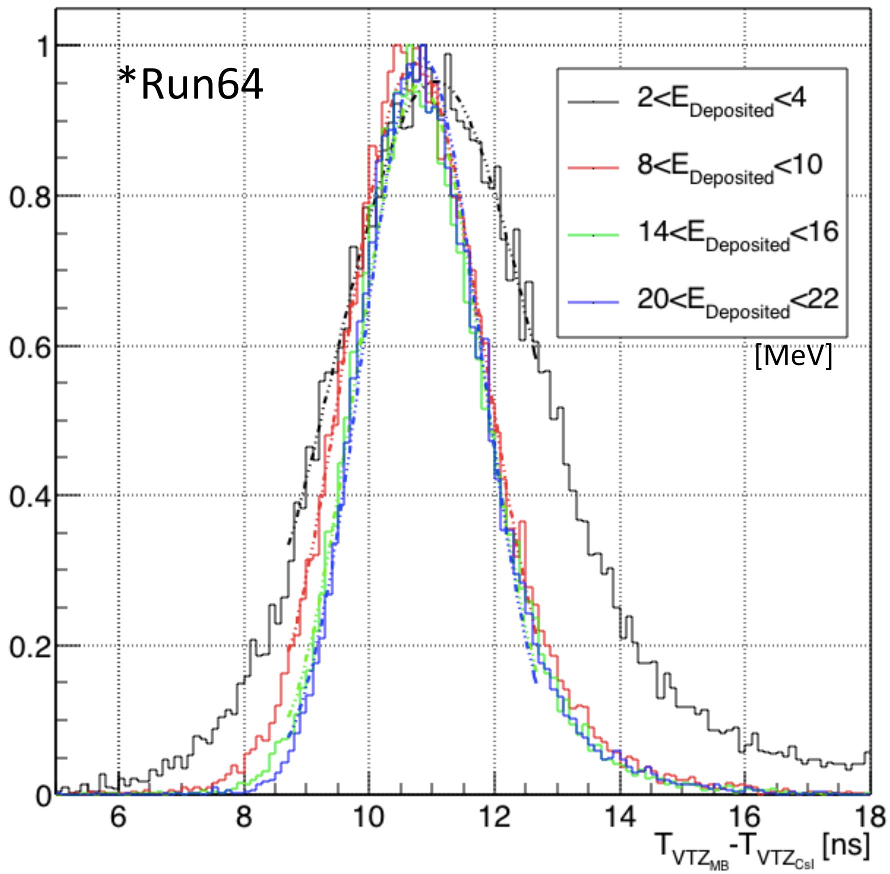
$$T_{VTZ_B} = T_{Barrel} - ToF$$

$$T_{VTZ_C} = T_{CsI} - ToF$$

$$T_{VTZ_B} = T_{VTZ_C}$$

- Estimation of decay time of K_L using Barrel Detector and CsI Detector independently.
  - With clean γ going to Barrel

Spectra. & Fitting of Vertex Time Difference



Entries	27426
Mean	11.36
RMS	1.953
χ^2 / ndf	12.55 / 23
Prob	0.961
Constant	555.9 ± 6.8
Mean	11.01 ± 0.04
Sigma	1.539 ± 0.067

Entries	32418
Mean	10.86
RMS	1.298
χ^2 / ndf	23.29 / 23
Prob	0.4437
Constant	1100 ± 10.2
Mean	10.71 ± 0.01
Sigma	1.108 ± 0.019

Entries	31757
Mean	10.94
RMS	1.181
χ^2 / ndf	32.79 / 23
Prob	0.08484
Constant	1213 ± 10.9
Mean	10.74 ± 0.01
Sigma	0.9781 ± 0.0133

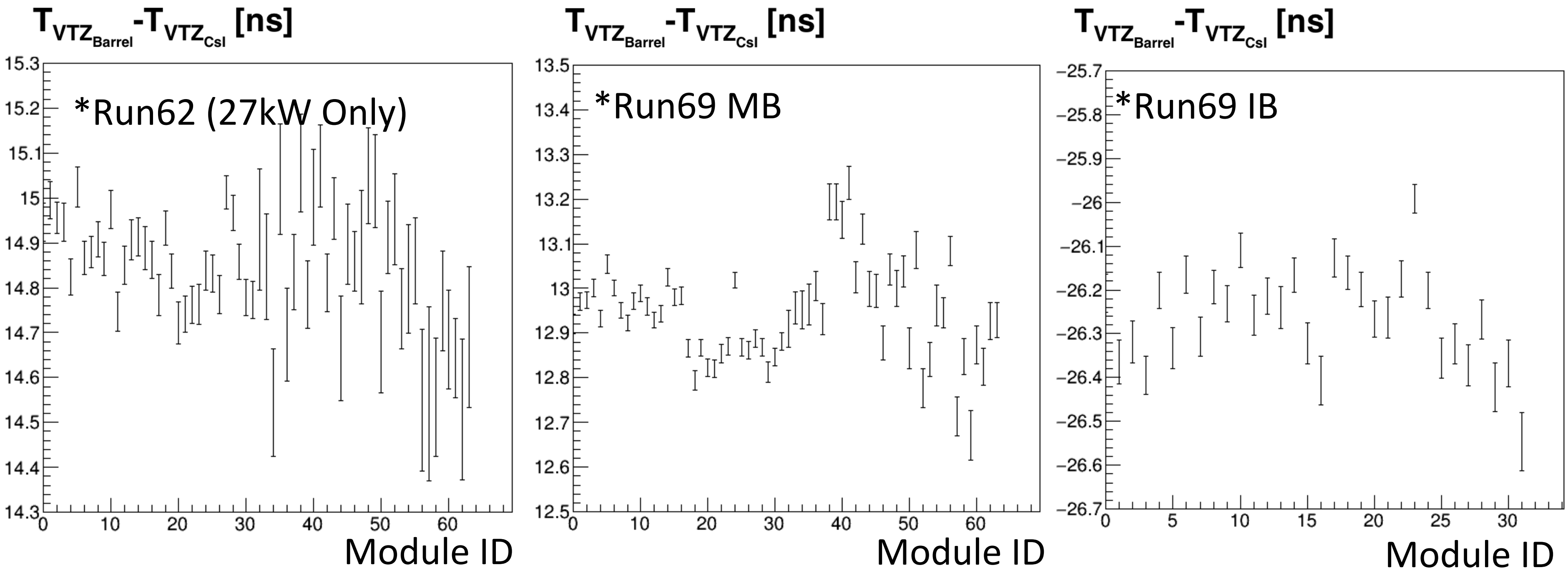
Entries	26230
Mean	10.99
RMS	1.139
χ^2 / ndf	39.13 / 23
Prob	0.0192
Constant	1046 ± 10.1
Mean	10.79 ± 0.01
Sigma	0.9535 ± 0.0133

- Vertex Time Difference = T_{VTZ_B}-T_{VTZ_C}
- Fitted with Gaussian
  - Mean : Offset
  - Sigma : Time Resolution affected by CsI and Barrel
- All modules are integrated
- Deposited energy on Barrel affects Vertex Time Difference distribution

$$T_{VTZ_B}-T_{VTZ_C}=\text{Offset}$$

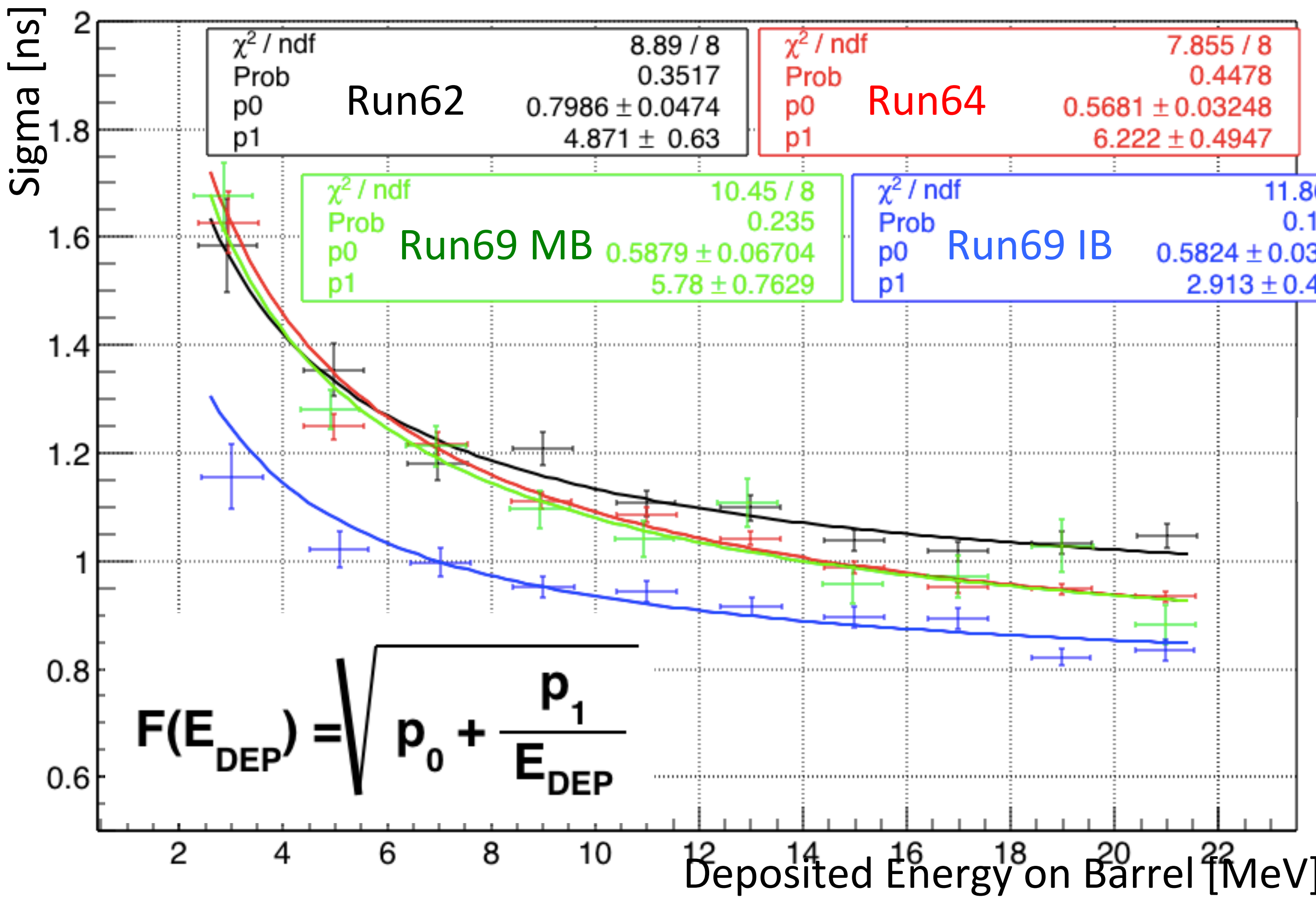
$$\delta(\text{Offset}) = \sqrt{\delta T^2_{VTZ_B} + \delta T^2_{VTZ_C}}$$

Module consistency



- Evaluation of Barrel Calibration from Vertex Time Difference distributions

Resolution of Vertex Time Difference & Evaluation of Barrel Time Resolution



$$\delta(T_{Barrel} - T_{CsI})^2$$

$$\delta T^2_{Barrel} + \delta T^2_{CsI}$$

$$\delta T^2_{CsI} \sim \text{const} = P_0$$

$$\delta T_{Barrel} = \frac{C_1}{\sqrt{E_{Dep}}} + C_2$$

Ignored C_2

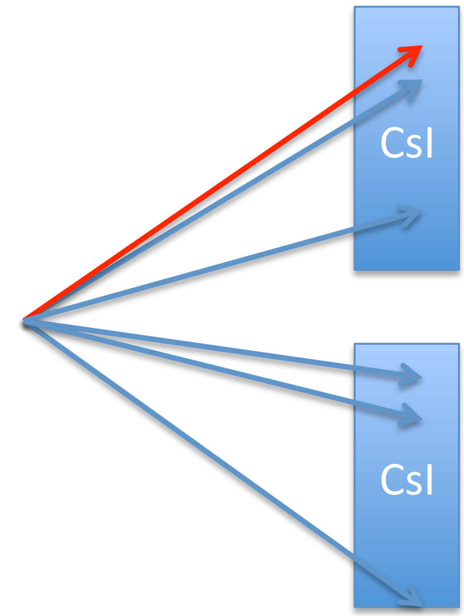
arrel $= \frac{P_1}{E_{Dep}}$

- P_0 presents resolution from other terms(Mainly CsI)
  - In Run62, P_0 is higher than other data set.
- P_1 presents resolution of Barrel
  - In Run69 IB, P_1 is better than other data set(MB).

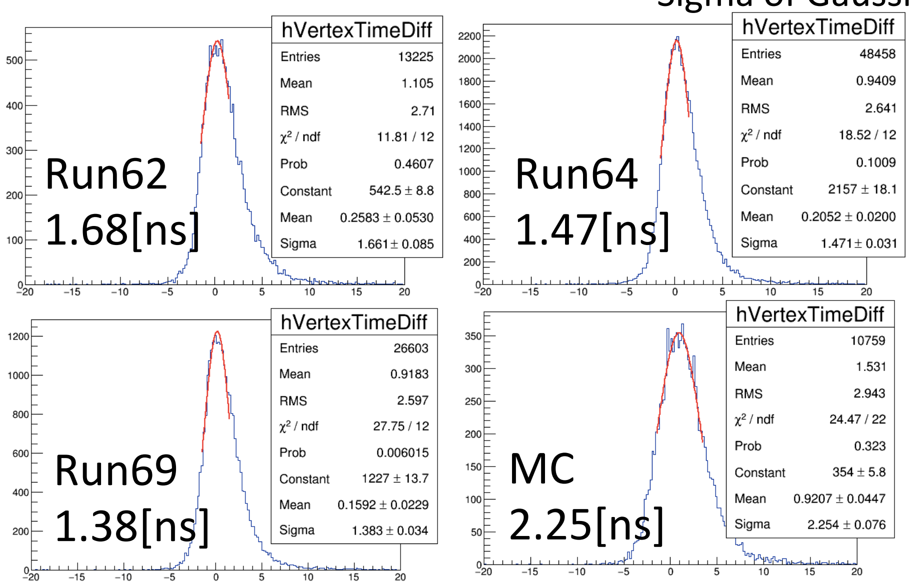
Vertex Time Difference at g6 Analysis

- As 5γ+1γ analysis, Vertex time differences could be calculated at g6 analysis.
  - Gamma which has highest energy among 6 gammas is selected as 6th gamma

Highest energy selection (Red Cross)



Data Set
Sigma of Gaussian



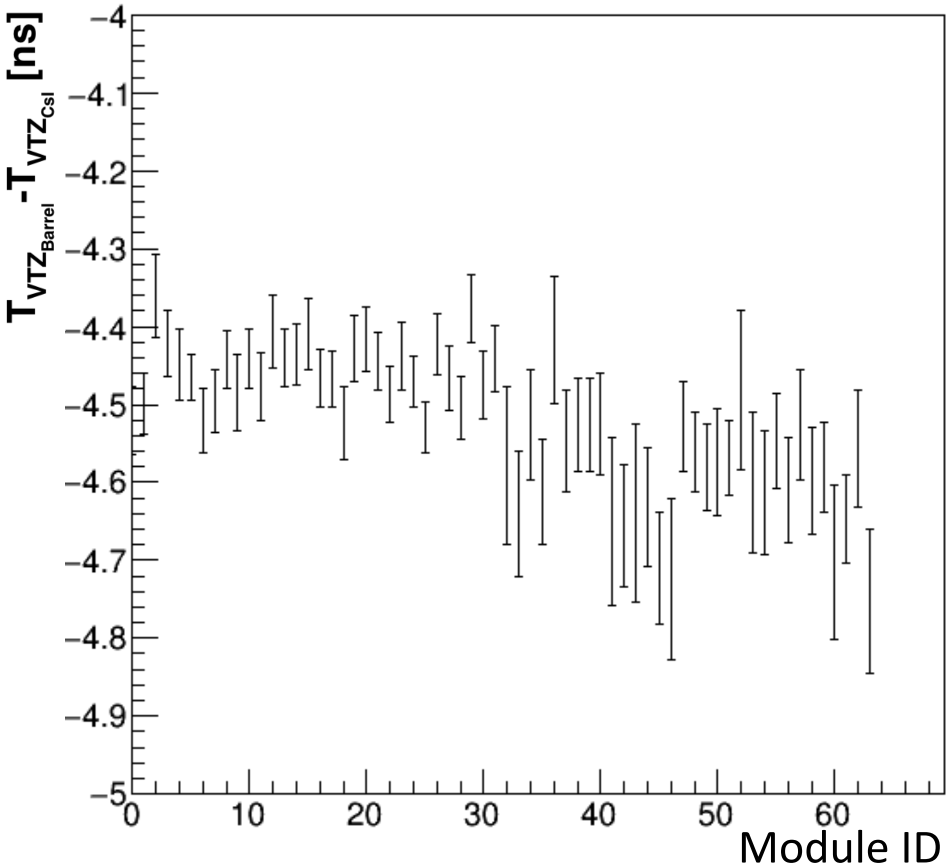
T_{VTZ_B}-T_{VTZ_C}=Offset

$T_{VTZ_{6th}}$ - T_{VTZ_C} = Offset

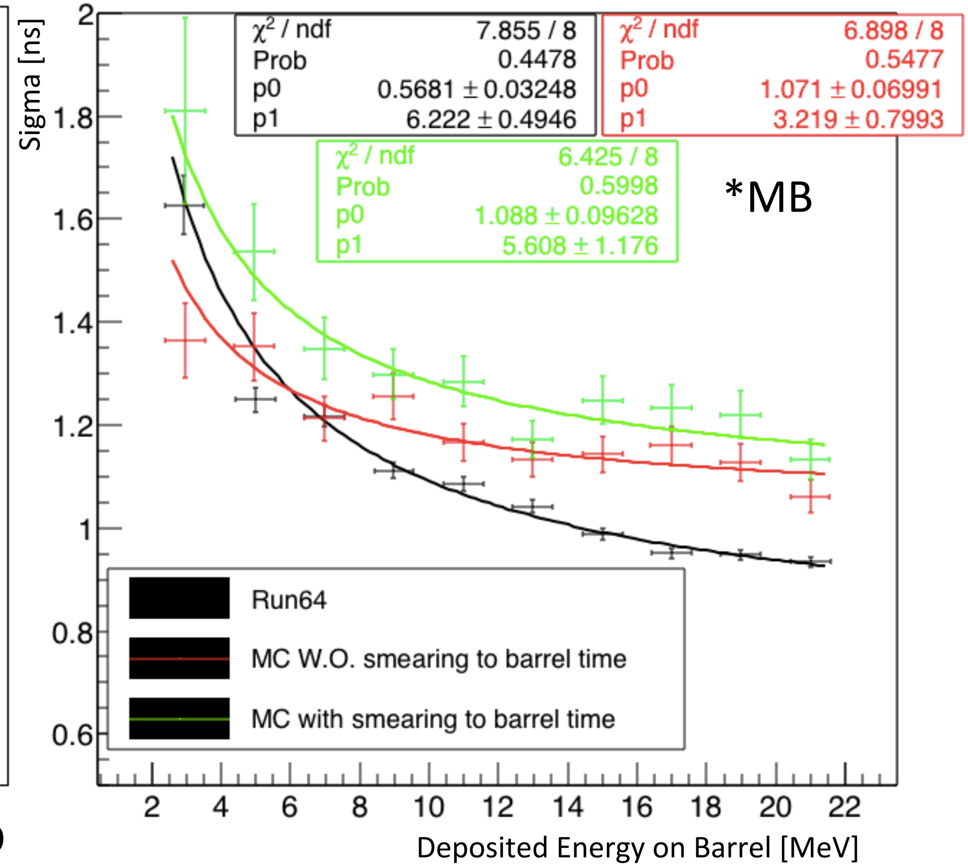
- Is it relate to fit parameter ’P_0’ in Page 11?

Comparison with MC
Vertex Time Difference

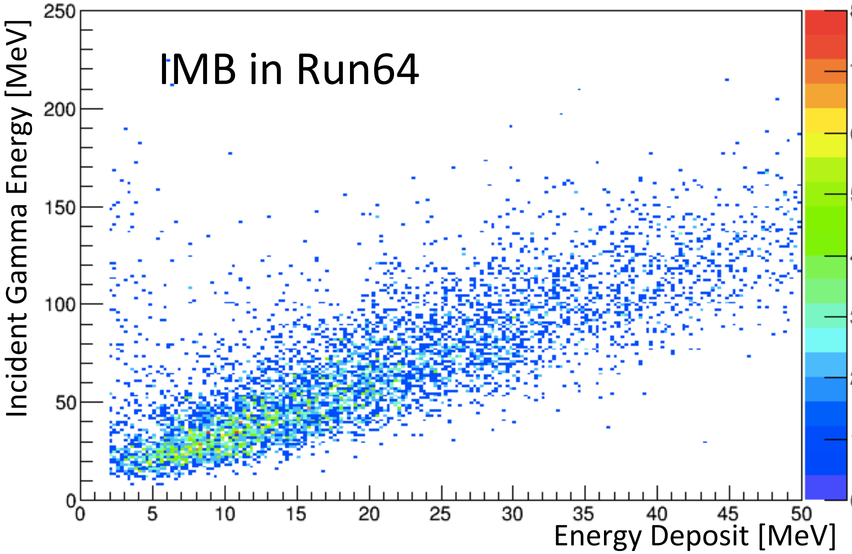
Module consistency

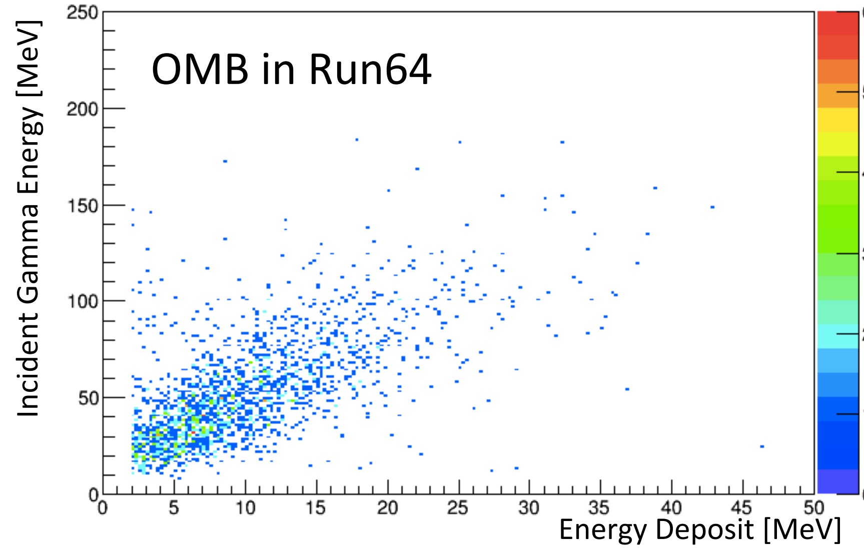


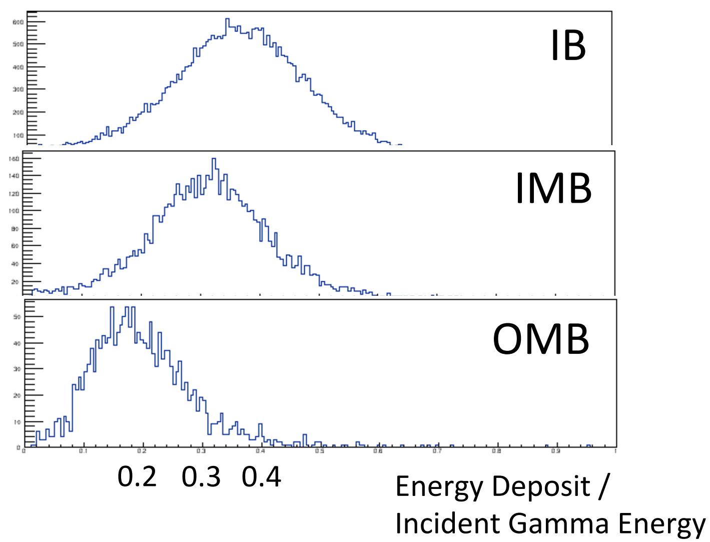
Time Resolution with regard to Barrel Energy Deposit

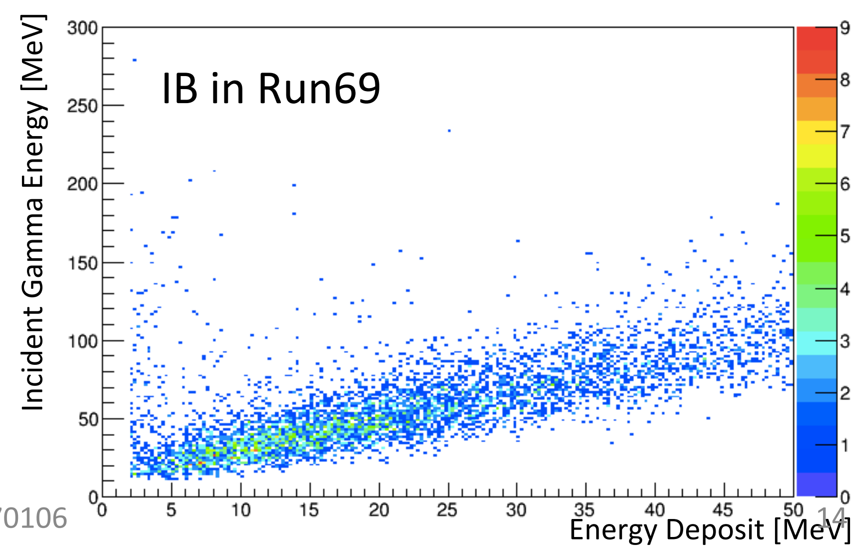


Deposited energy & Incident gamma energy

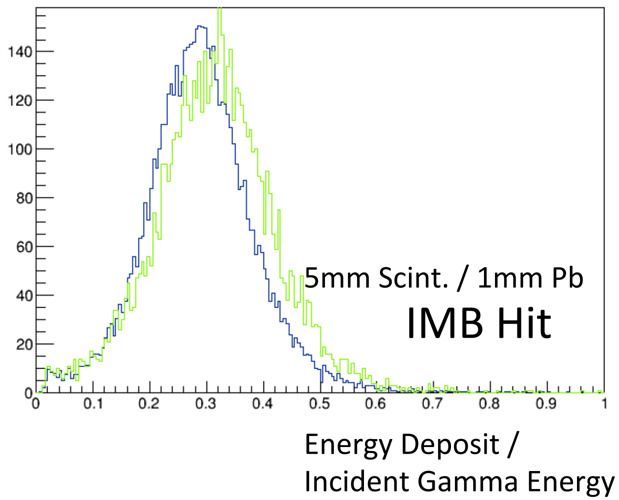


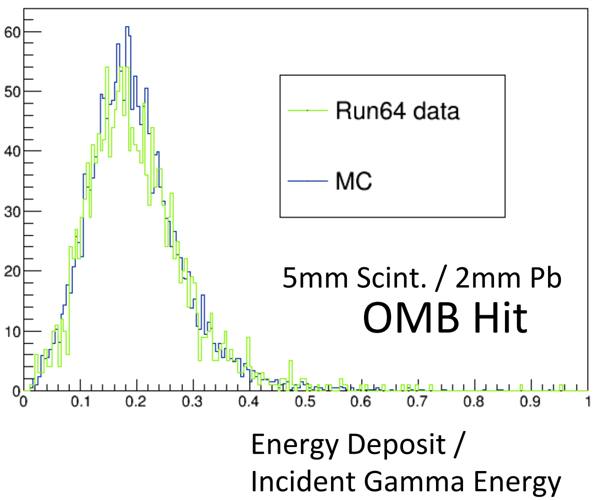


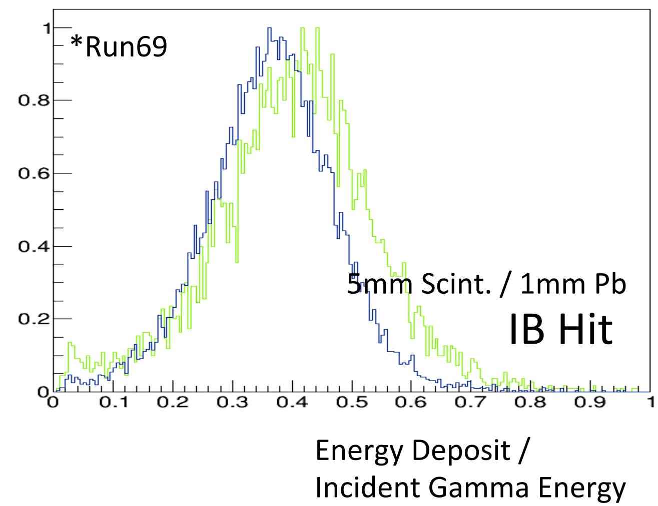




Comparison with MC
Sampling Fraction







- Sampling Fraction is inconsistent between MC and data for IMB and IB
  - We are trying to understand the reason.
- In GsimE14CBAR.cc of E14lib, there is no definition of material of reflectors(TiO_2)

Summary

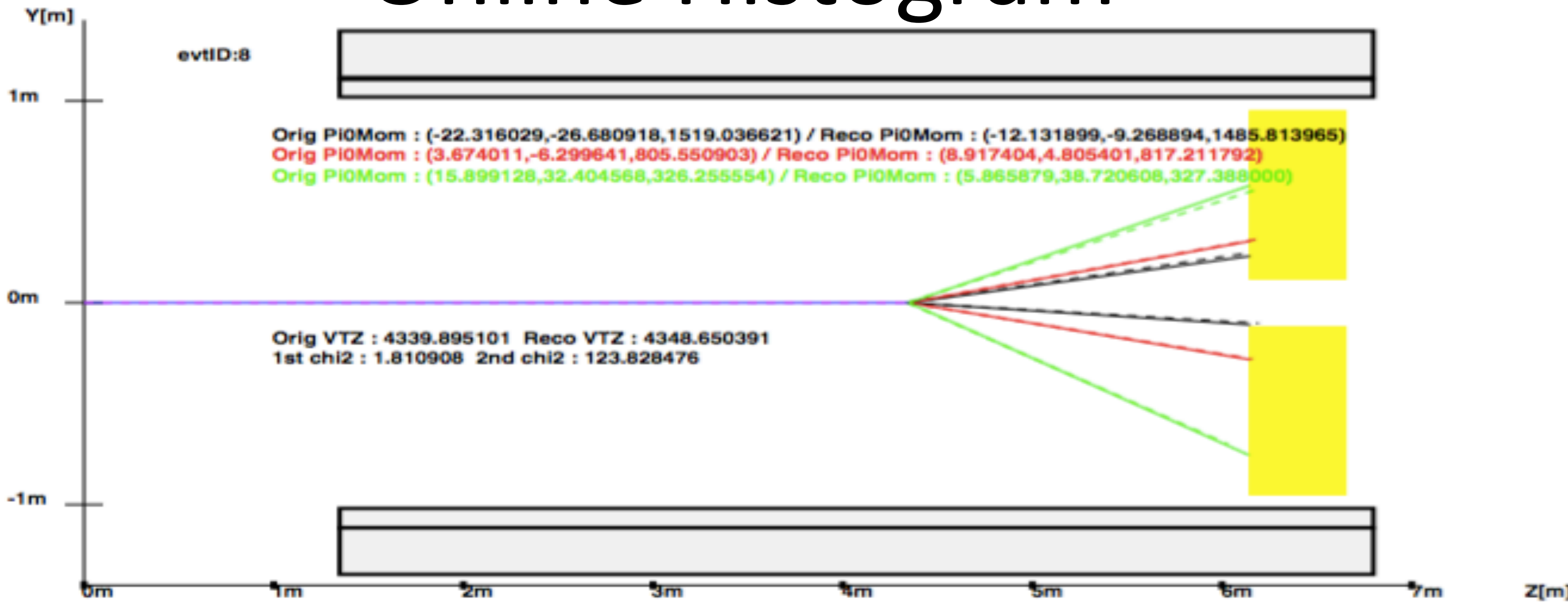
- $5\gamma+1\gamma$ analysis is done with ~6% wrong pair of $2\pi^0$
  - We can choose gamma incident barrel events
- Time Resolution of Barrel with the function of energy deposit is firstly evaluated
  - The energy-independent term of Barrel time resolution is ignored

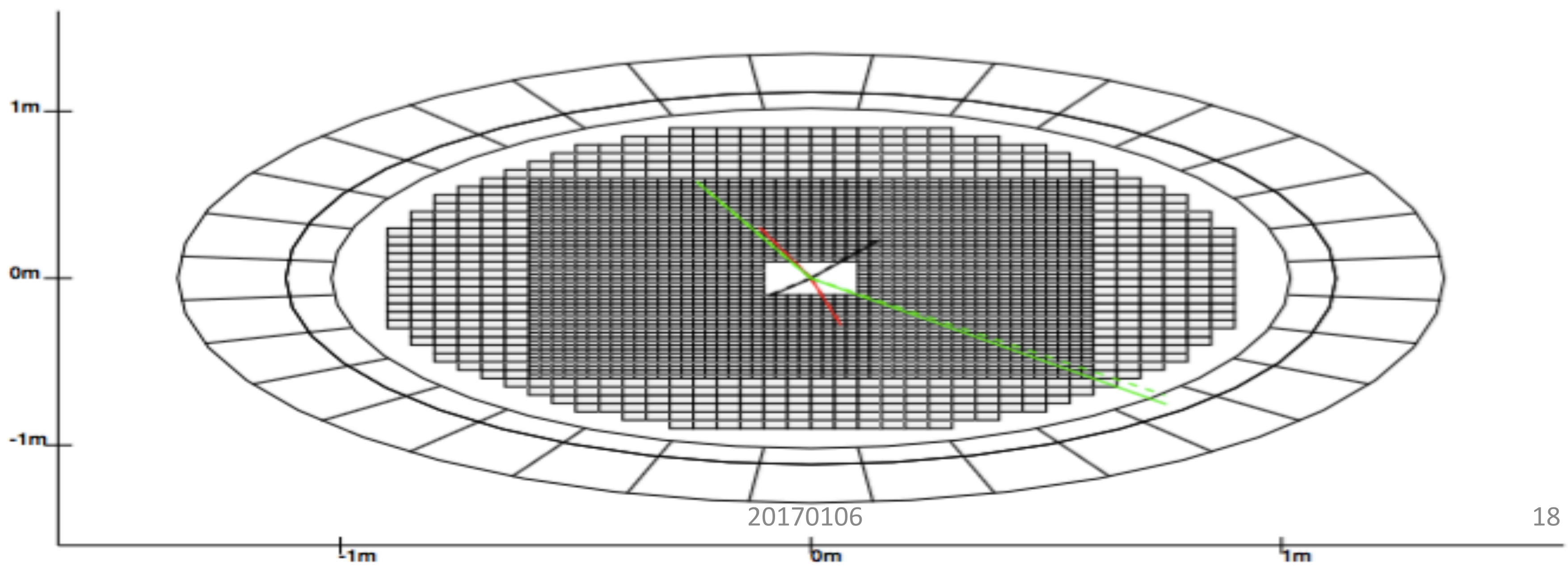
$$\sigma_{Barrel} = P_1 + \frac{P_2}{\sqrt{E_{dep}}}$$

  - We can check Quality of Barrel Calibrations through 6^{th} gamma.
- Sampling Fractions are inconsistent between MC and Data
  - Effect of reflectors? Other reason?

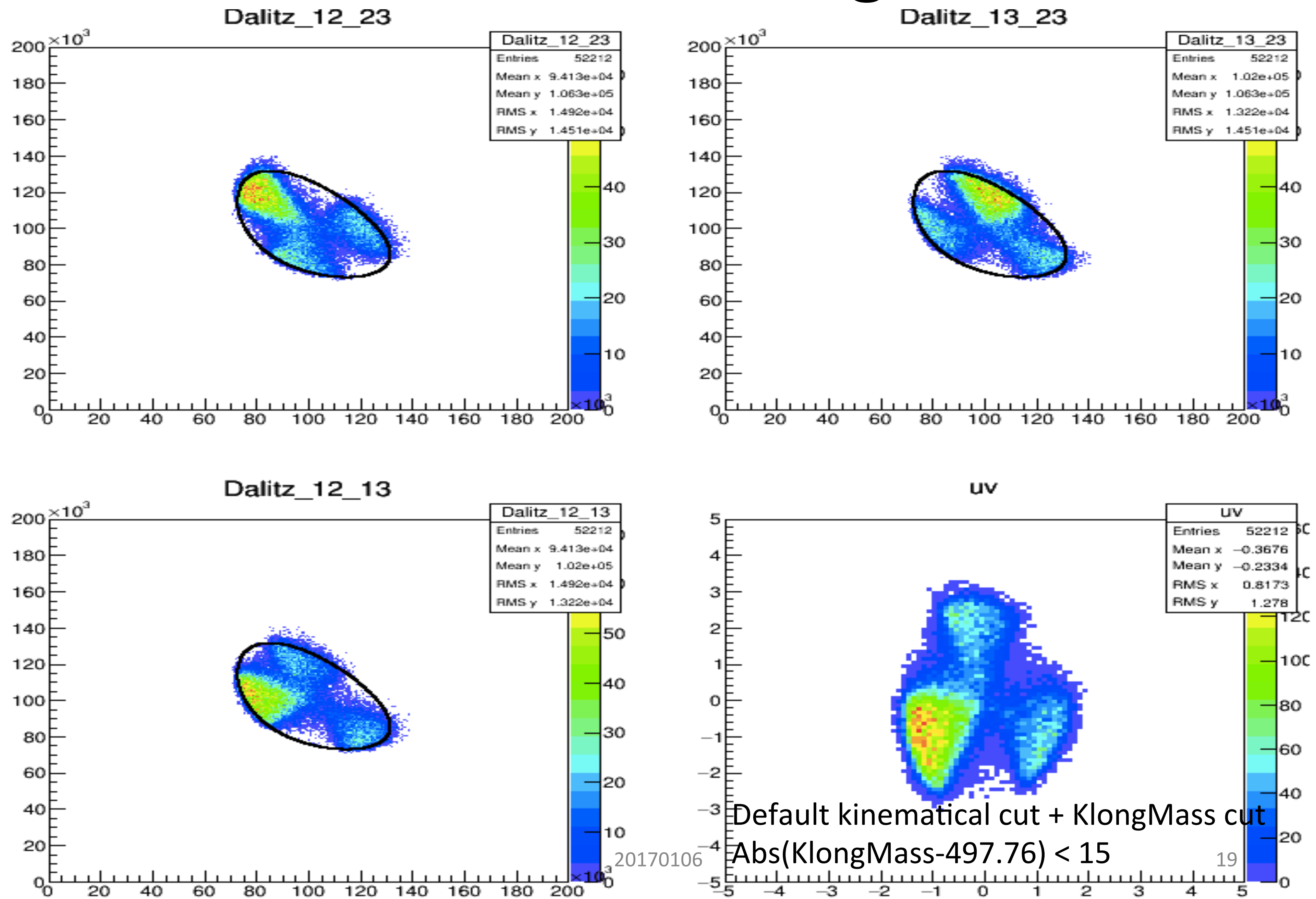
Back up

Online Histogram



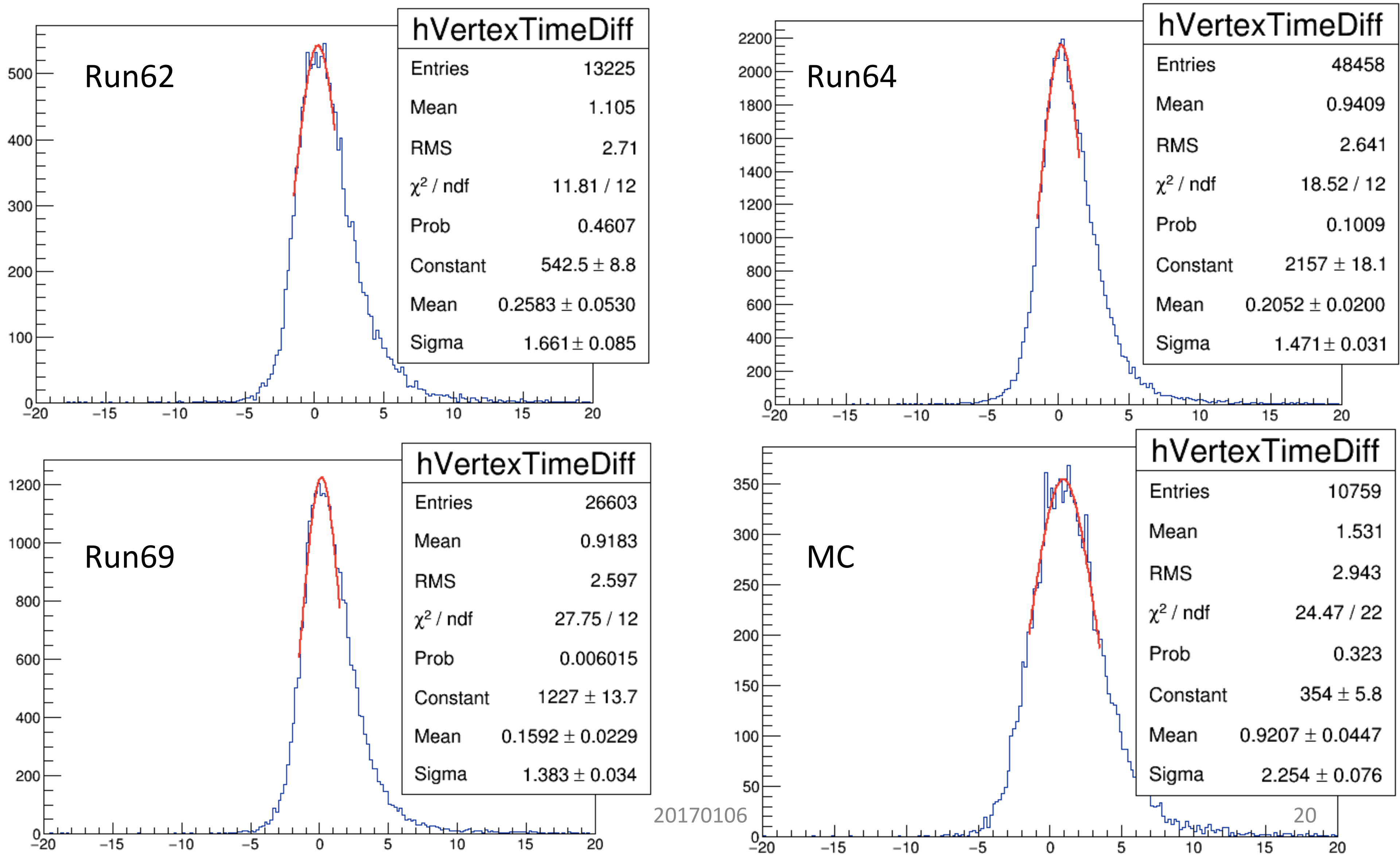


Dalitz Plots in g6



Default kinematical cut + KlongMass cut
Abs(KlongMass-497.76) < 15

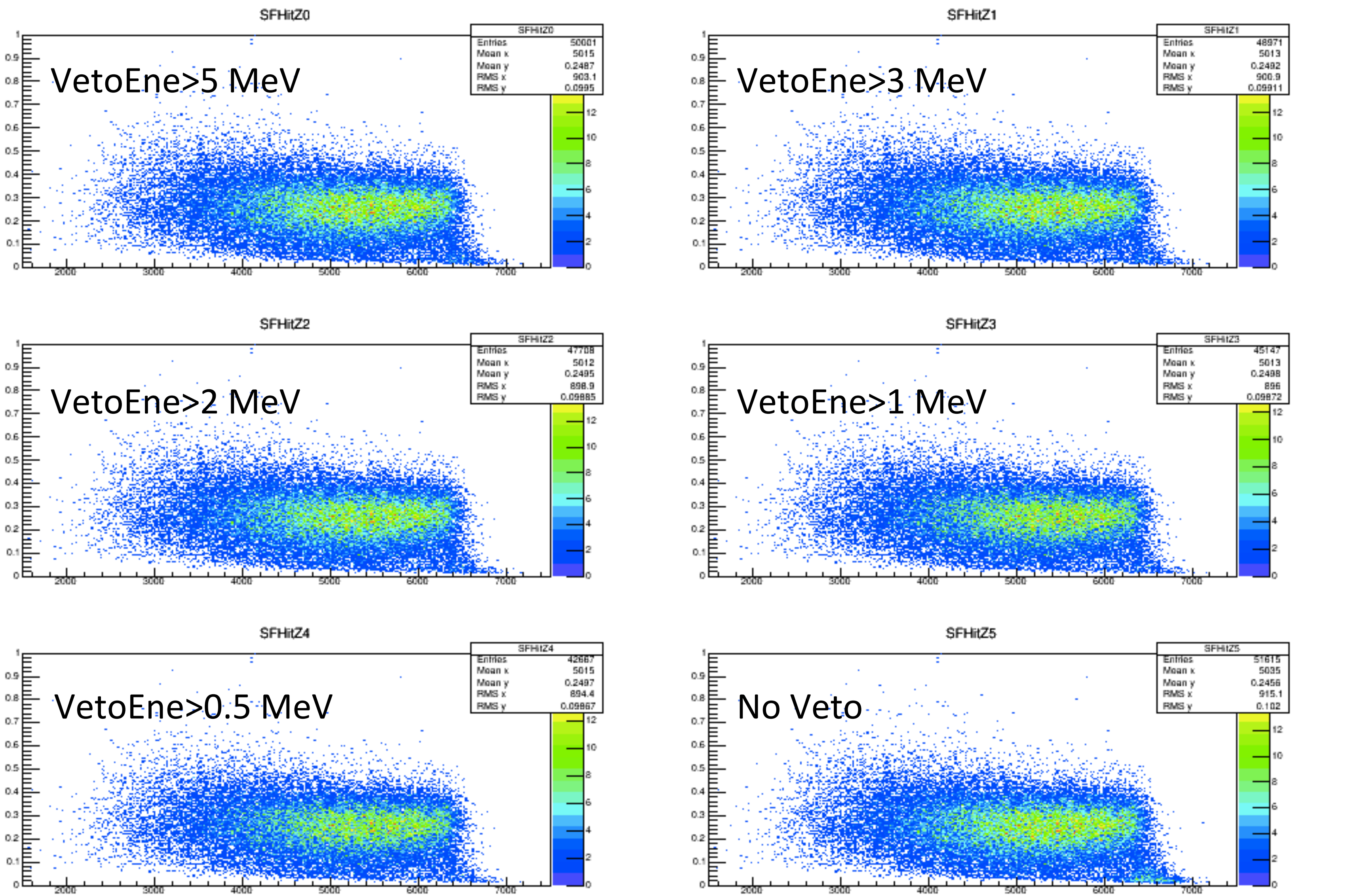
6g Vertex Time difference



OEV veto efficiency

All veto applied /
All veto except OEV

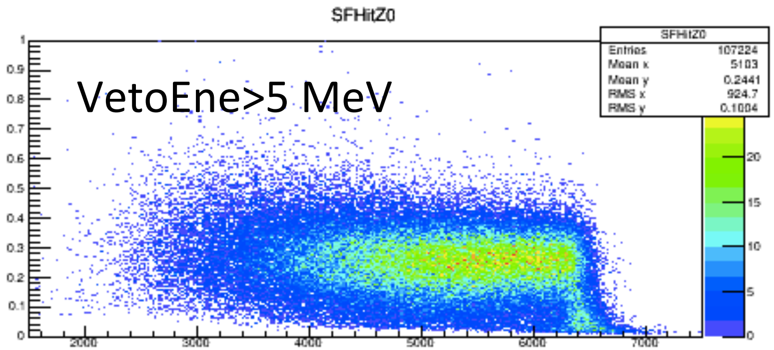
- In MC without Barrel resolution,

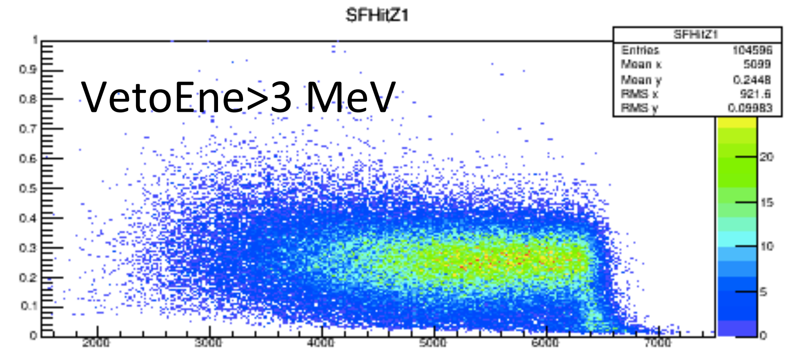


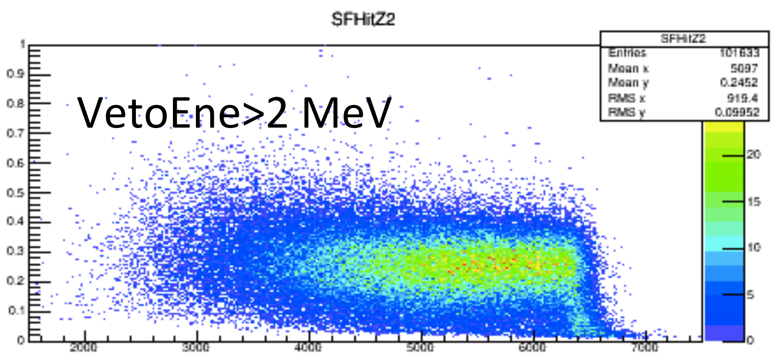
OEV veto efficiency

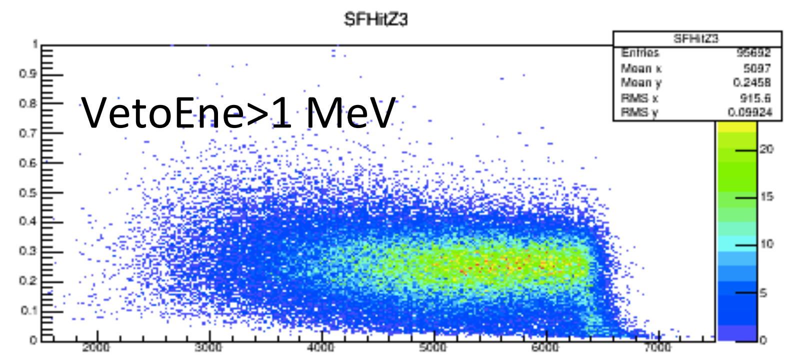
Single OEV veto

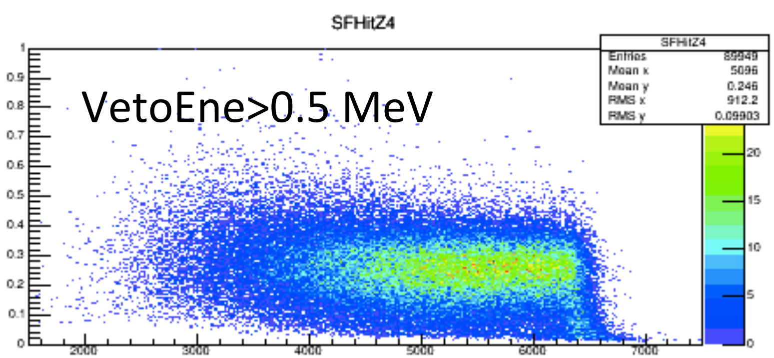
- In MC without Barrel resolution,

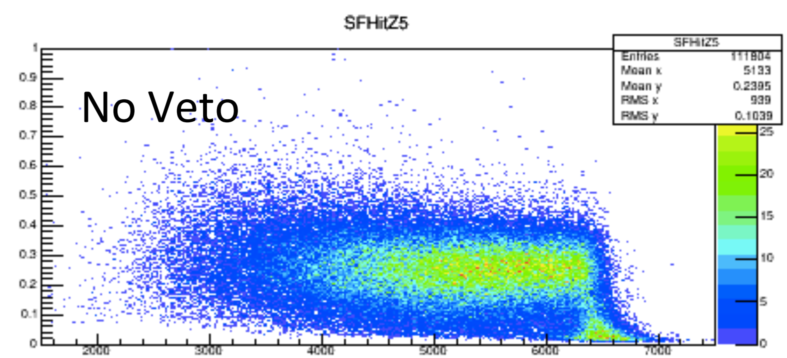












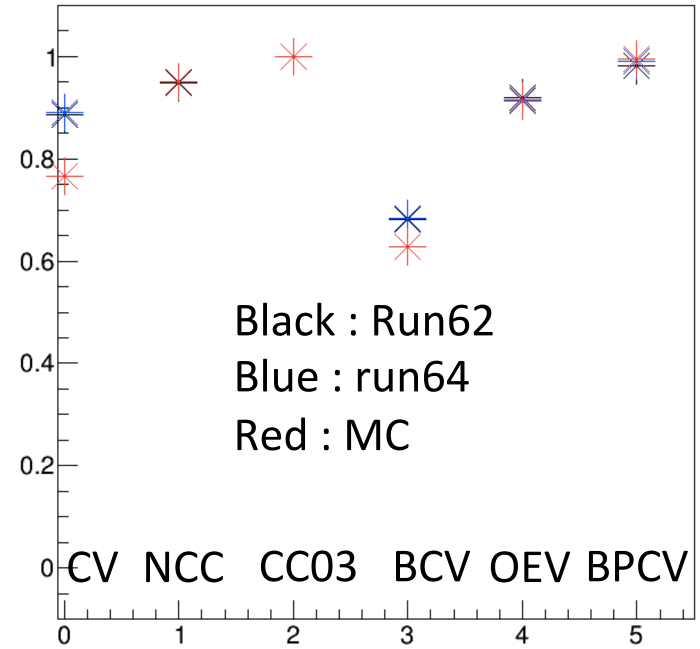
P.O.T. (Min. Bias)

With 3.6e7 #KL = 2e14 POT

- Run62 : 1.39e18
  - /300 = 4.63e15 -> 8.33e8
  - # KL3pi0 reconstructed : 9110
- Run64 : 4.38e18
  - /300 = 1.46e16 -> 2.63e9
  - # KL3pi0 reconstructed : 31347 (9941)
- Run69 : 5.21e17
  - /70 = 7.44e15 -> 1.34e9
  - # KL3pi0 reconstructed : 12799 (7950)
- MC Generation
  - KL3pi0 Gen : 1e6*2000
  - #KL ~ 5.13*1e6*2000 = 1.03e10
  - # KL3pi0 reconstructed : 132659 (10729)

POT -> #KL

Single Veto Efficiency



Global Time shift in Run69