J-PARC KOTO実験における横方向光子検出器の性能向上

Main Barrel upgrade for J-PARC KOTO exp.

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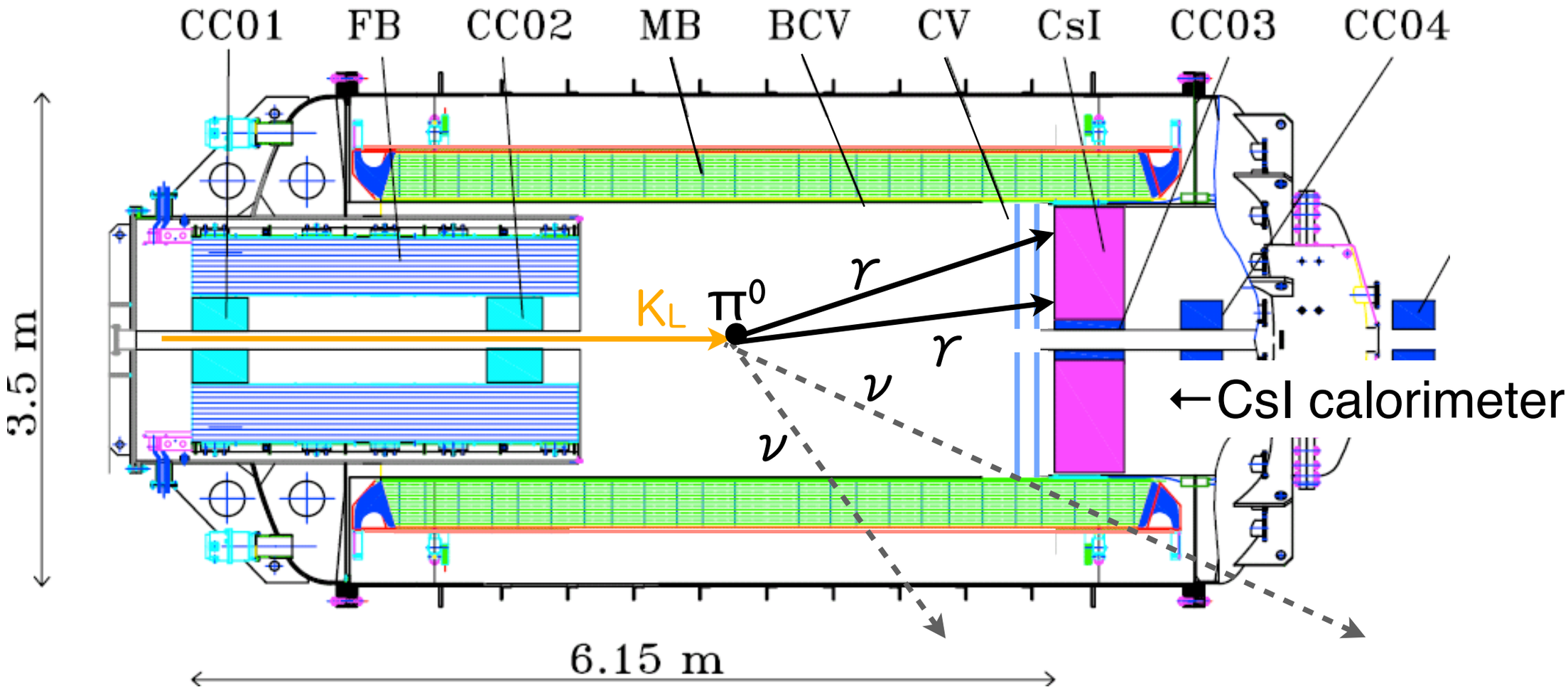
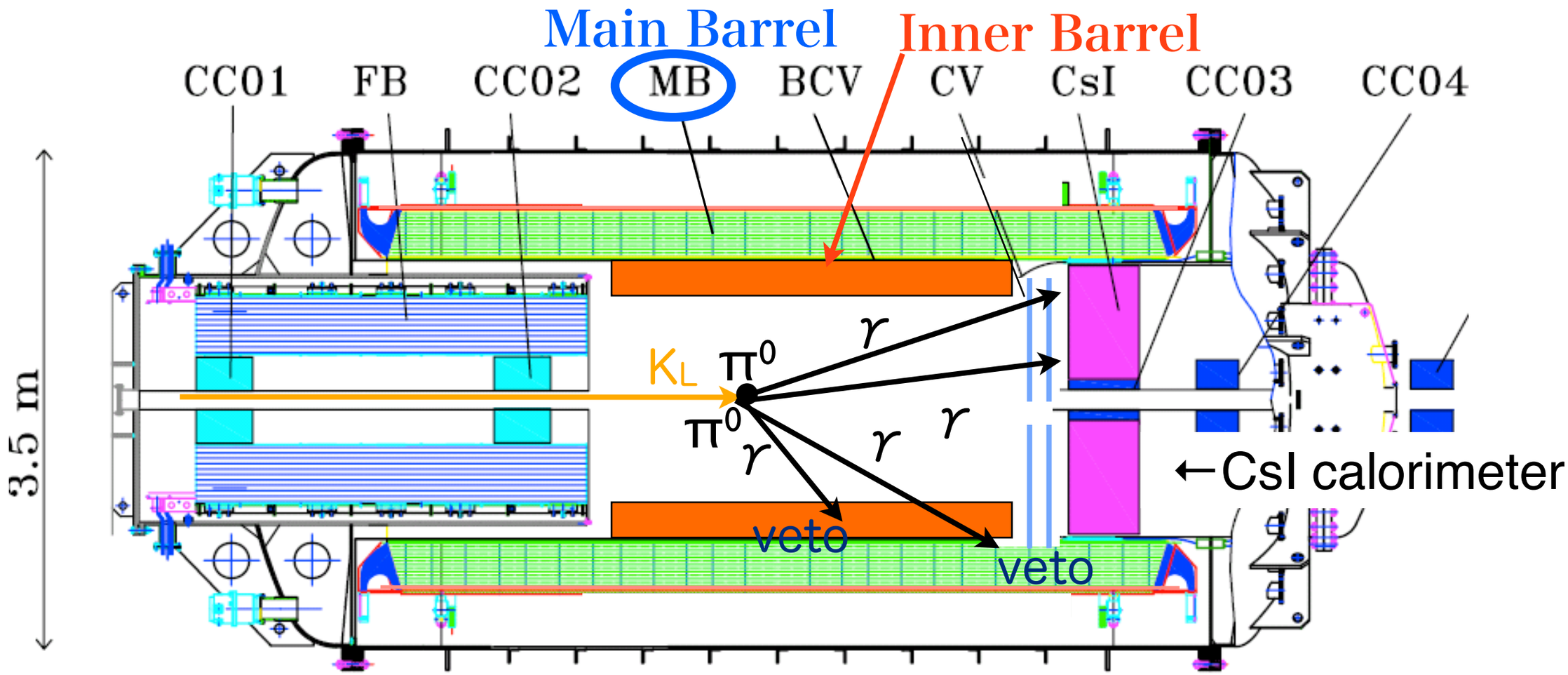
KOTO experiment

- KOTO measures the branching ratio of $K_L \to \pi^0 \nu\nu$ estimated 2.4×10^{-11} by SM.



- CsI calorimeter detects 2γ from π^0 in $2K_L \to \pi^0 \nu\nu$.
- All detectors surrounding decay region veto other particle in other decay mode.

Issues of Main Barrel region and new detector



- γ missing in main background $K_L \rightarrow \pi^0\pi^0$.

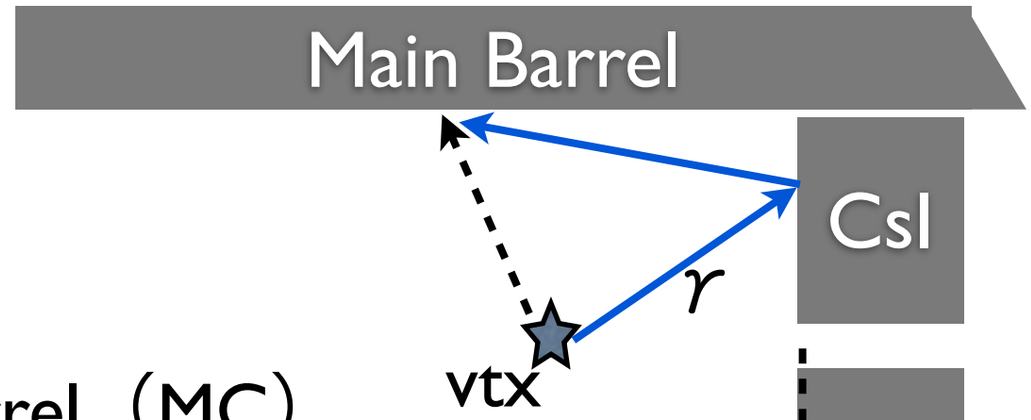
→ Additional detector thickness makes # $2\pi^0$ 2.0→0.6, S/N 1.0→1.7. (same condition about signall loss)

- Signal loss due to over veto of accidental event.

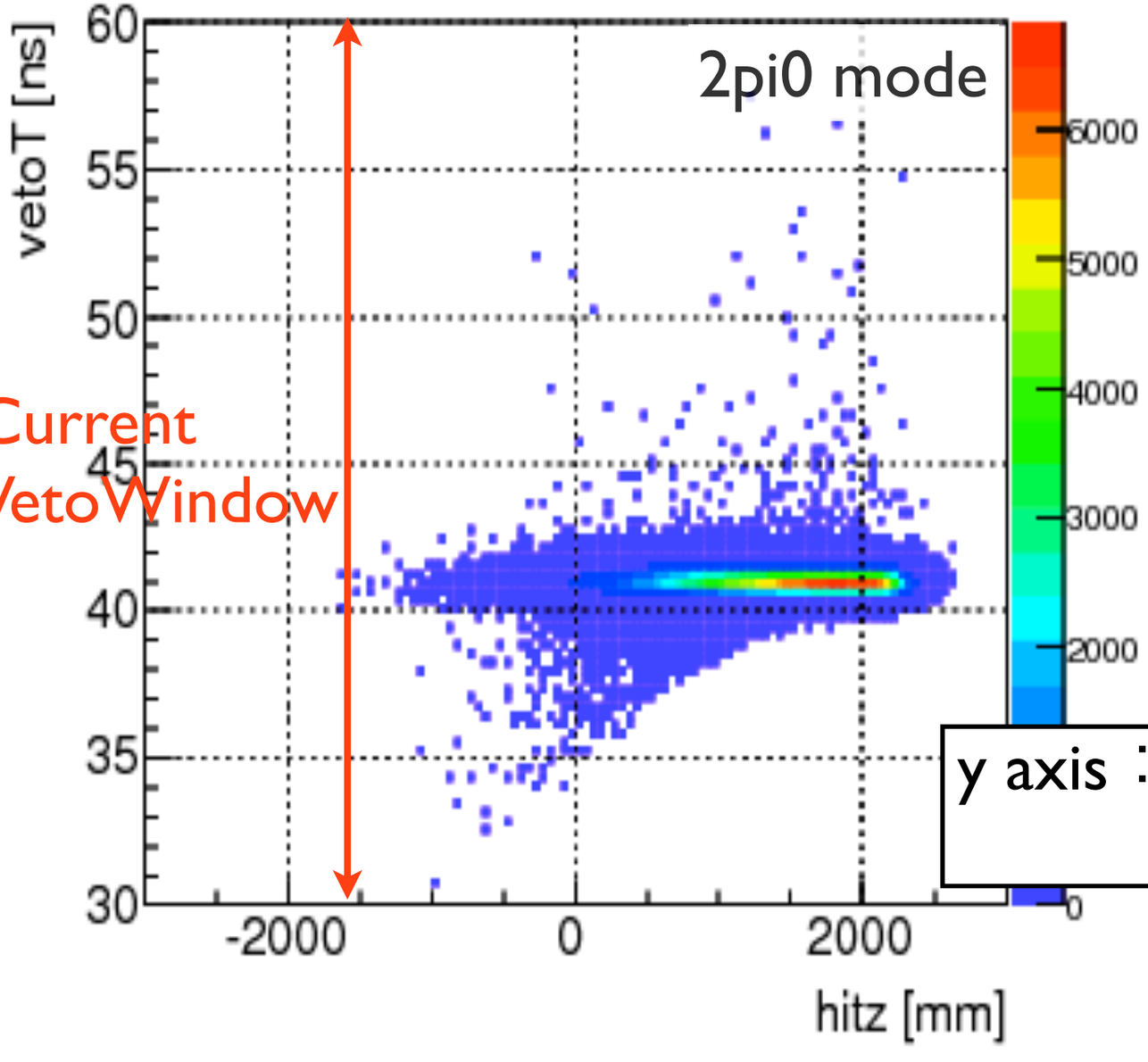
→ High resolution fiber of Inner Barrel makes good timing resolution.

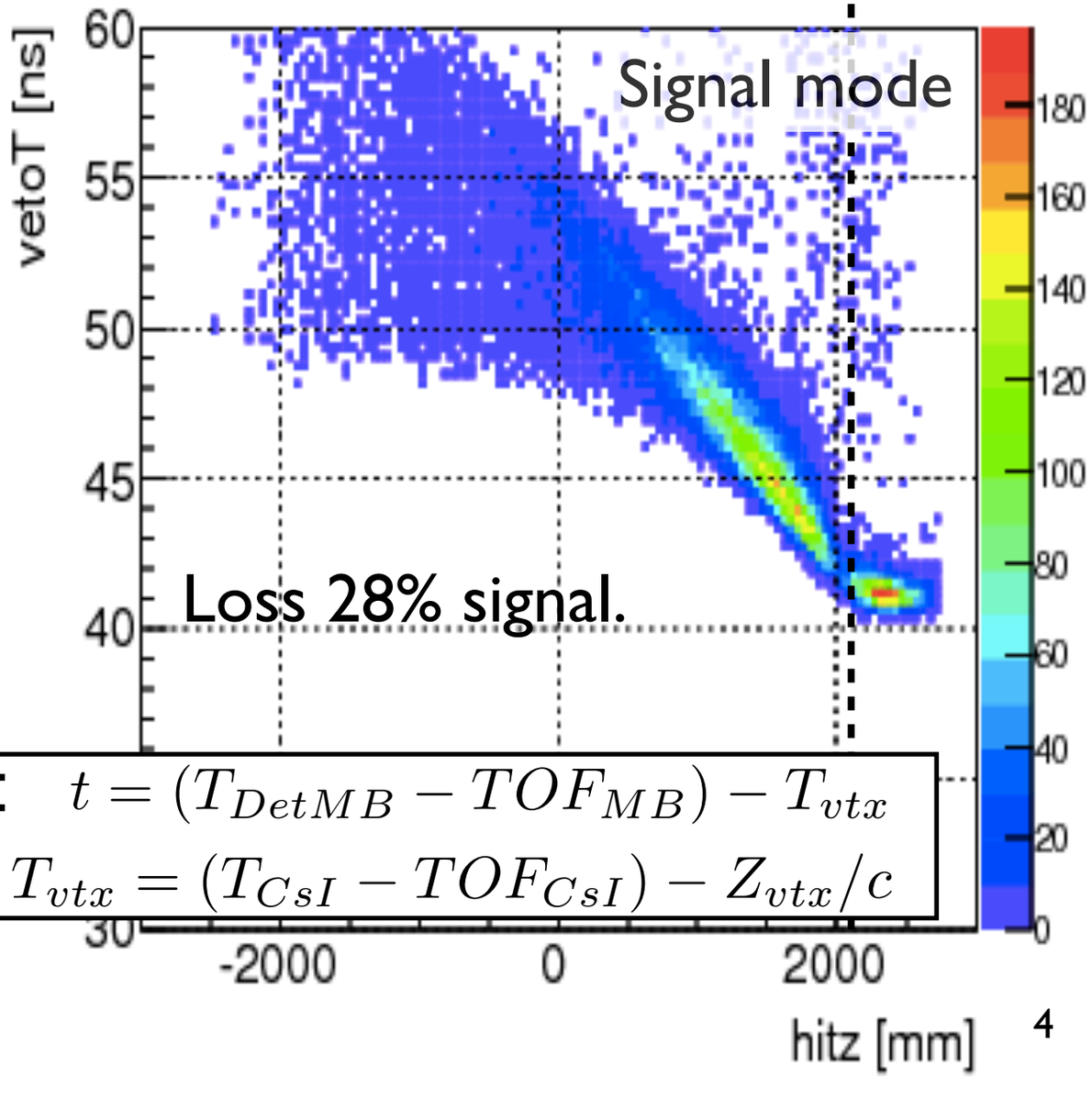
Signal loss case 1) Back splash

- Back splash ... Electromagnetic shower leakage from CsI calorimeter



- Detect position z and timing at Main Barrel （MC）





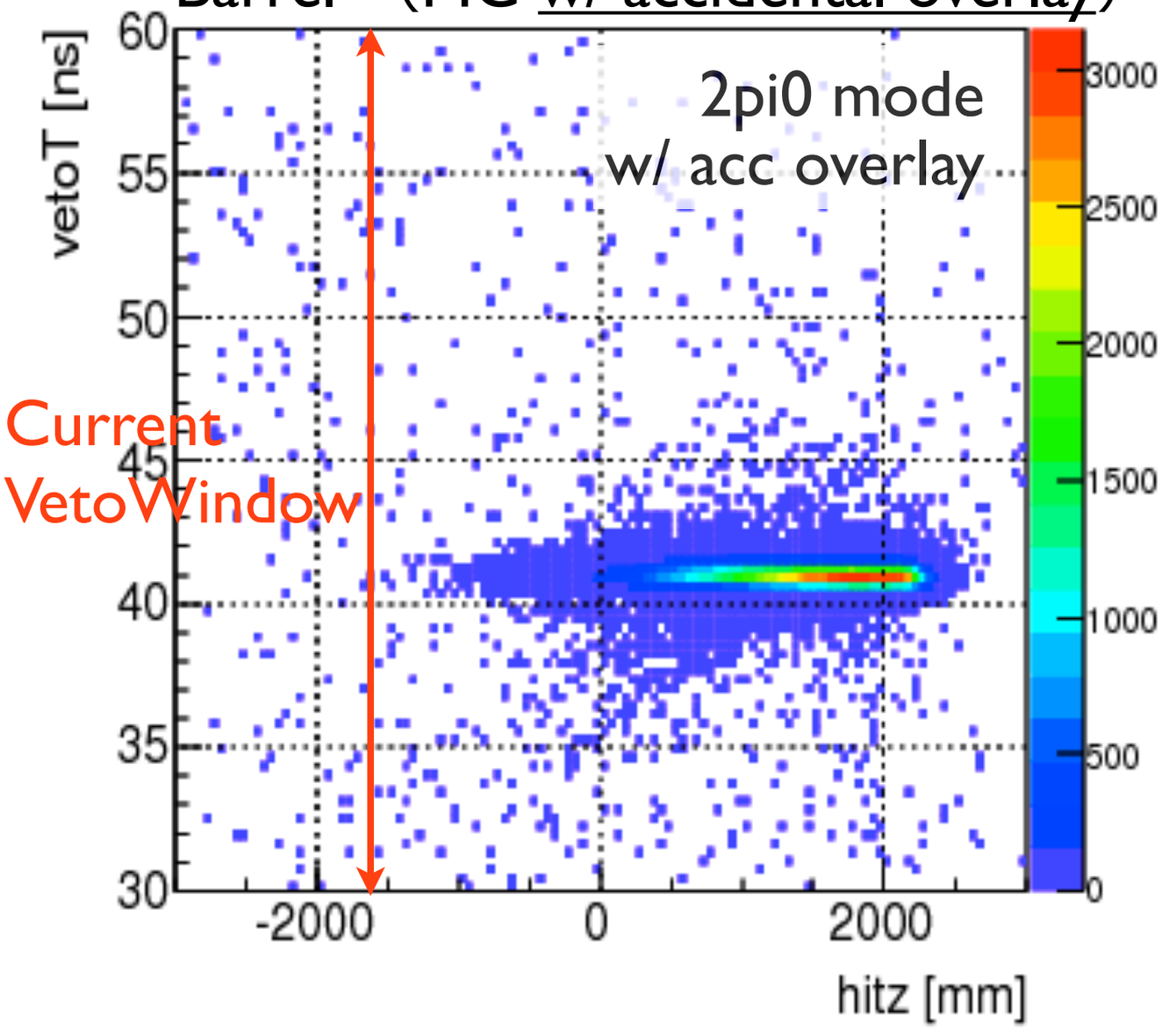
y axis : $t = (T_{DetMB} - TOF_{MB}) - T_{vtx}$

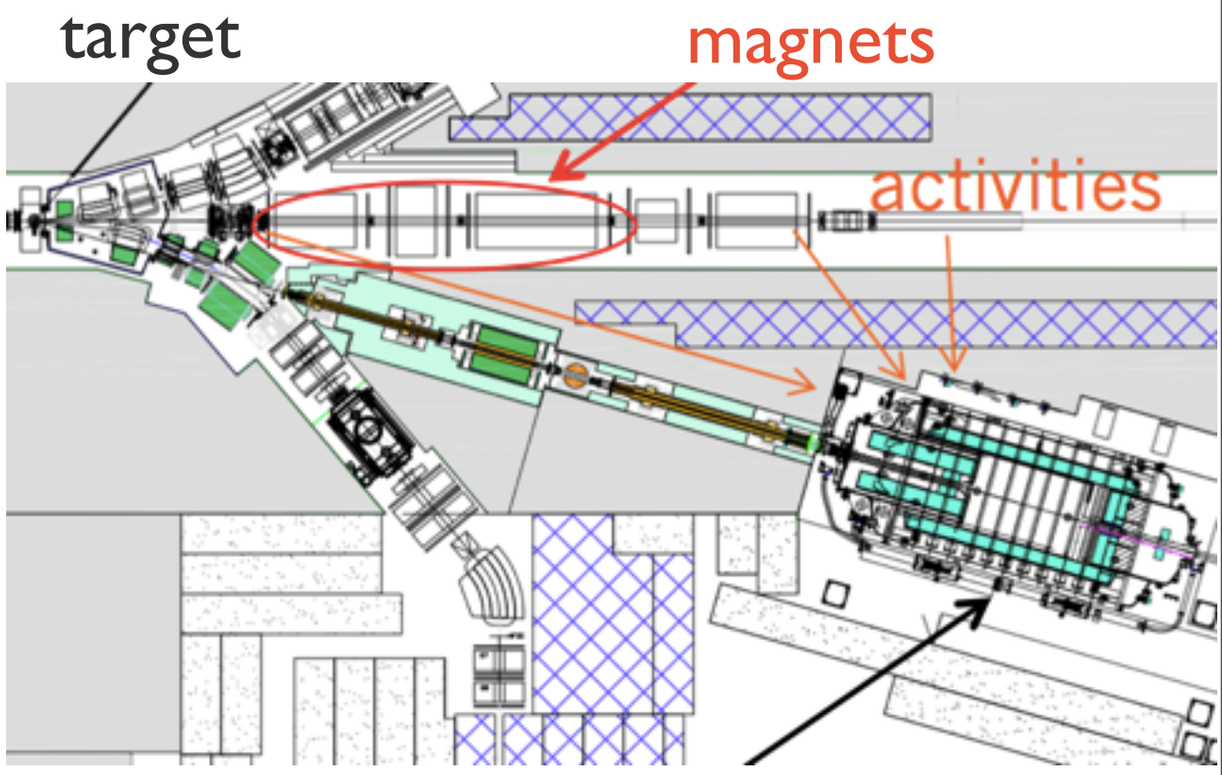
$T_{vtx} = (T_{CsI} - TOF_{CsI}) - Z_{vtx}/c$

Signal loss case 2) Primary beam origin

- Activities from primary beam line make high accidental counting rate. Magnet tuning is on trial.

- Detect position z and timing at Main Barrel (MC w/ accidental overlay)





KOTO detectors

Timing resolution at Barrel

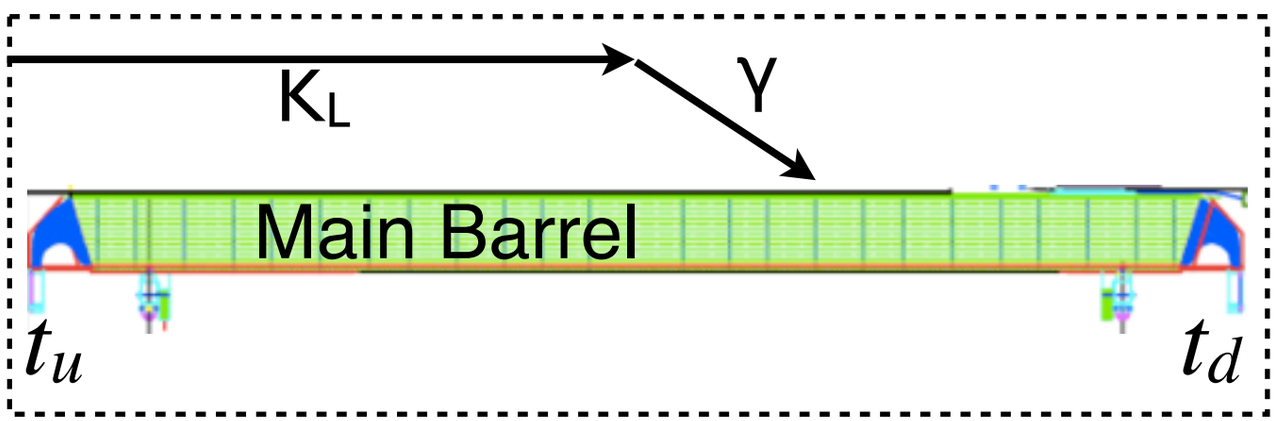
- Timing / z position is important for long veto Barrel detector.

  Z position resolution is in propotion to timing resolution.

  ※ Resolution caused by CsI is already included.

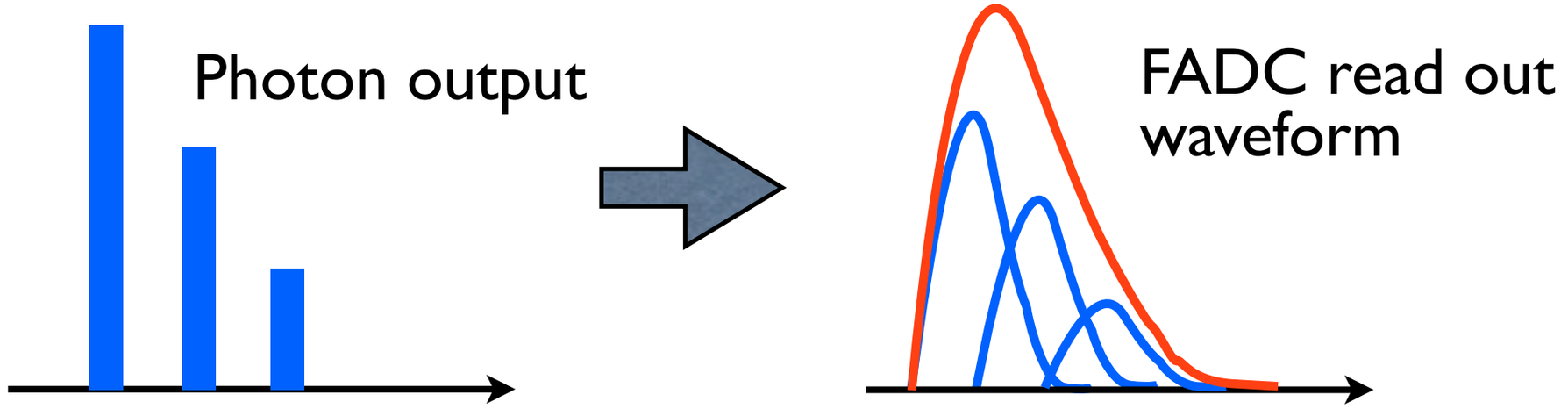
  < Timing / z position at Barrel >

$$
\begin{aligned}
t_{MB} &= (T_{DetMB} - TOF_{MB}) - T_{vtx} \\
T_{DetMB} &= (t_u + t_d)/2 \\
z_{MB} &= v(t_u - t_d)/2 \\
\sigma_z &= v\sigma_t
\end{aligned}
$$



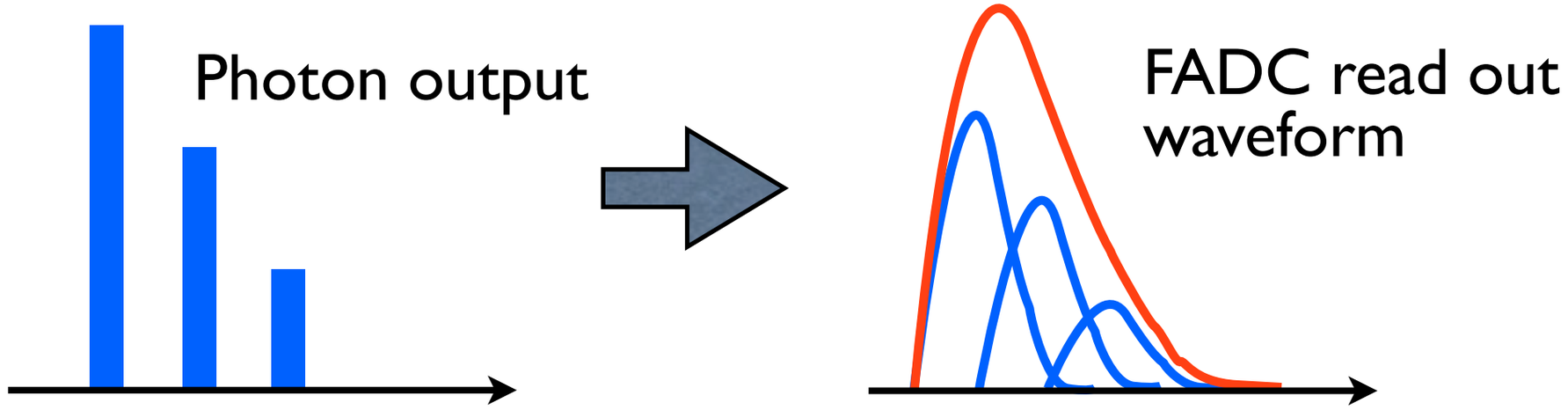
- Timing is decided by waveform taken by FADC.

Waveform of Barrel detectors



	scinti.	fiber (catalog decay time)	PMT	FADC w/ or w/o filter	
MB	MS-resin 15+30 layers	Y11 (8.8 ns)	R329EGP	125 MHz w/ Bessel filter	→total waveform
IB	MS-resin 25 layers	BCF92 (2.7 ns)	R329EGP (up) R7724 (down)	500MHz w/o filter	→total waveform

Waveform of Barrel detectors



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Cosmic ray by Oscillo.
→ timingPDF

1p.e. counting by Oscillo.

1p.e. counting by FADC

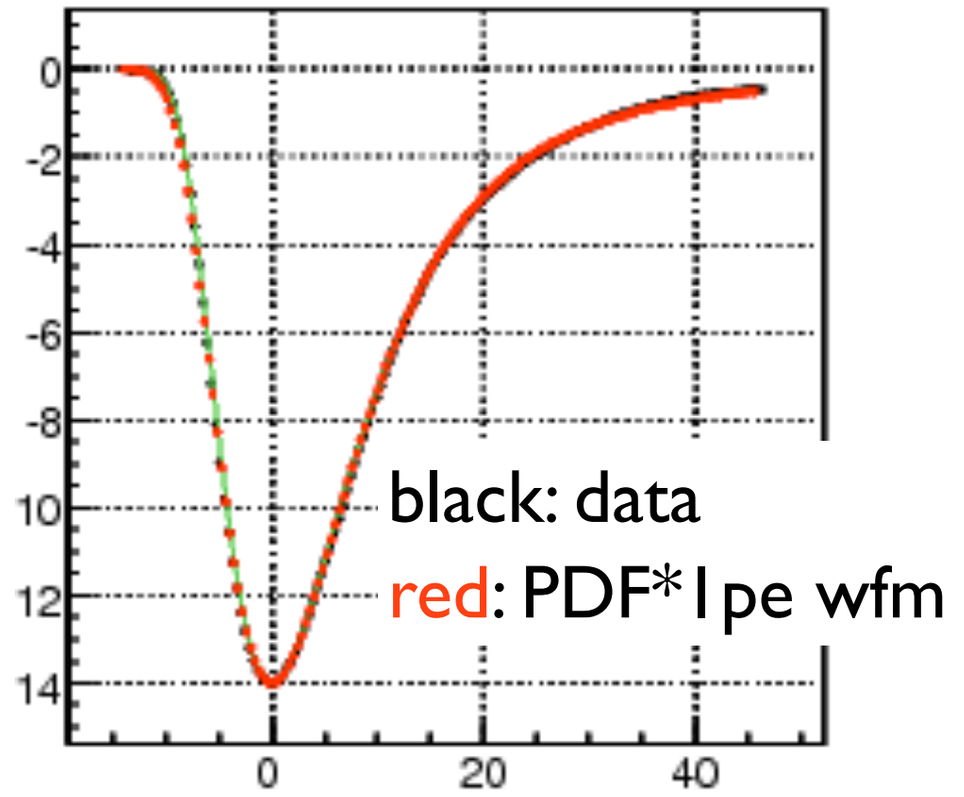
Timing PDF finding

- Pile up cosmic ray data on assumed timing PDF * 1p.e. waveform at PMT.

Timing PDF

$$f = A\exp\left[-\left(\frac{t-\mu}{a(t-\mu)+\sigma}\right)^2\right]+C$$

Fitting waveform at minimum chi2 →

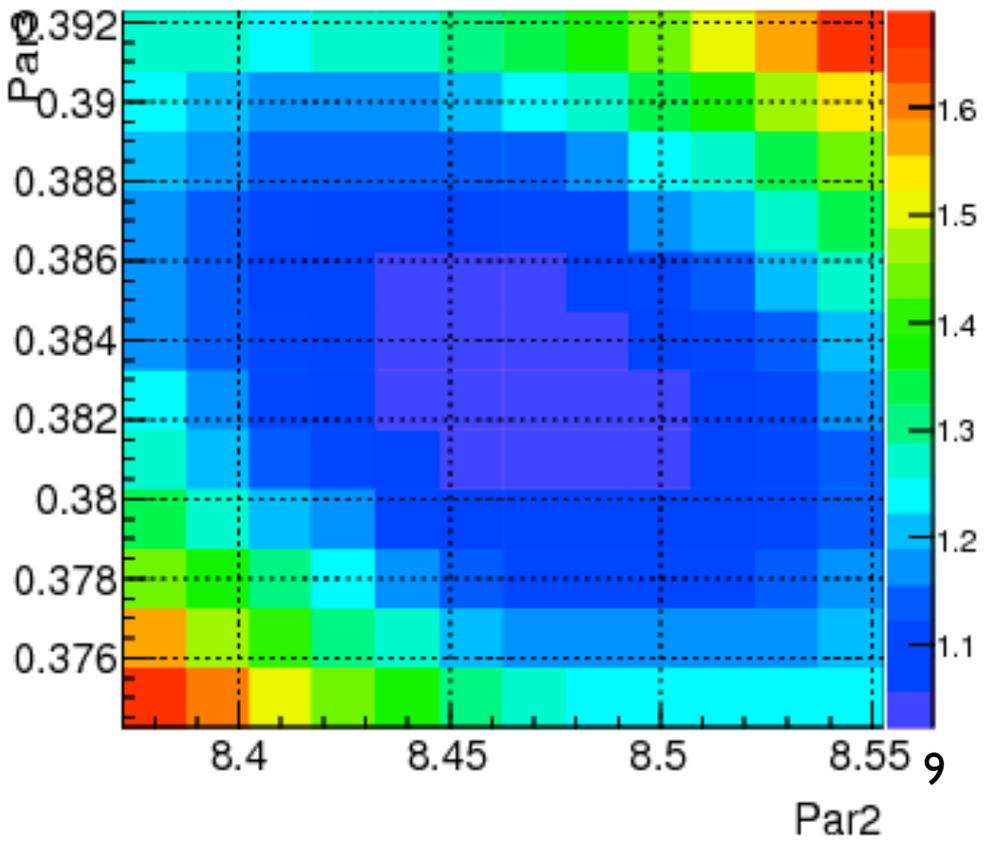


- Search minimum chi2.

$$\frac{\chi^2}{NDF} = \frac{1}{N-2}\sum_i^N \frac{\left(H_i^{cos}-H_i^{pdf}\right)^2}{\alpha_{min}\sigma_i(H_i^{cos})^2+\sigma_i^{pe}(H_i^{pdf})^2}$$

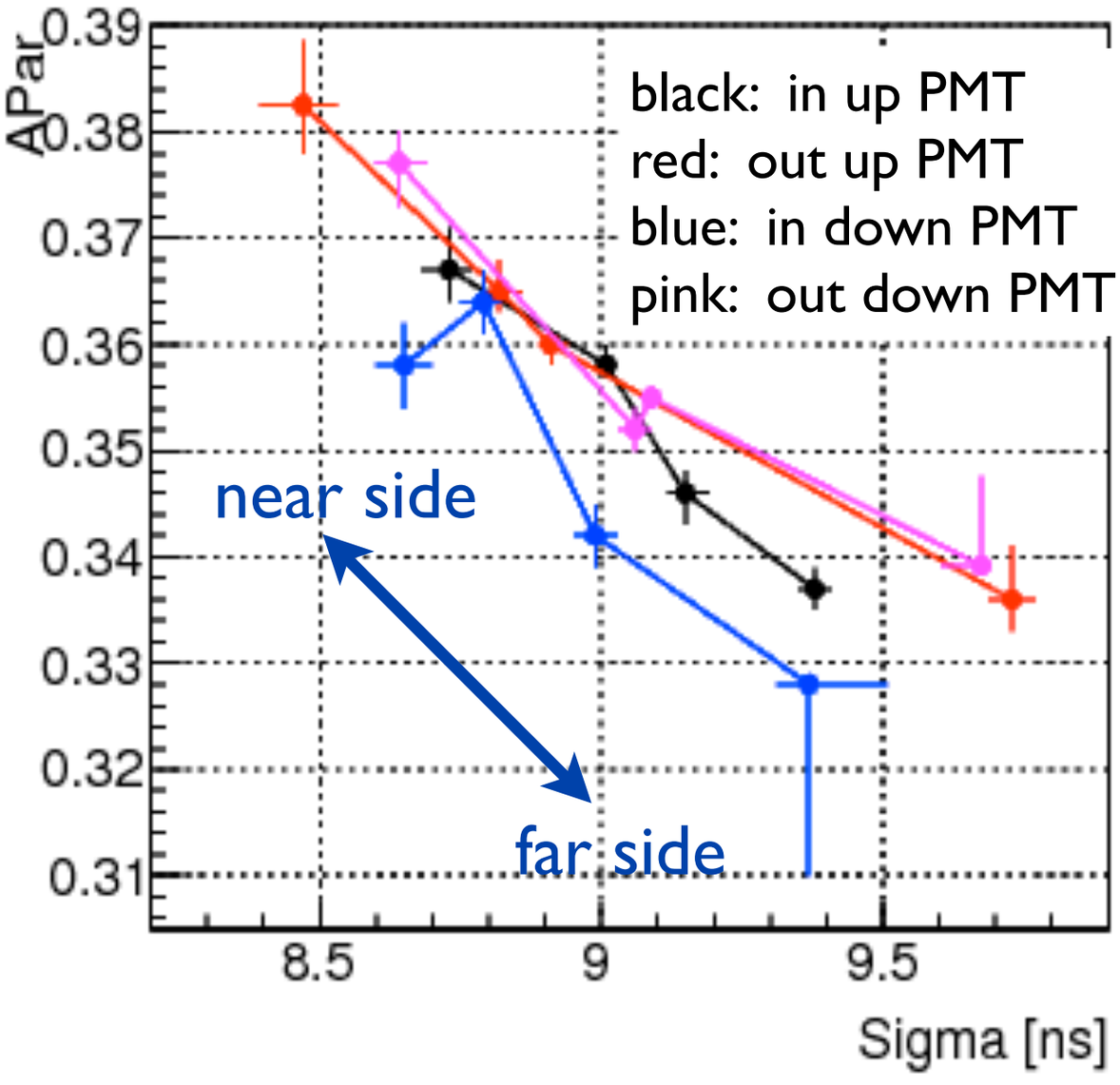
$$\alpha \sim \frac{1}{N-2}\sum_i^N \frac{\left(H_i^{cos}-H_i^{pdf}\right)^2}{\sigma_i(H_i^{cos})^2+\sigma_i^{pe}(H_i^{pdf})^2}$$

Chi2 value at each σ and *a* →

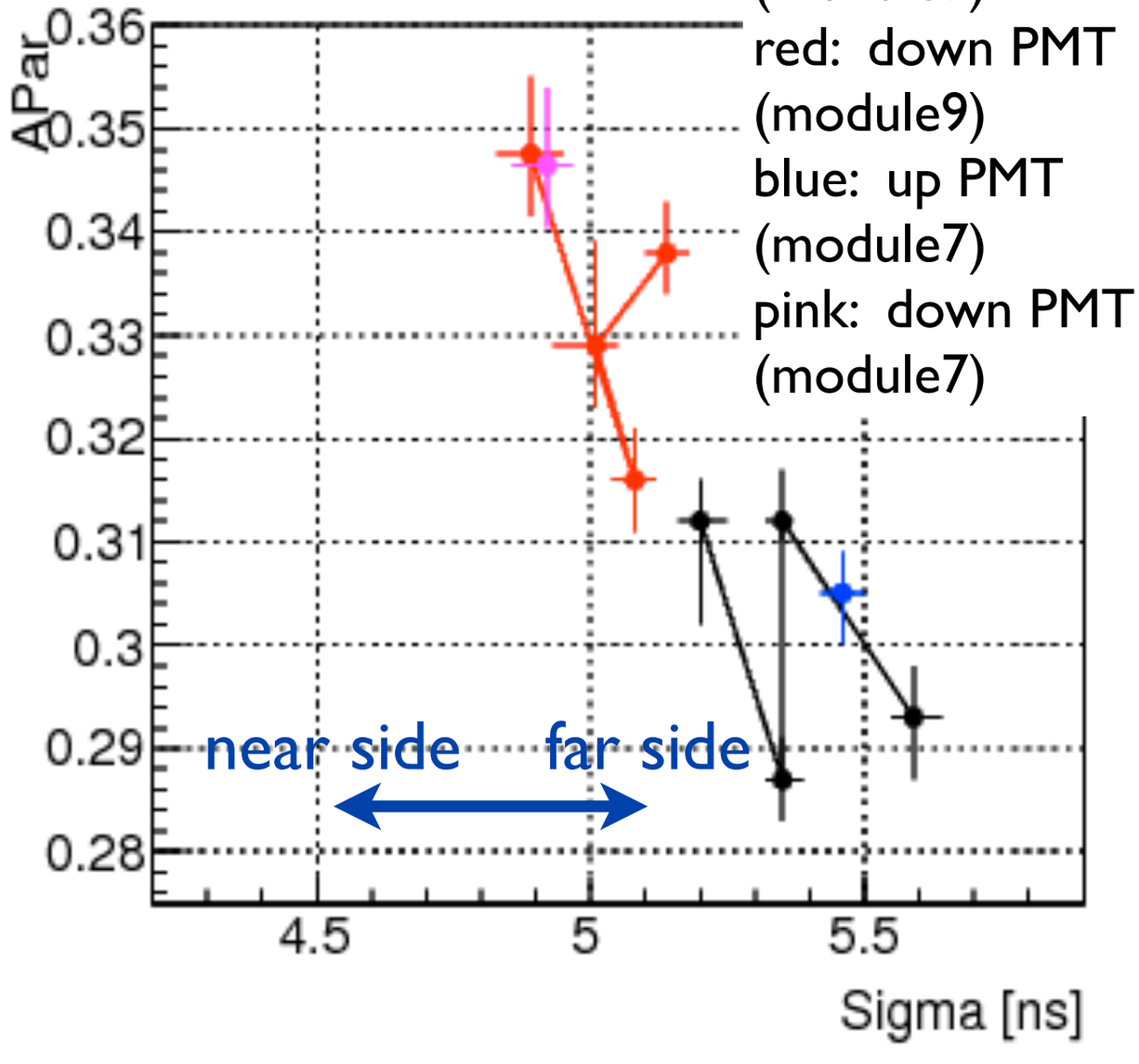


Parameters of timing PDF

Main Barrel

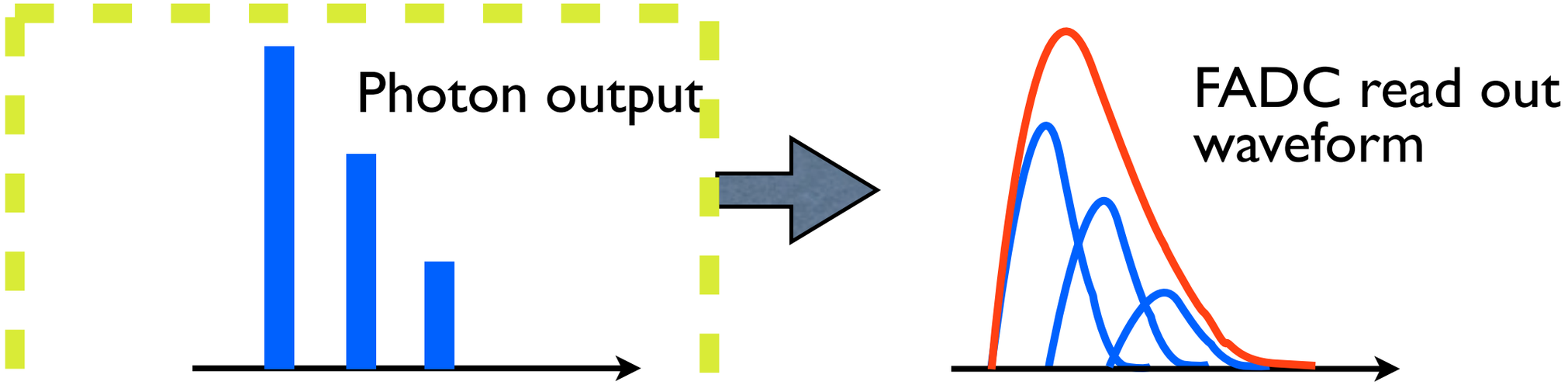


Inner Barrel



- Error bar is set reducedχ^2 < 1.1.

Waveform of Barrel detectors



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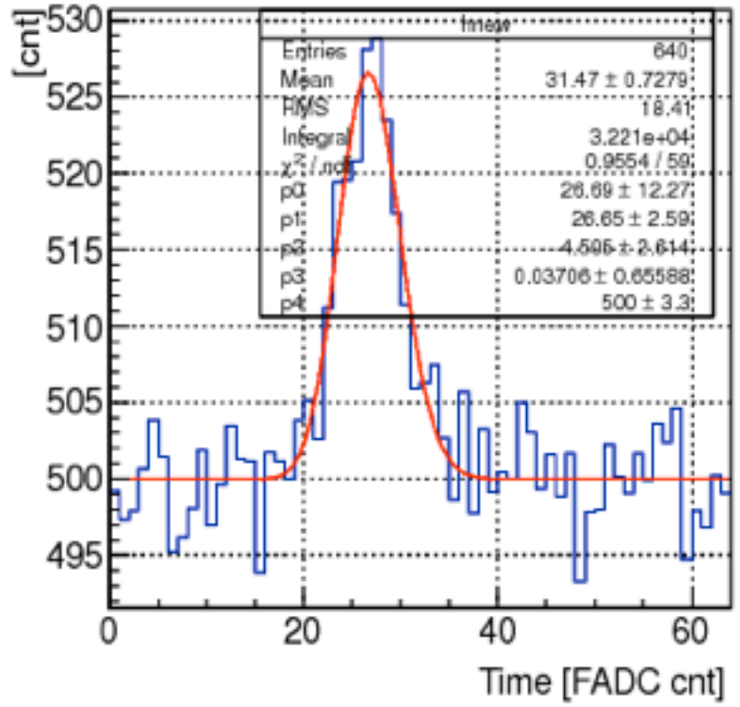
Timing resolution difinition

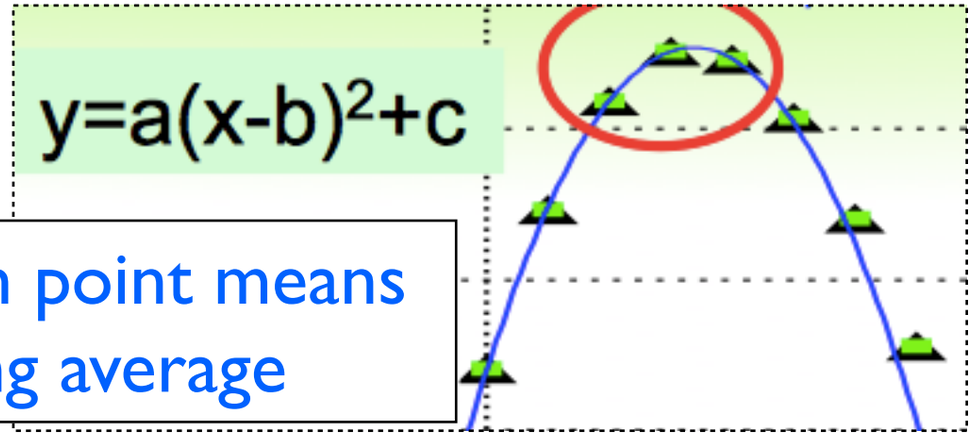
- Method 1) Peak of asymmetric gaus fitting →

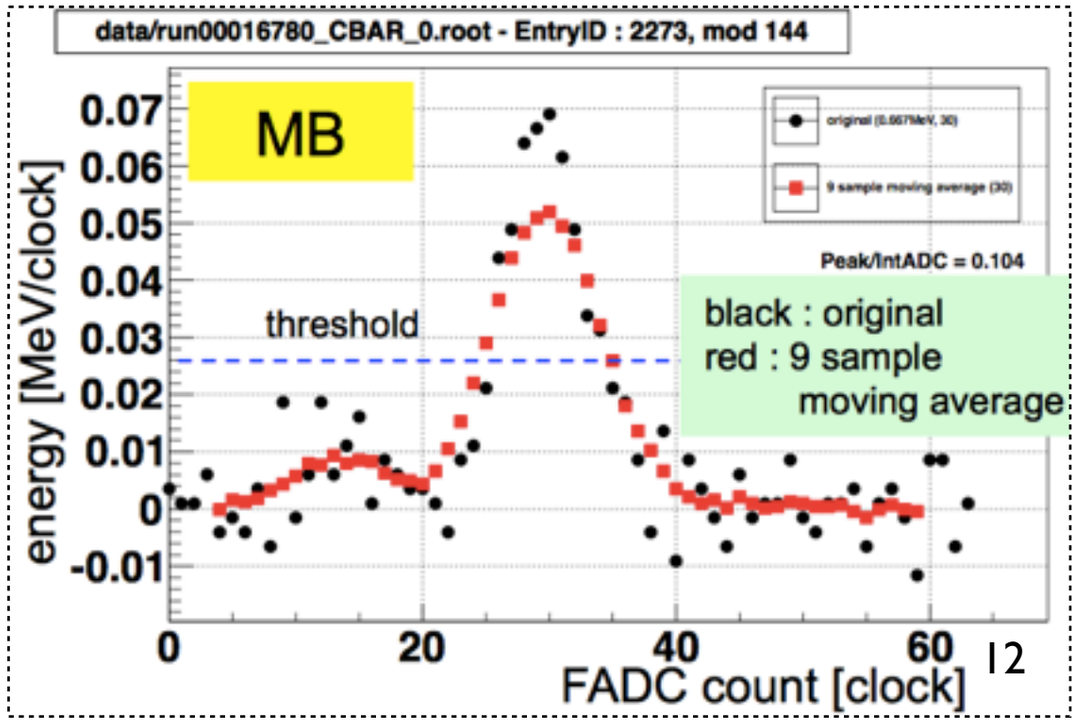
Fit function

$$f = A\exp\left[-\left(\frac{t-\mu}{a(t-\mu)+\sigma}\right)^2\right]+C$$



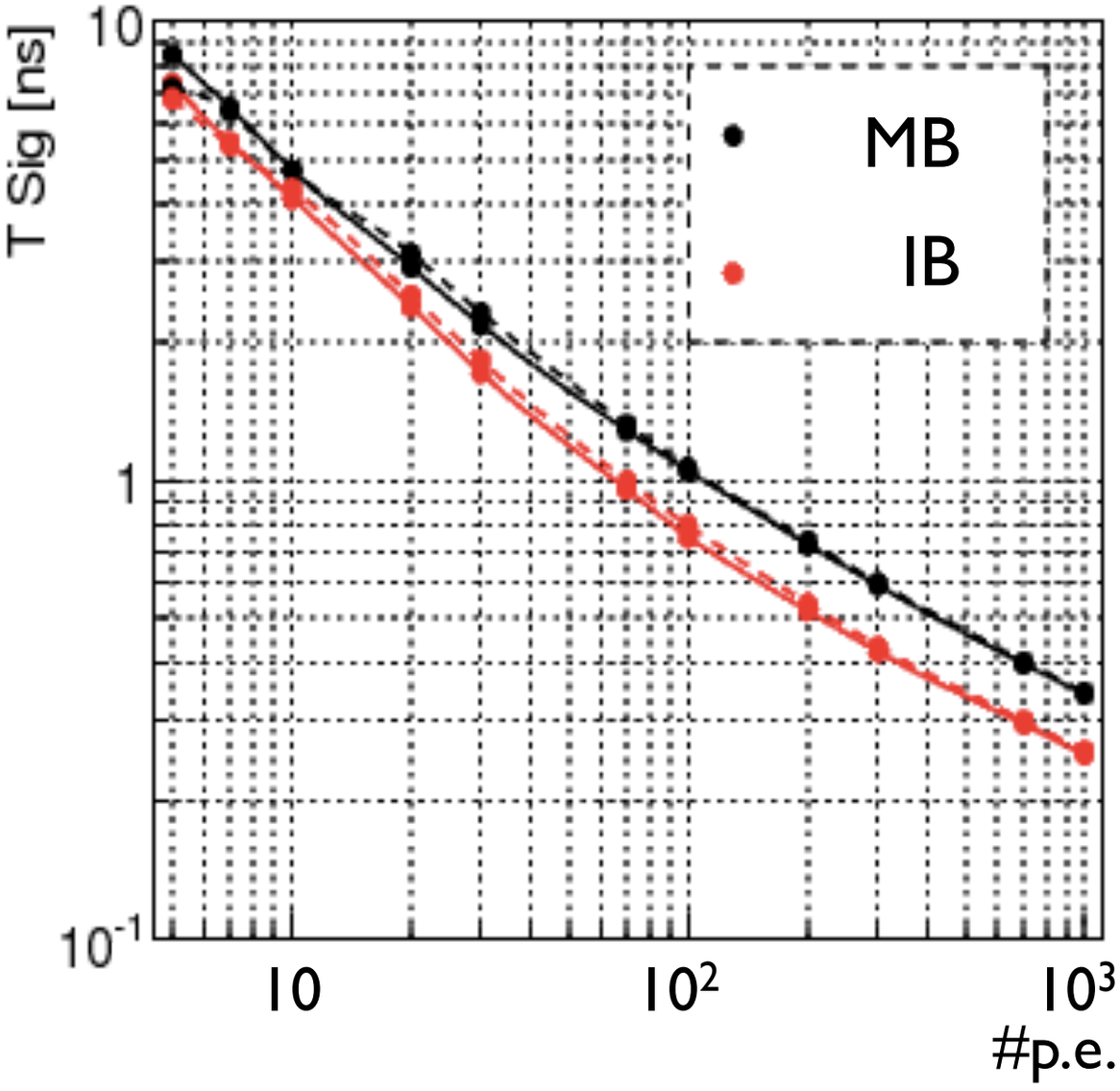
- Method 2) Parabola fitting
  - Parabola peak of moving average.
  - Nearest peak to “Nominal time”.
  - Bias to suppress background enough and avoid event masking.



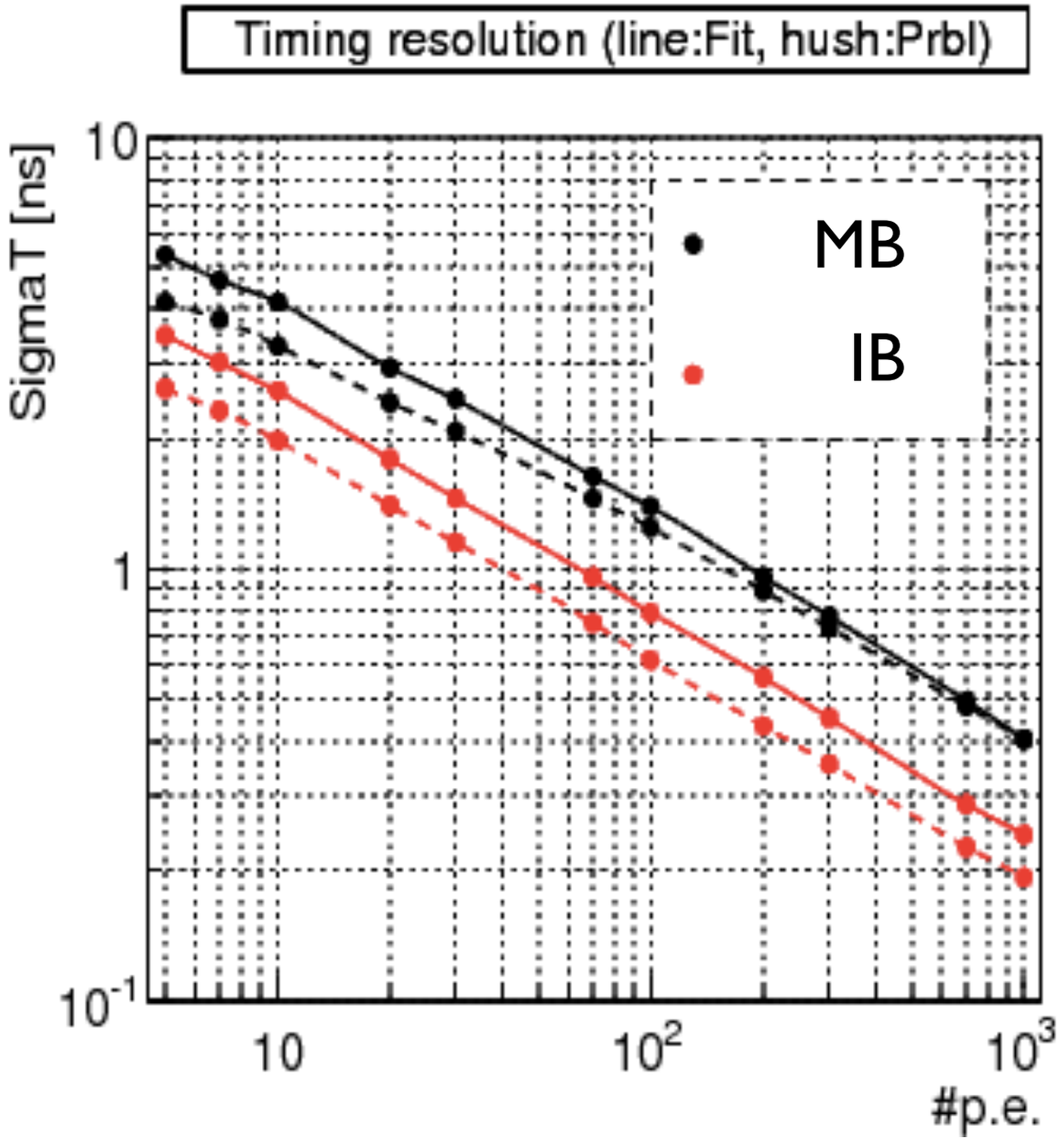


Timing resolution

125 MHz FADC



500 MHz FADC



Summary

- Timing resolution for 125 MHz FADC and 500 MHz FADC is estimated.

- Things to do...
- Check parabola method about peak selection bias.
- Check wfm dependence of timing resolution of 500 MHz FADC.
- Estimate the effect on veto timing condition.