# J-Parc $K^0$TO実験における横方向光子検出器の高精度化

～最内層の構造～

2011/03/25

関西高エネルギー研究発表会

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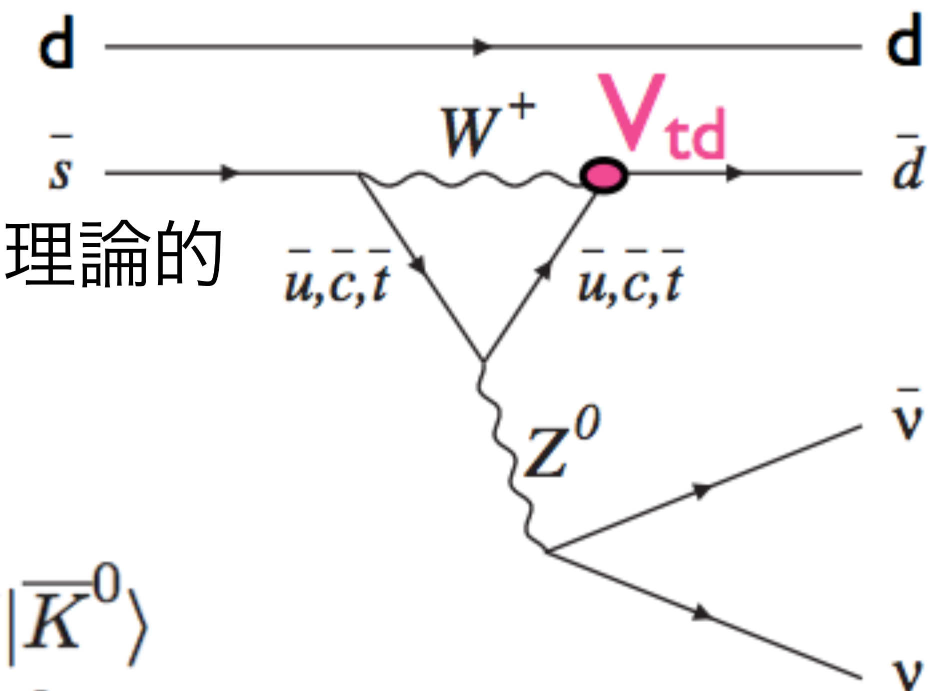
- E14 exp. and ”MB” detector
- The effect of MB upgrade in proposal
- Possibility for additional upgrade
- CsI to reduce sampling effect & photo-nuclear interaction effect
- Possible structure
- Back-splash estimation
- Summary

# K⁰TO実験

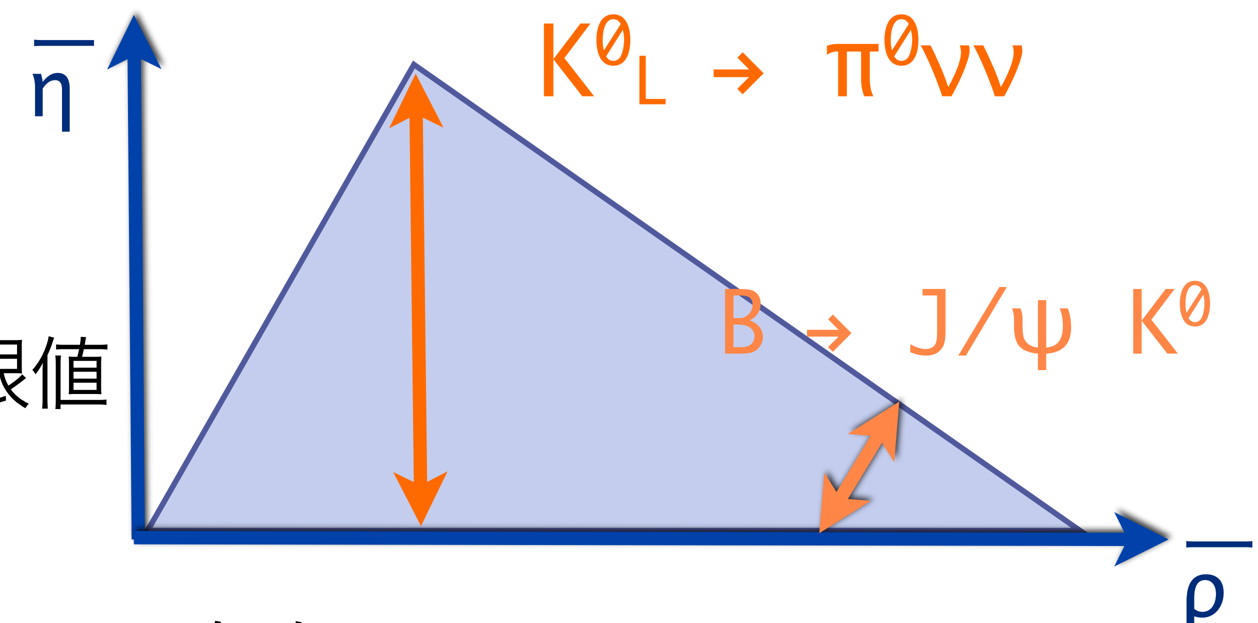
- $K_L \to \pi^0 \nu\nu$ の分岐比を検証
- 小林益川行列の複素成分ηを数%の小さな理論的不定性で測定可能な Golden Mode

$$\langle \pi^0 \nu\bar{\nu} | H | K_L \rangle \simeq \langle \pi^0 \nu\bar{\nu} | H | K_{odd} \rangle$$
$$\propto \langle \pi^0 \nu\bar{\nu} | H | K^0 \rangle - \langle \pi^0 \nu\bar{\nu} | H | \overline{K}^0 \rangle$$
$$\propto V_{td} - V_{td}^* \propto i\mathrm{Im}(V_{td}) = i\lambda^3 \eta.$$




- 稀崩壊

小林・益川理論のユニタリ三角



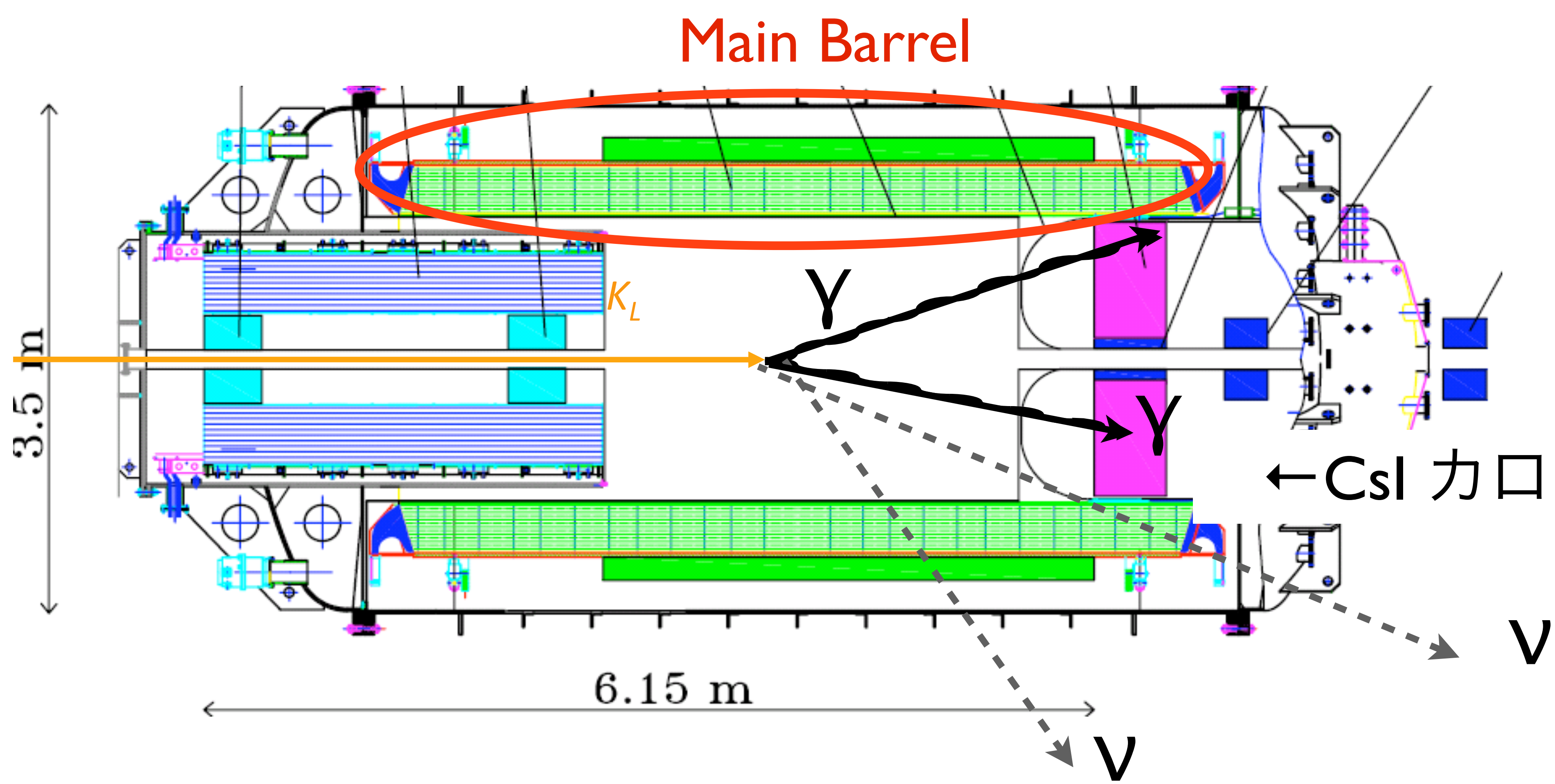

標準理論(SM)ではBR=$3\times10^{-11}$と予想

E391a実験：$2.6\times10^{-8}$ (90%レベル)上限値

K⁰TO実験ではSMの感度を目指す

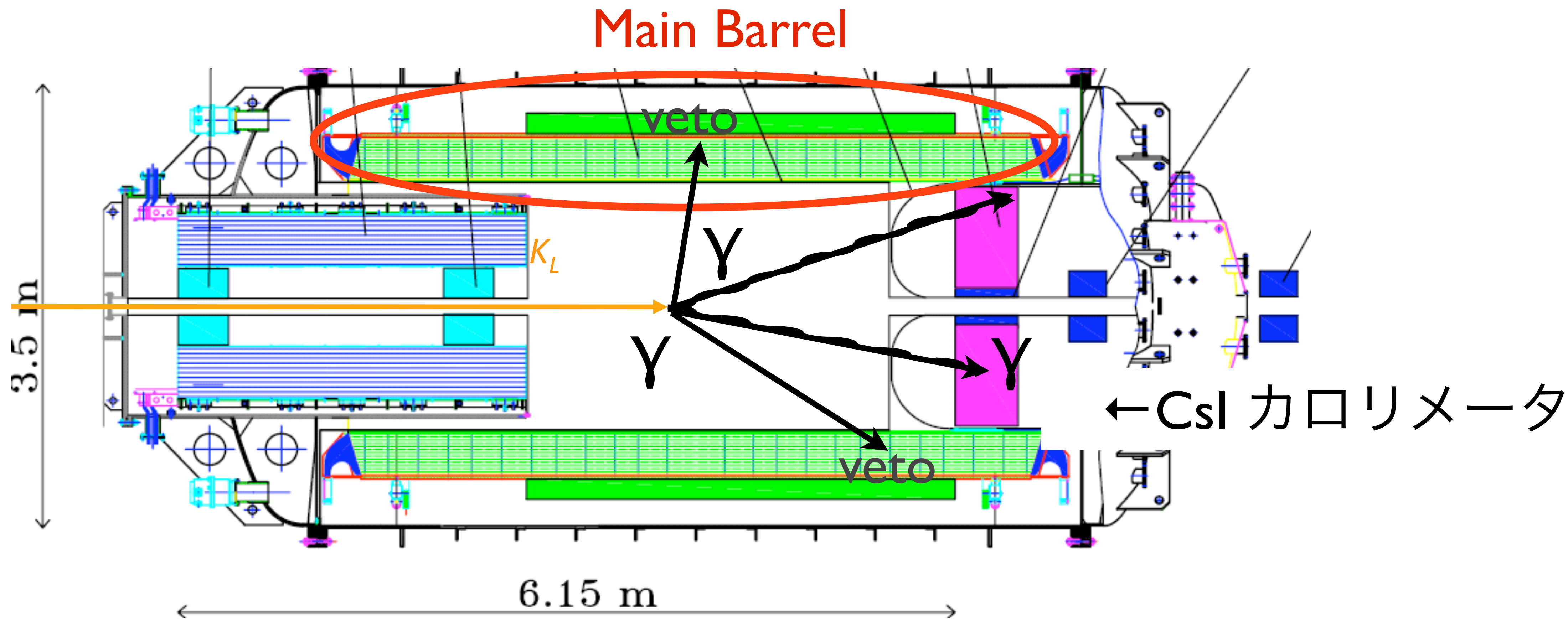
分岐比がより大きければ、新しい物理の存在を示す

# KOTO実験 でのシグナル検出




- CsIカロリメータにて$\pi^0$からの2γを検出
- CsIカロリメータ以外の全ての検出器にて他事象をveto(除去)

# 横方向光子検出器(Main Barrel(MB))




✴E391a実験のMBを再利用、改良して使用

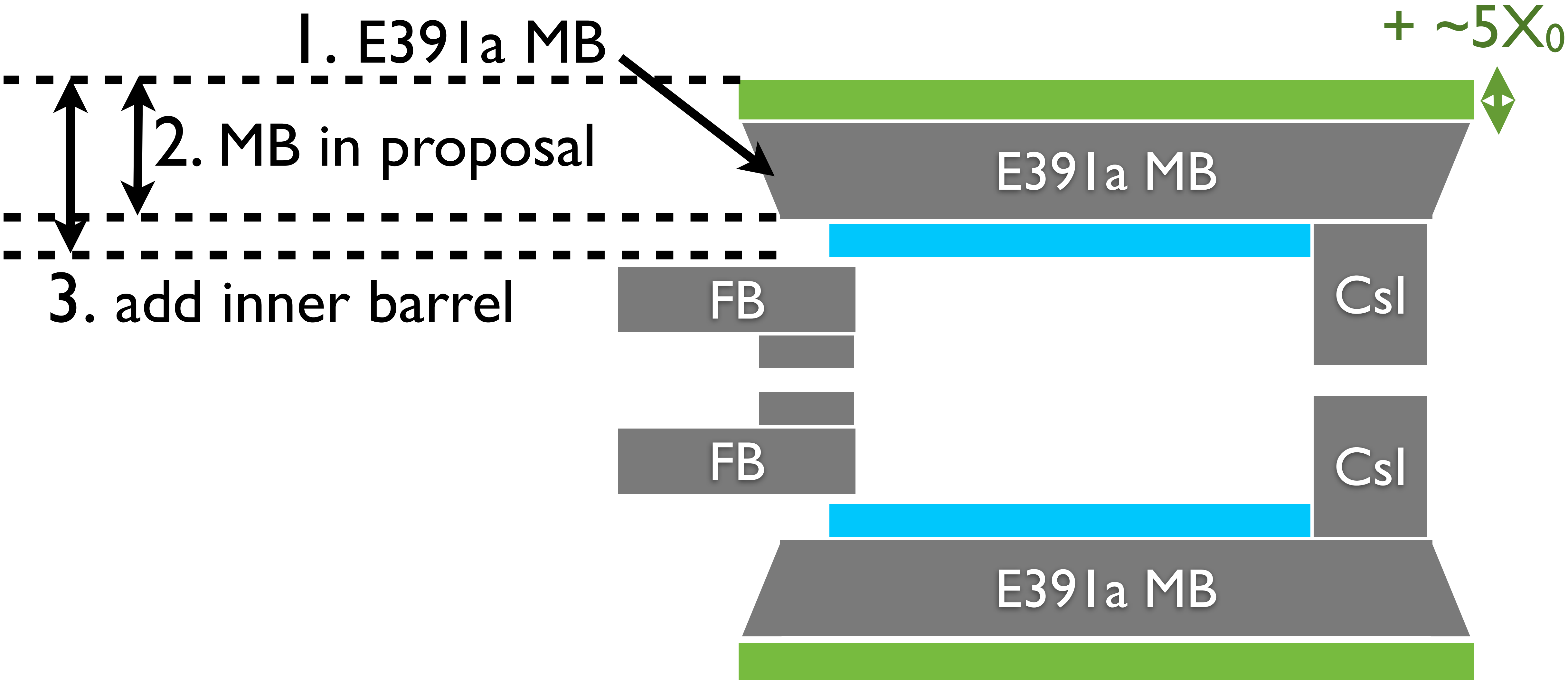
✴E391aでは鉛とシンチレータ積層構造

| | # π0π0 background | # signal |
|---|---|---|
| E391a MB | 2.9±0.4 events | 3.42±0.02 events |

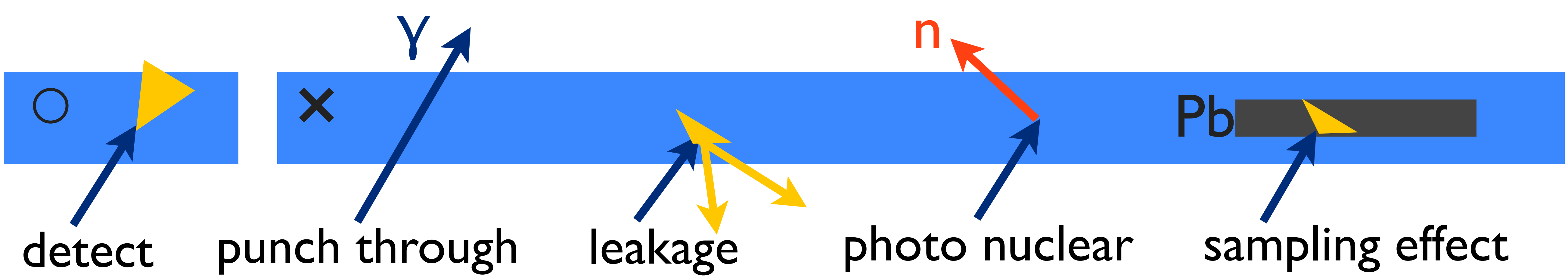
- 現在予想される主なback groundは、 $K_L \to \pi^0\pi^0$からの計4γのうち2γをlossした場合が該当
- signal lossも要検討

# MB and source of inefficiency

- Gamma inefficiency




- Gamma inefficiency



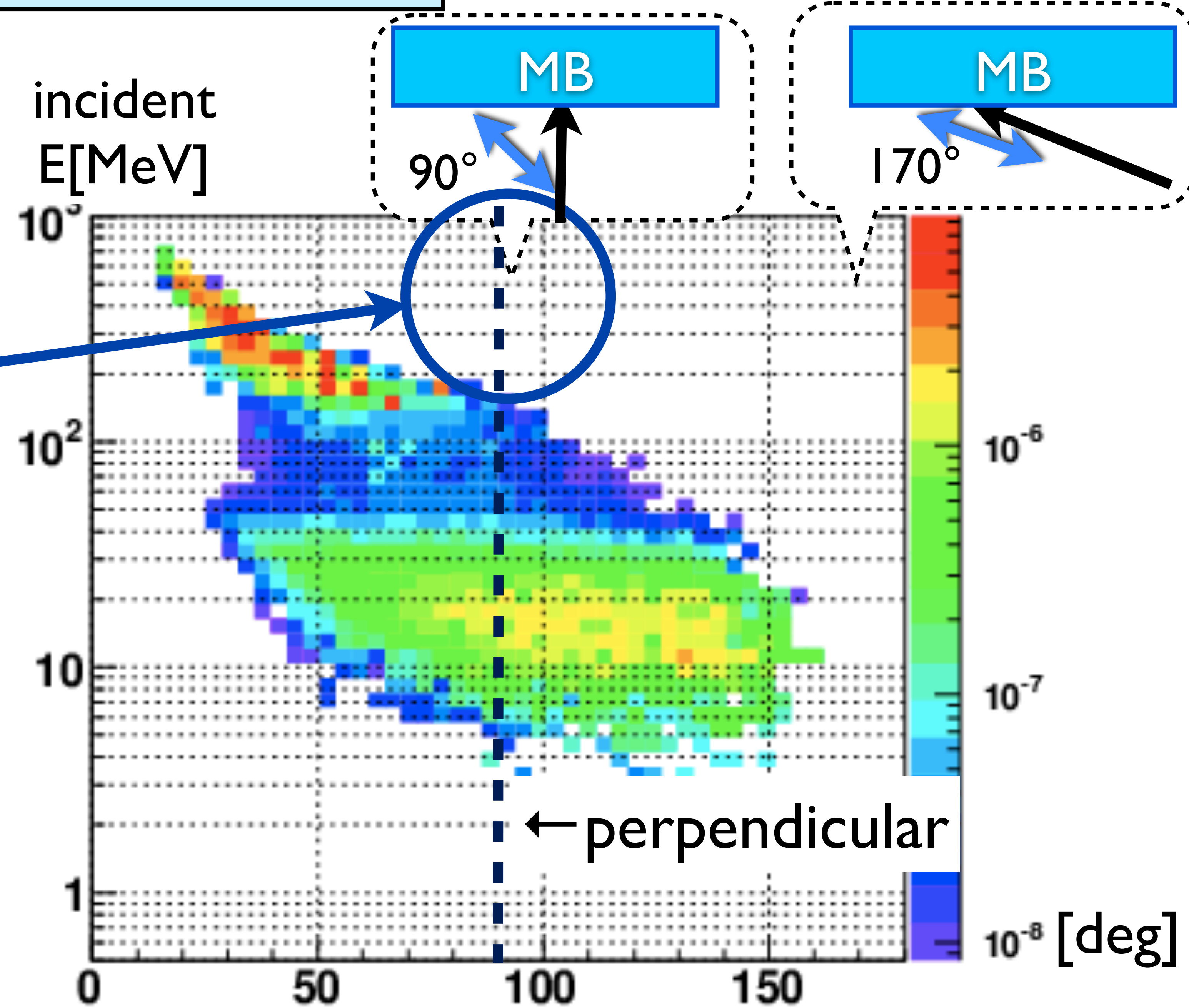
# # $\pi^0\pi^0$ background vs MB thickness

| | # π0π0 background |
|---|---|
| E391a MB | 2.9±0.4 events |
| proposal MB | 1.39±0.09 events |
| test | 1.3±0.1 events |

+5$X_0$

+10$X_0$

- Not many high $E_\gamma$ with normal incidence.




✦ No more thickness

✦ More improvement?
→inside?, →CsI?

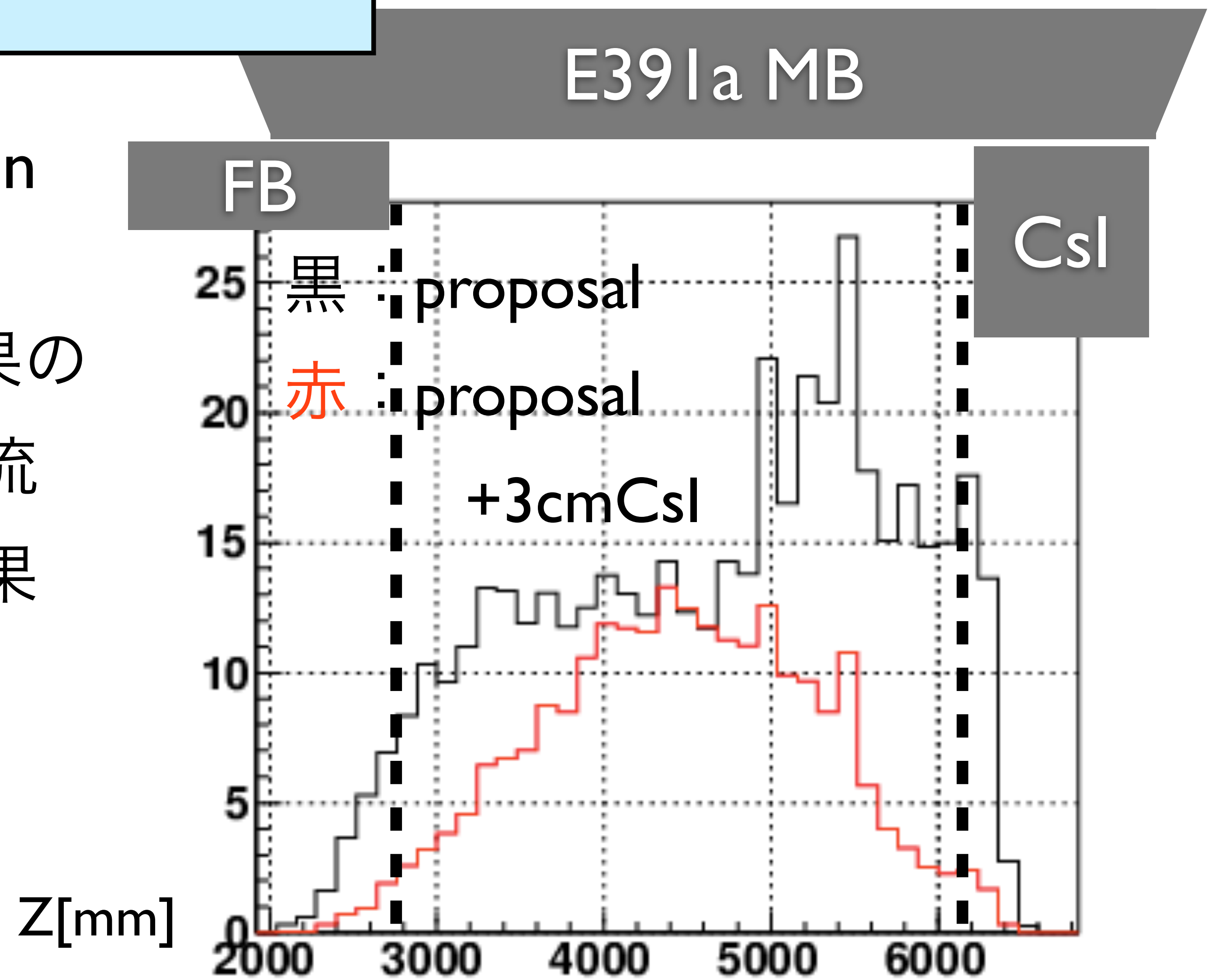
# CsI Barrel to reduce Sampling Effect & Photo Nuclear

| | # π0π0 background |
|---|---|
| E391a MB | 2.9±0.4 events |
| proposal MB | 1.39±0.09 events |
| test | 1.3±0.1 events |
| proposal MB<br>+ 3cm厚CsI | 0.87±0.03 events |

+5$X_0$

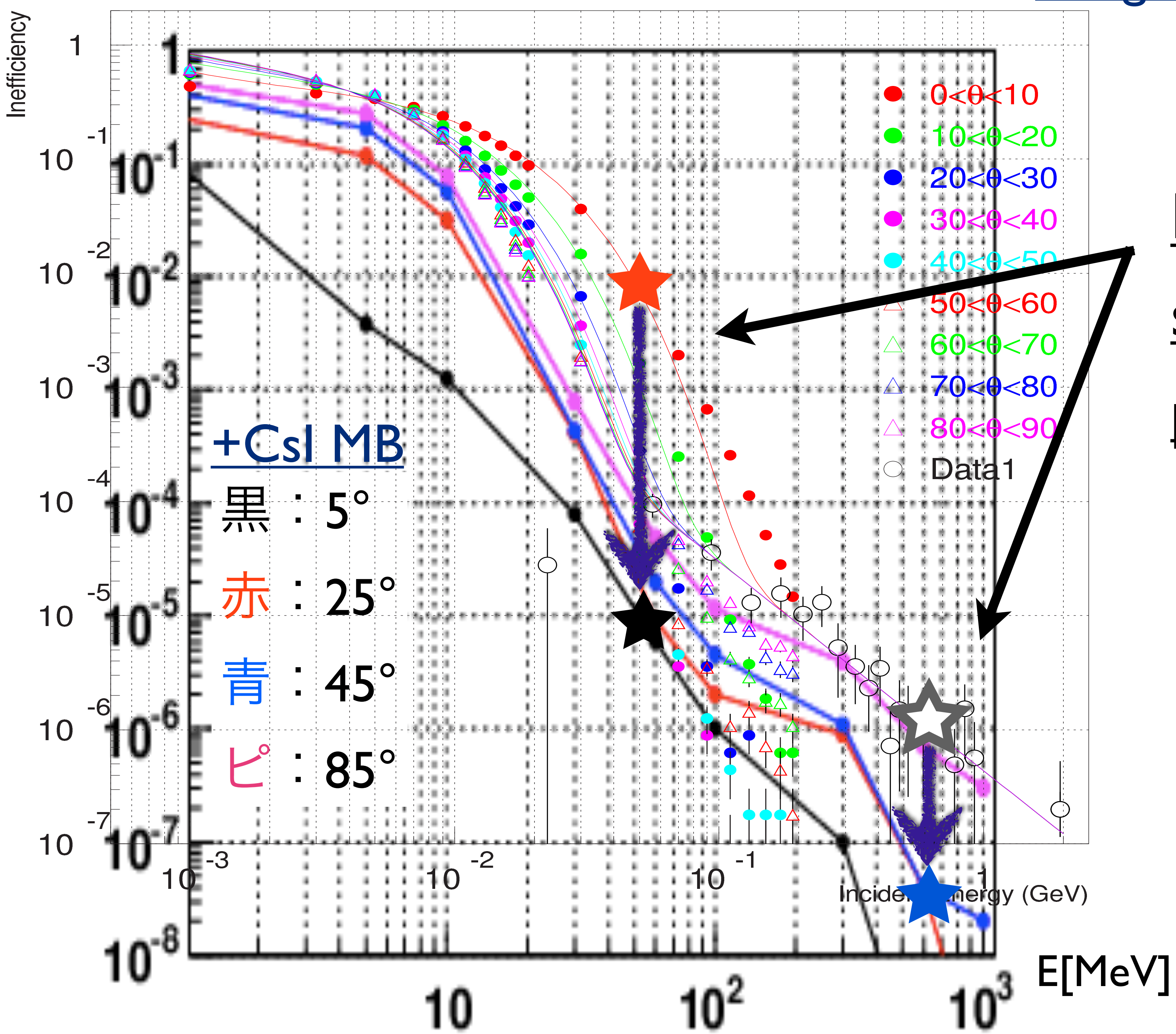
+10$X_0$

- $\pi^0\pi^0$ background incident position
  - ✦ 全面覆う必要はなく、改善効果の大きい上流(z=2500~4000)、下流(5000~)部分のみの改善でも効果

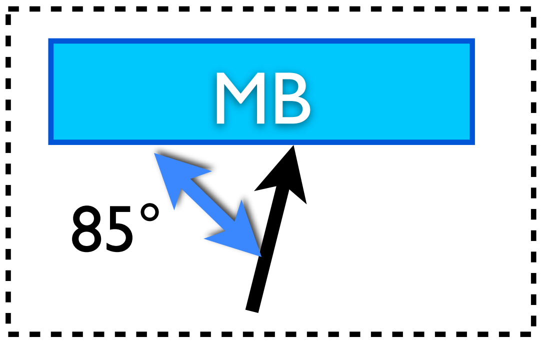


# Comparison with MB in proposssal

↓ Figure from proposal paper

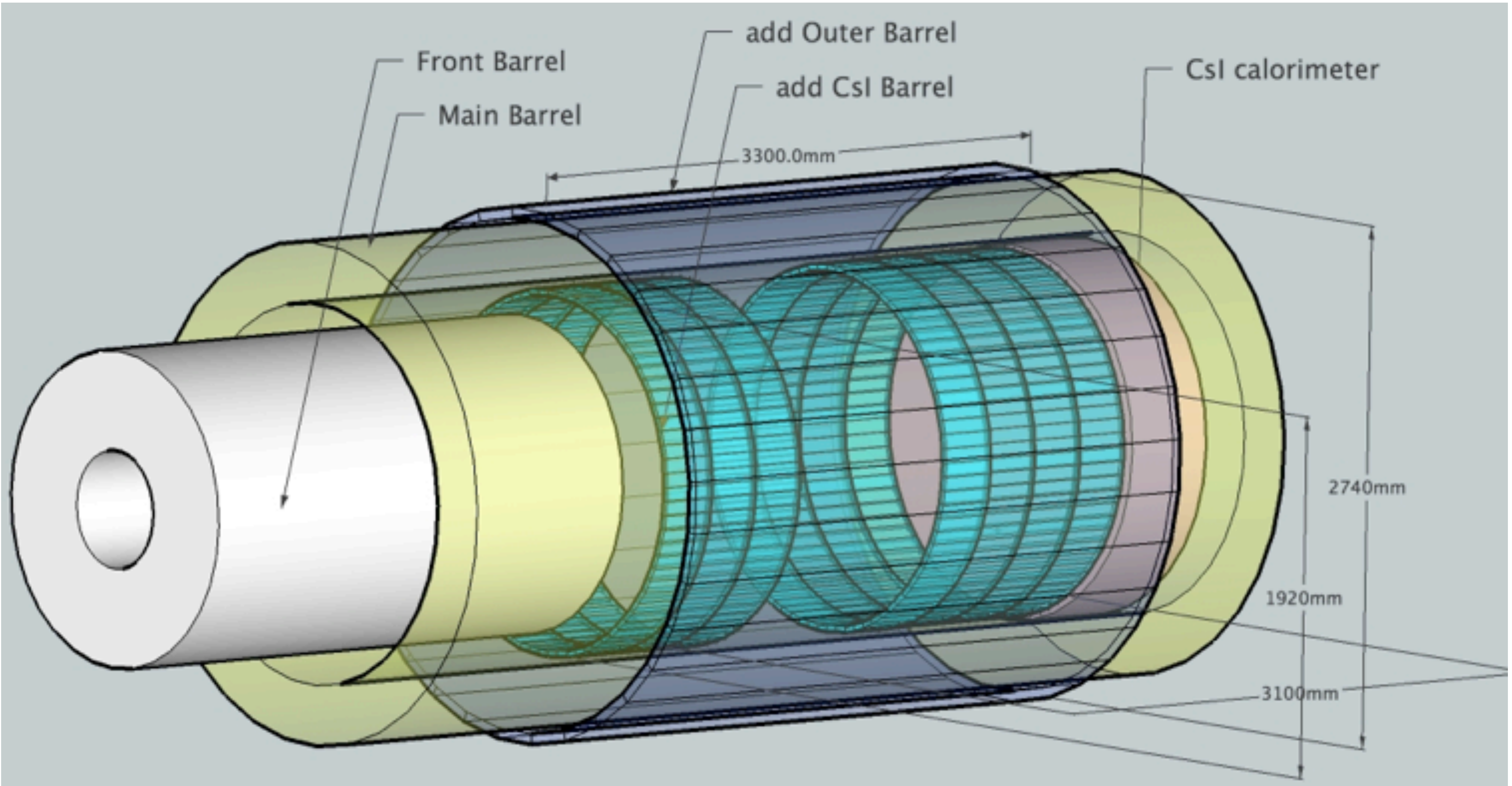



Effective for both sampling effect and photo nuclear reaction



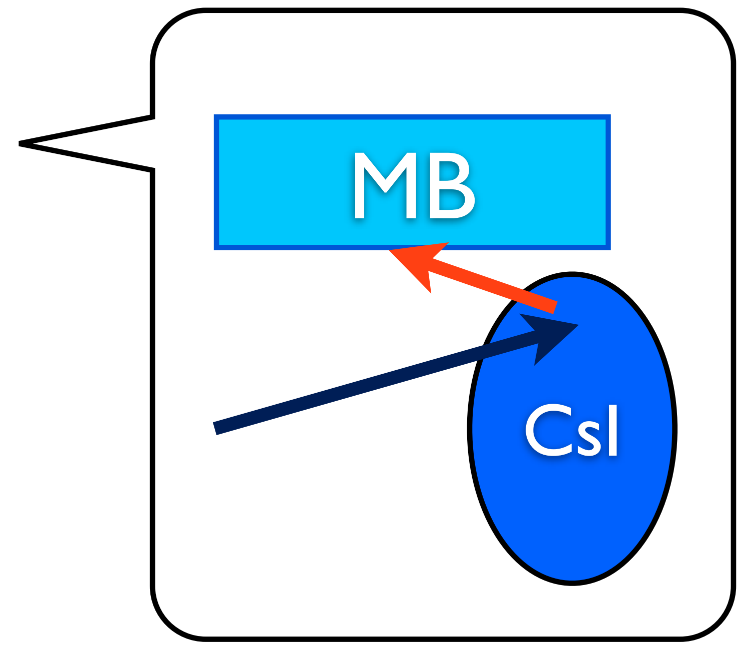
# An Idea of CsI Barrel structure

- 3cm thick × 7.5cm wide × 30cm long /crystal
- 80 crystals/2π
- if we cover 3meters in z direction, need 800modules (total 400 E391aCsI)
- read out by pmt (or fiber) from one side (?)



# background & signal loss at CsI barrel

- back groundとback splash を検討
  - ✦ Back Splash Photon Effect
    電磁シャワーの漏れによりsignal event の一部がveto検出器に反応を生じるシグナルロス




※ Assumed resolution from detector structure

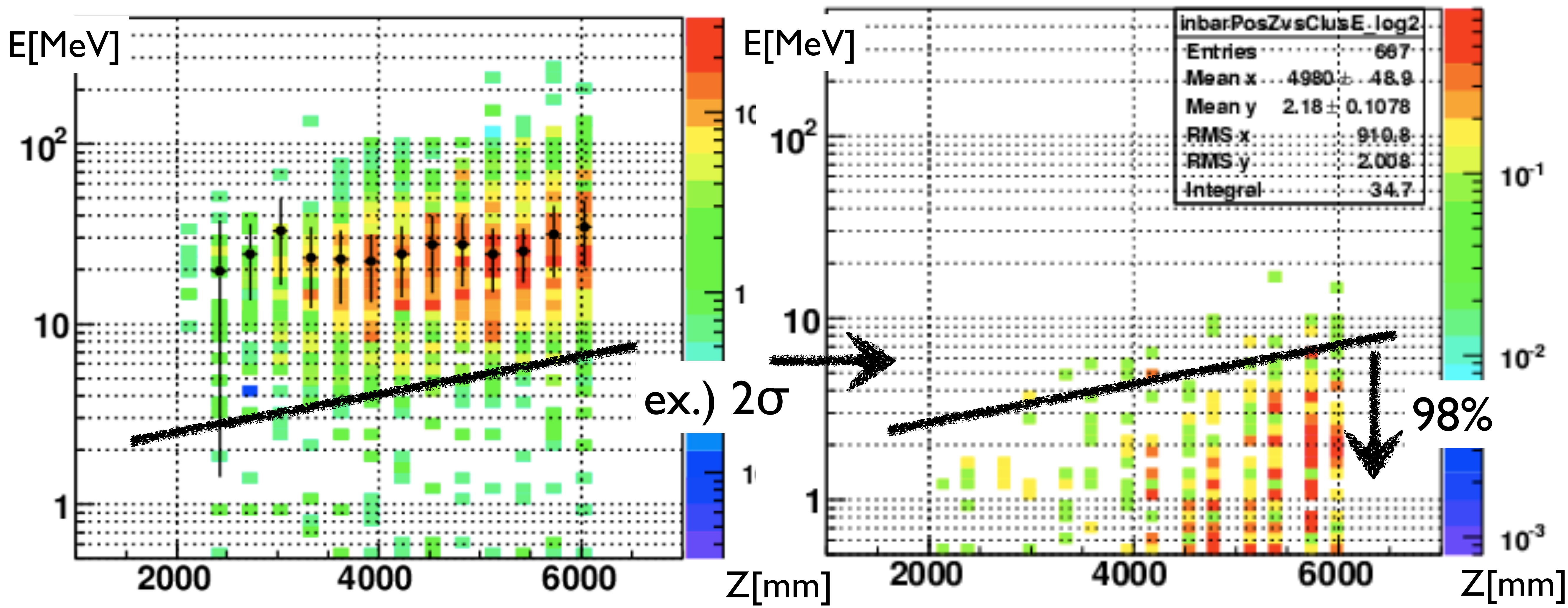
- inner barrel: $\sigma_{Ei} = C_{Ei}\sqrt{N_{p.e.}E_{dep}}/N_{p.e.}$ [MeV]
  $\sigma_T = C_T/\sqrt{N_{p.e.}E_{dep}}$ [ns]
  where $N_{p.e.} = 10, C_{Ei} = 1, C_T = 9.0$
  $\sigma_z$~10cm (fixed position in each module)

proposal MB: $\sigma_{Eo} = C_{Eo}\sqrt{N_{p.e.}E_{dep}}/N_{p.e.}$ [MeV]
where $N_{p.e.} = 13.8, C_{Eo} = 2.8$

# Low Energy γ separation

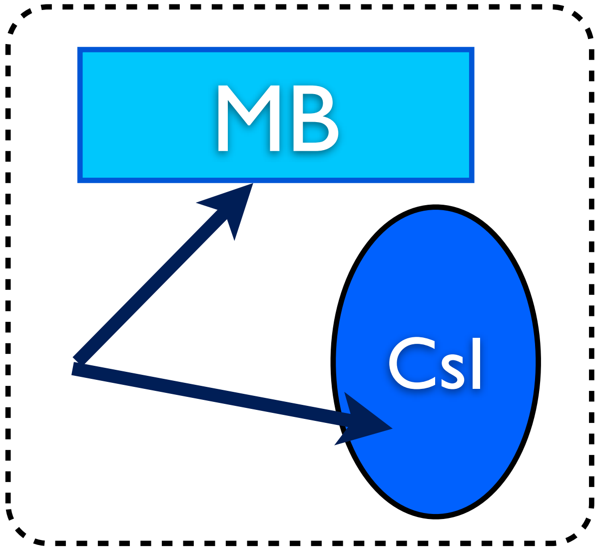
- $E_{dep}$ / Z in inner barrel ($E_{dep}$ ... a cluster energy sum)
  - cut line ......gaussian fit in each Z,   threshold = Peak - Nσ
  - $E_{dep}$ on proposal MB < 0.5MeV

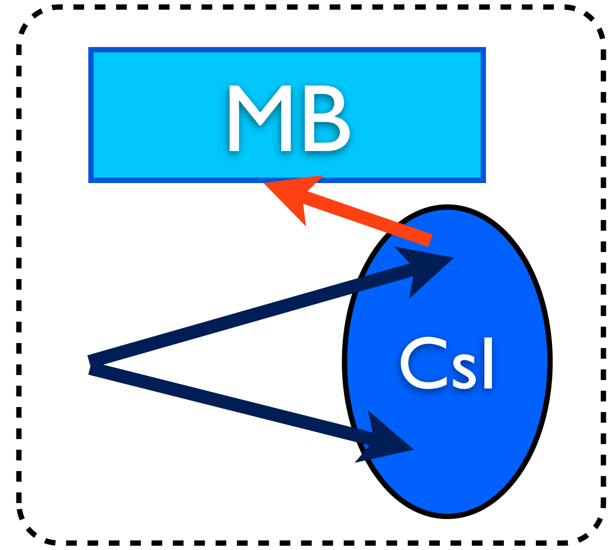
- $E_{dep}$ / Z in inner barrel (左: 2pi0 BG, 右: pi0nunu signal events)



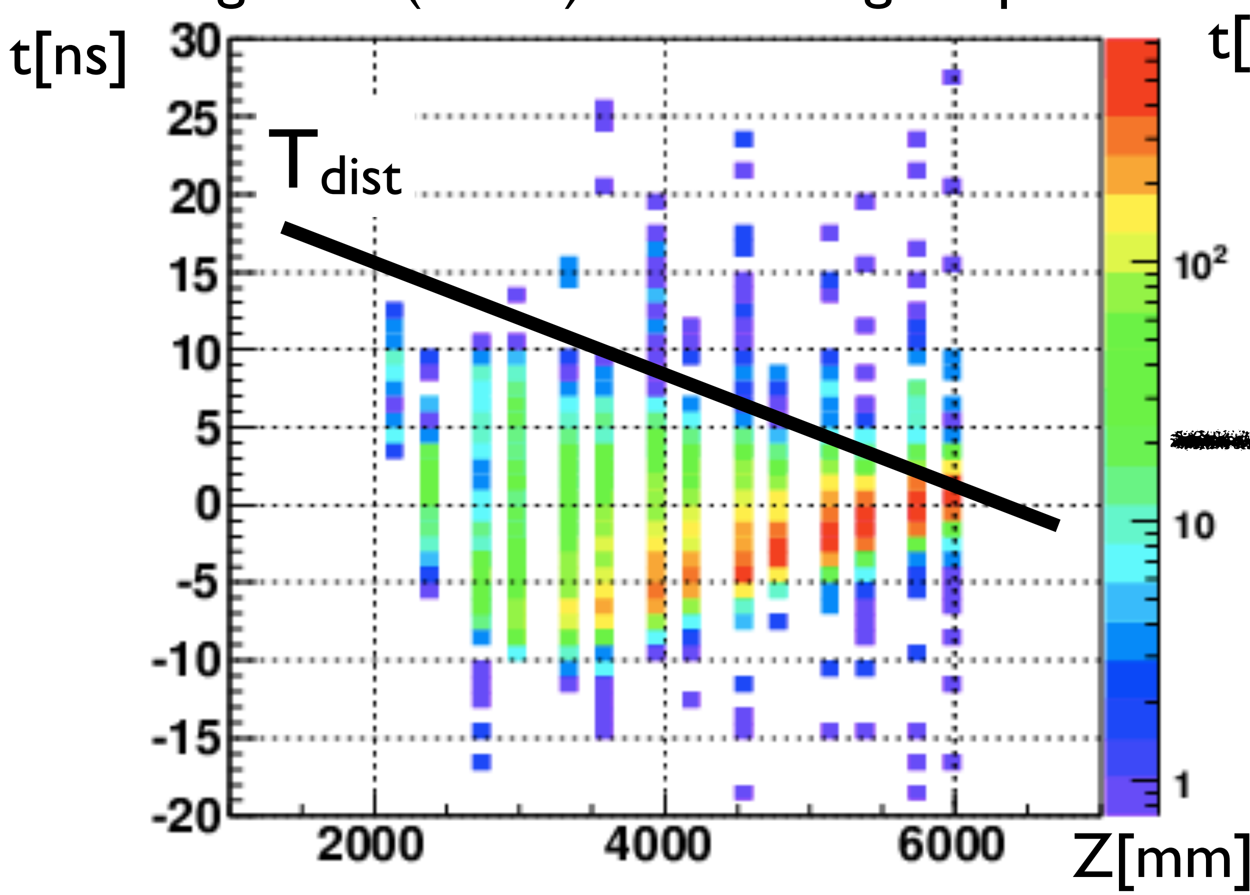
# timing difference ($T_{inbar}$-$T_{calo}$ / Z in inner barrel)

- $E_{dep}$ on proposal MB < 0.5MeV
- maximum Energy in modules

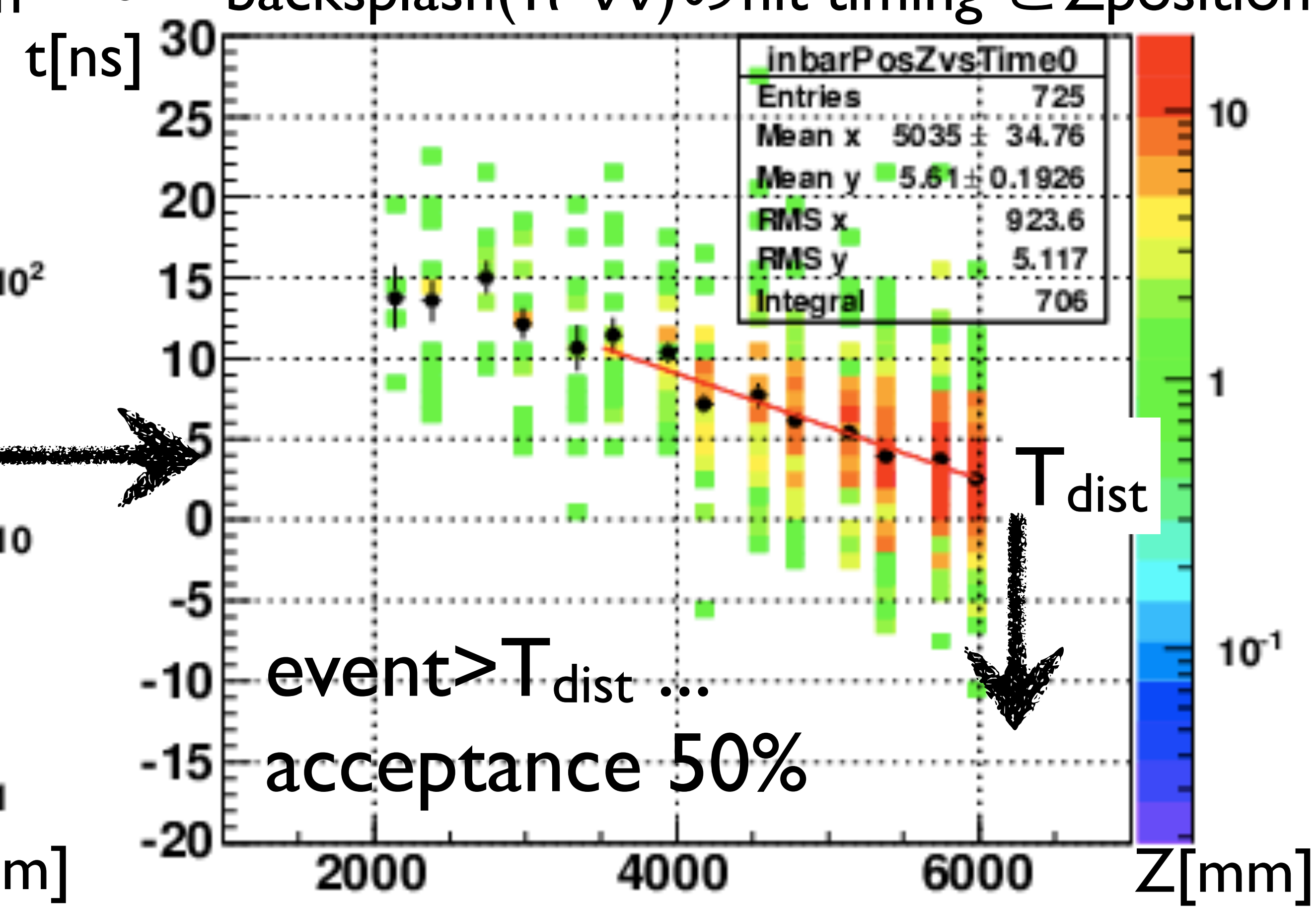



- background($\pi^0\pi^0$)のhit timingとZposition




- backsplash($\pi^0\nu\nu$)のhit timing とZposition

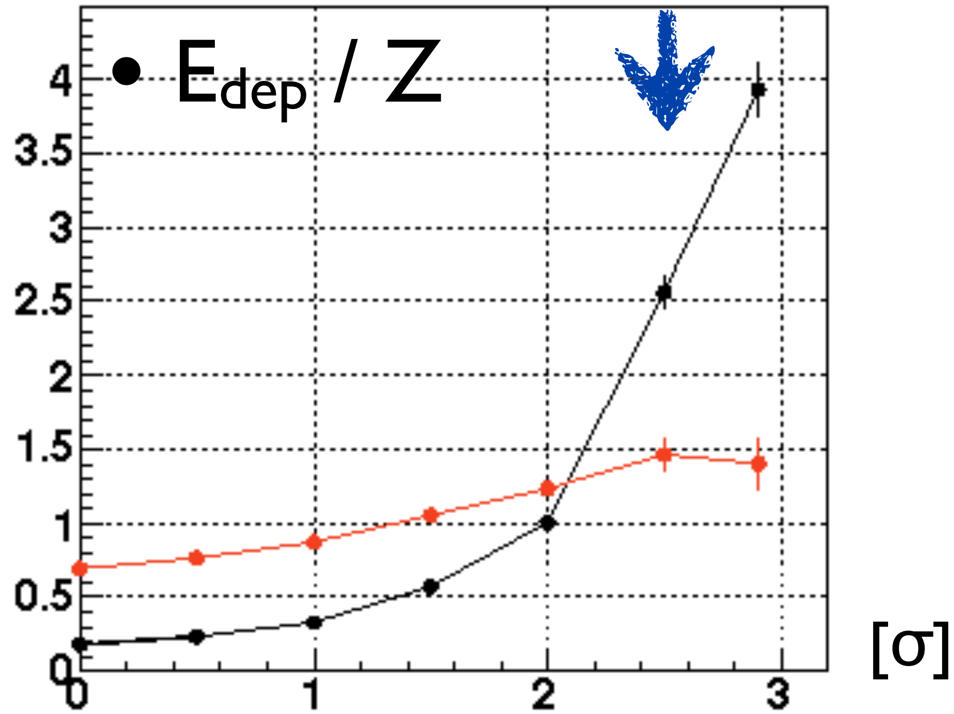


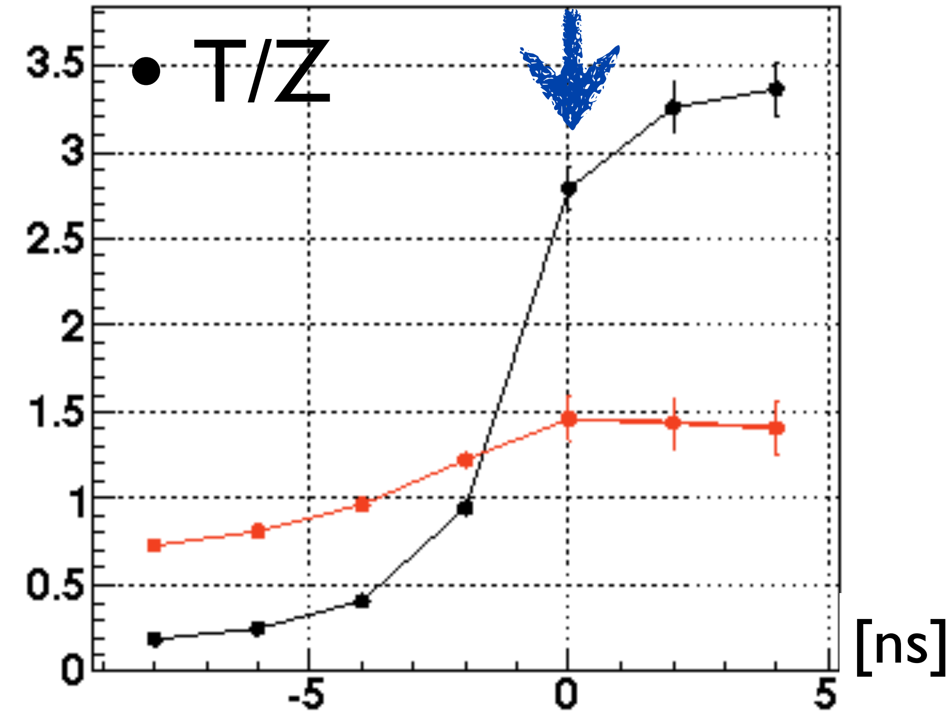
# background & signal loss ratio

- Cut condition in MB w/ CsI Barrel

黒：S/N

赤：S/√(S+N)



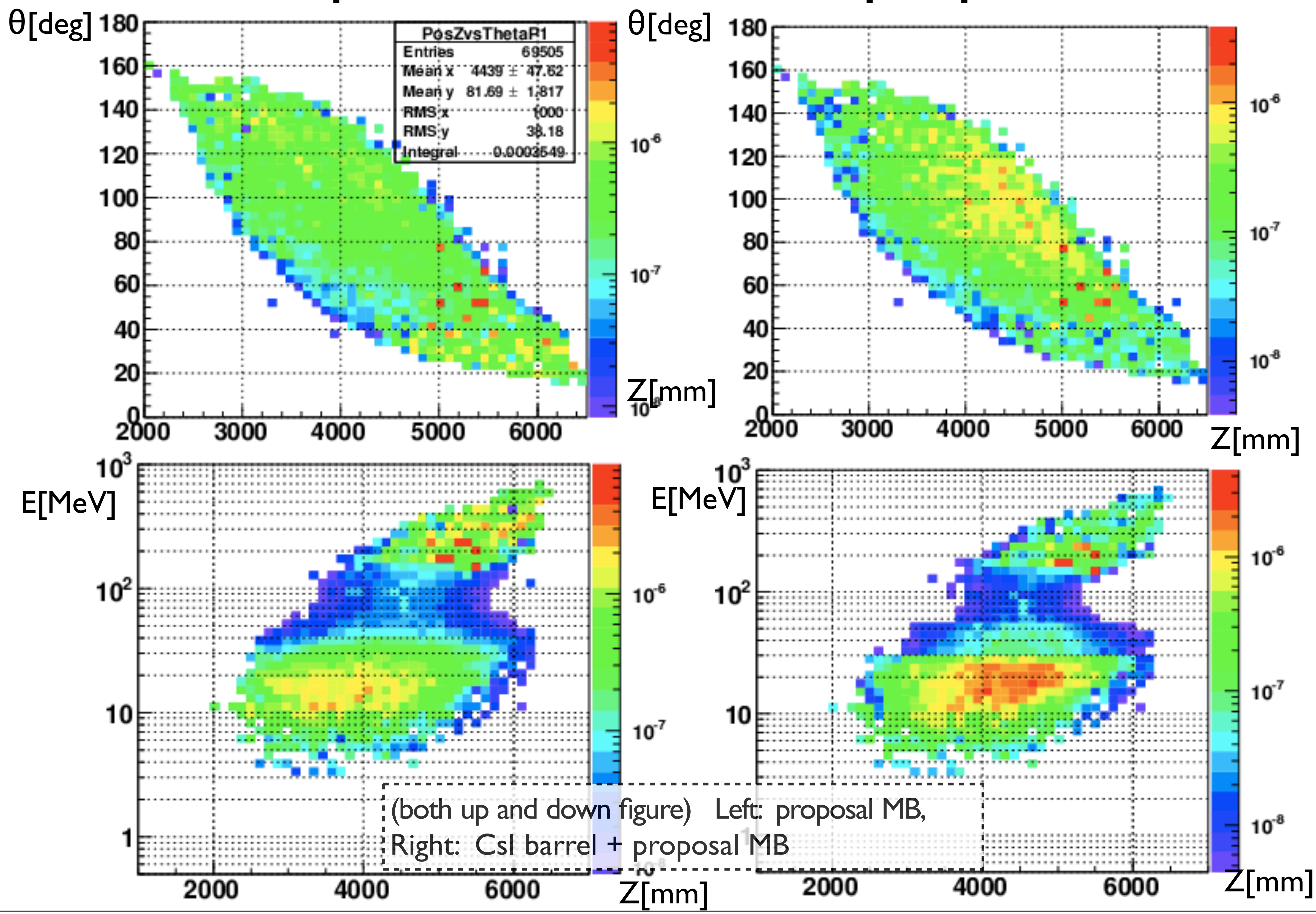

| | original | $E_{dep}$ / Z cut | T / Z cut |
|---|---|---|---|
| BkSp loss (※) | 31% | 14% | 16% |
| 2 pi0 BG | 0.60 ± 0.02 | 1.16 ± 0.05 | 1.04 ± 0.04 |
| accepted pi0nunu | 2.36 ± 0.02 | 2.98 ± 0.02 | 2.90 ± 0.02 |
| | | | |
| S/N | 3.93 ± 0.17 | 2.56 ± 0.11 | 2.78 ± 0.12 |
| S/√(S+N) | 1.37 ± 0.01 | 1.46 ± 0.01 | 1.46 ± 0.02 |

# Summary & to do

- MCにてMBの検出効率を検証
- Punch-through effectは既存MBに$5X_0$ の物質量を加えることでbackgroundが1/2に改善
- 既存MBの内側にCsIを加えた場合、sampling effectおよびphoto-nuclear interactionからのbackgroundに効果
- Energyと入射位置に対する時間情報の違いからBack-splash photonをbackground eventと分離することで、$S/\sqrt{(S+N)}$を改善
- 今後、想定した性能を満たすdetectorを開発

backup

# Comparison of CsI with proposal MB

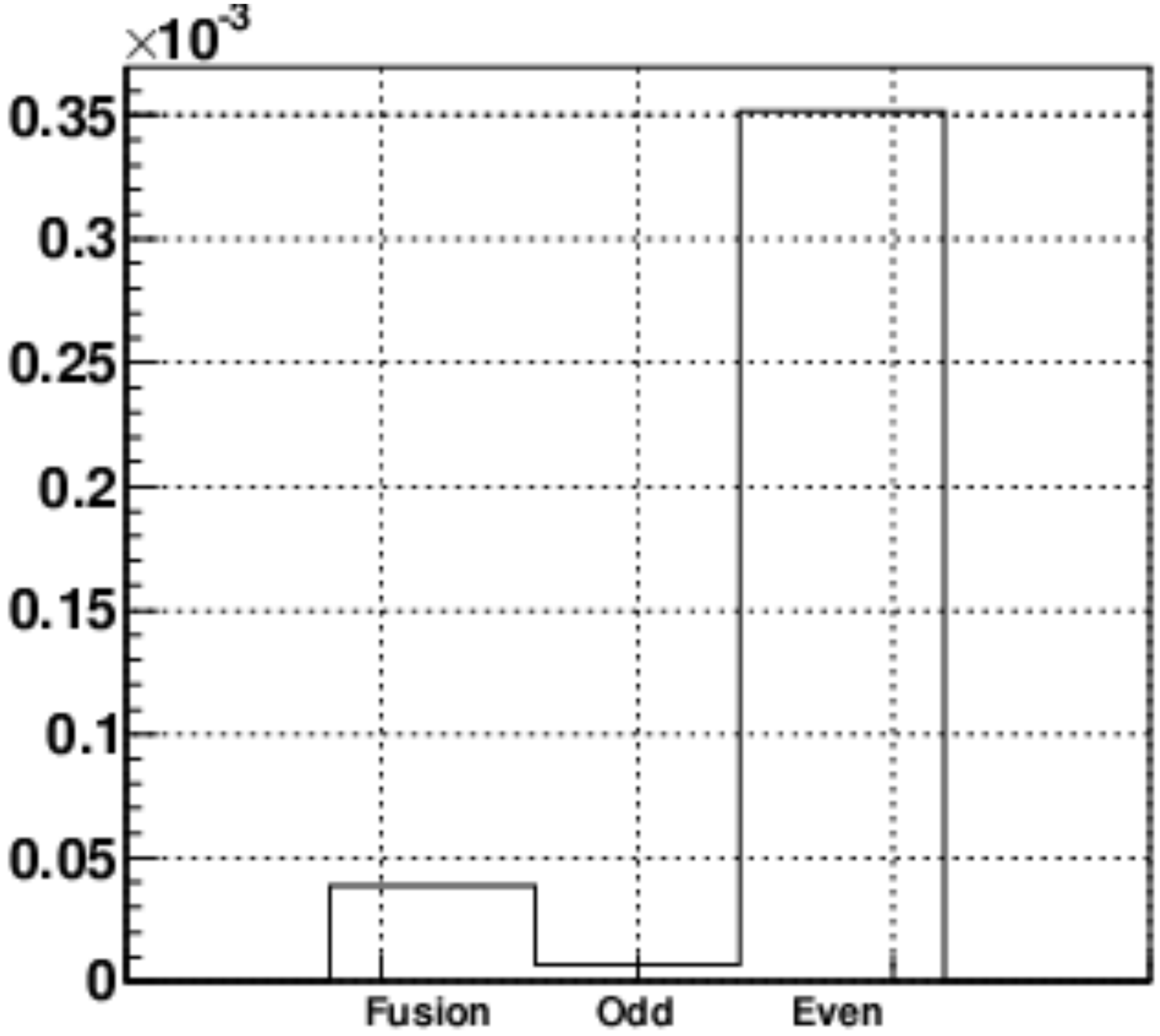


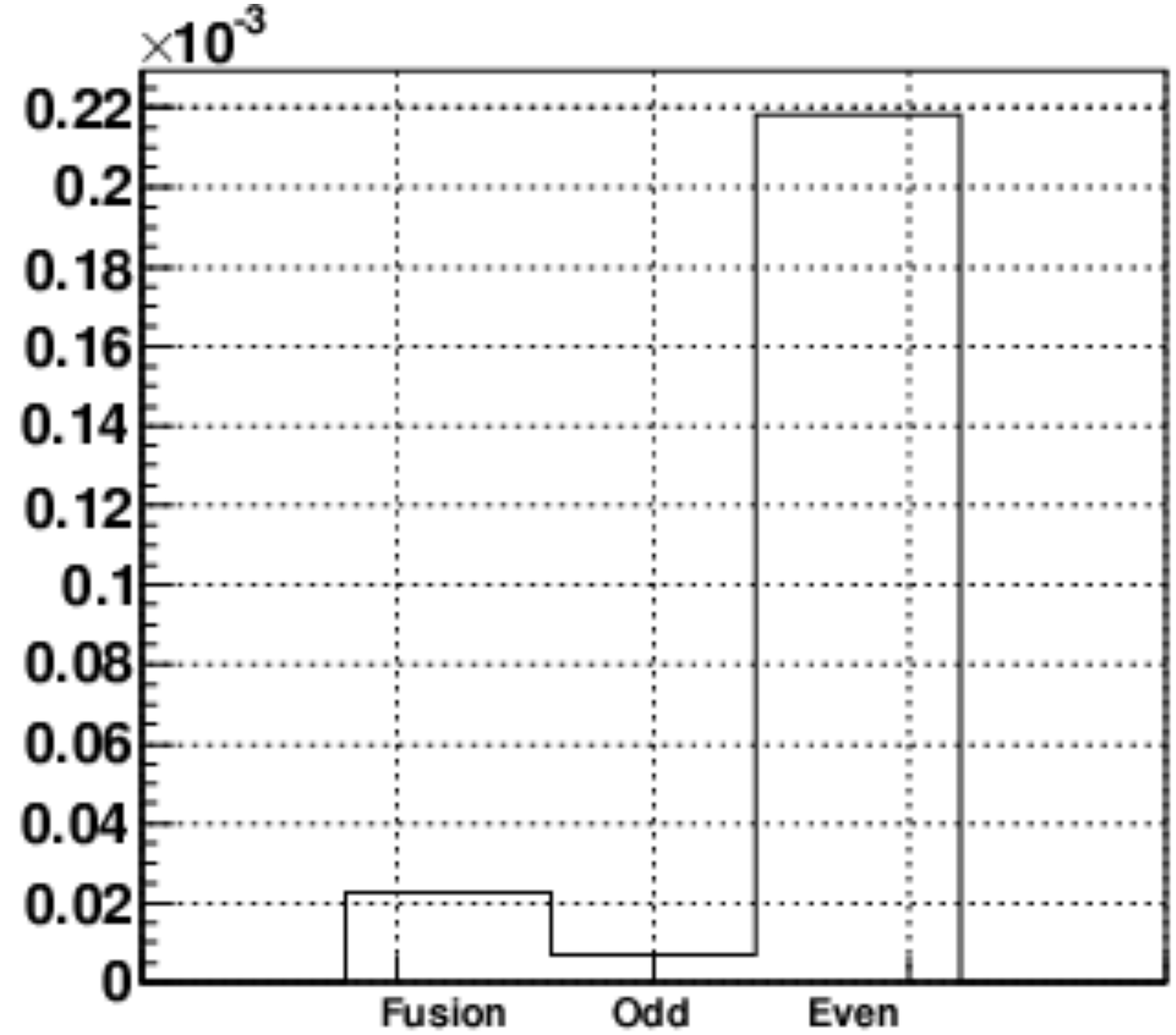

(both up and down figure)　Left: proposal MB,
Right: CsI barrel + proposal MB

# Comparison of CsI with proposal MB

- # $\pi^0\pi^0$ Background

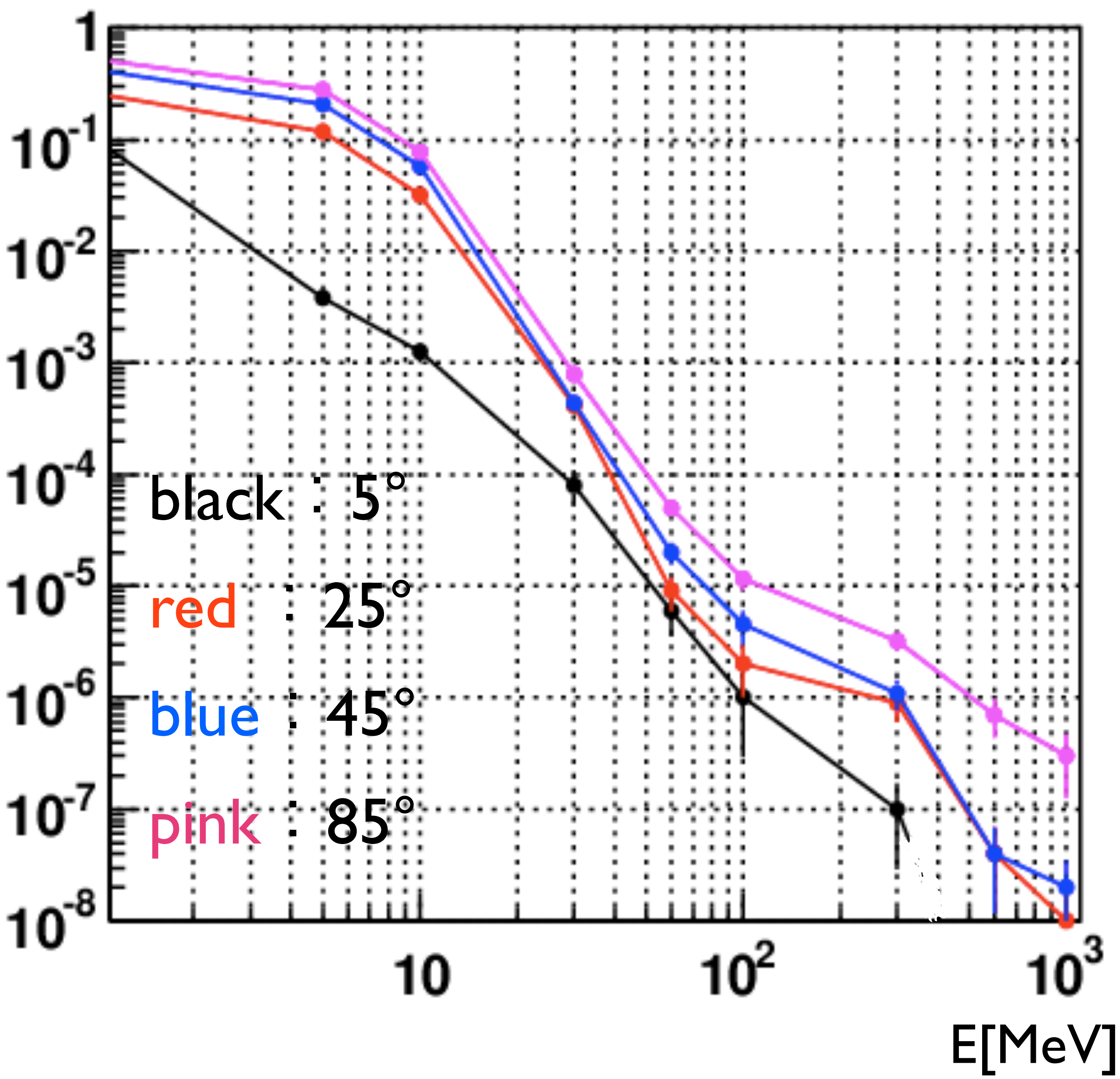
Left: proposal MB, Right: CsI barrel + proposal MB



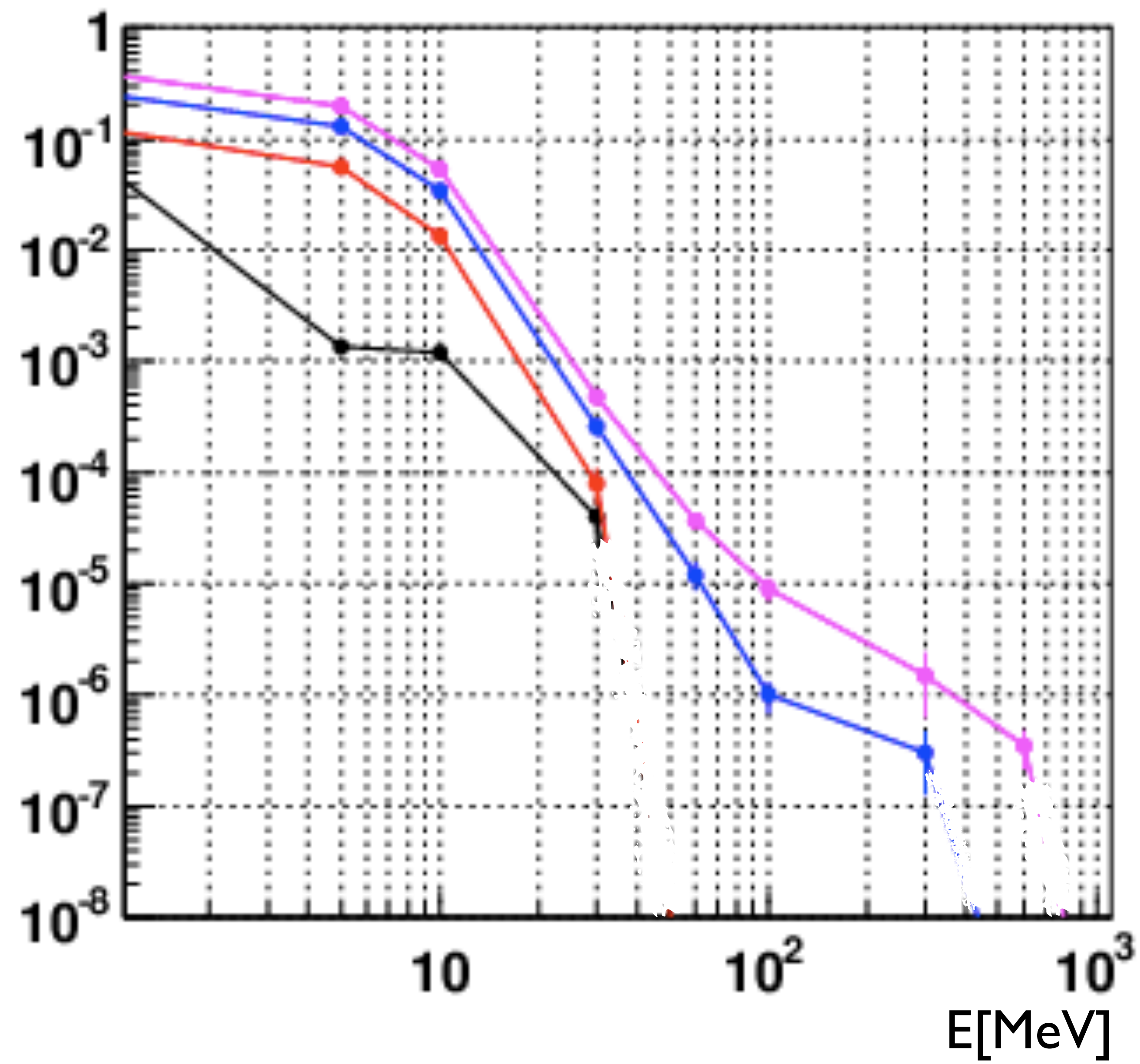



# Inefficiency of CsI Barrel + MB in proposal

CsI Barrel 3cm




CsI Barrel 5cm



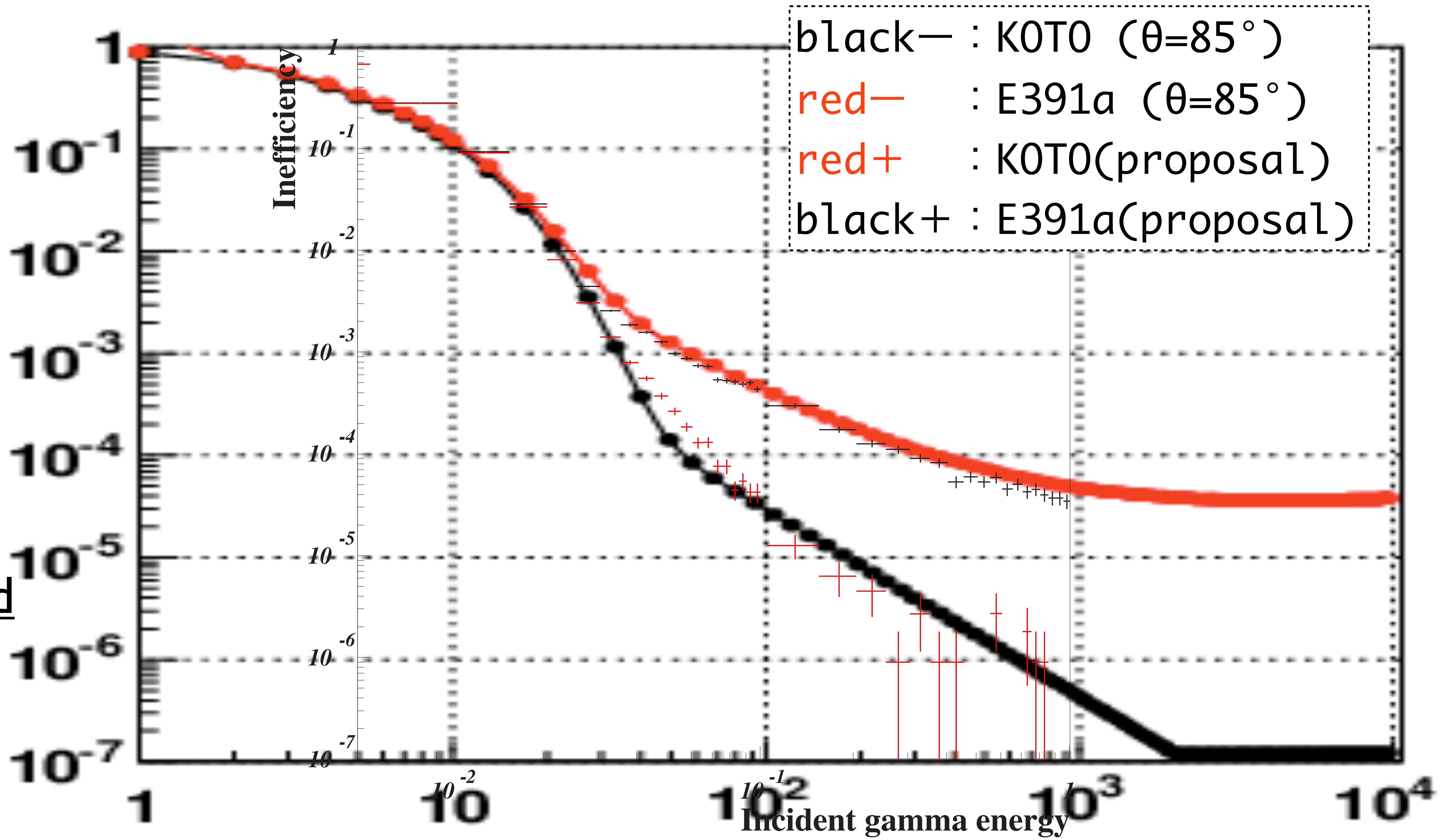

memo

5deg5MeV→10MeV......leak→photonucl

# Correction of punch through effect

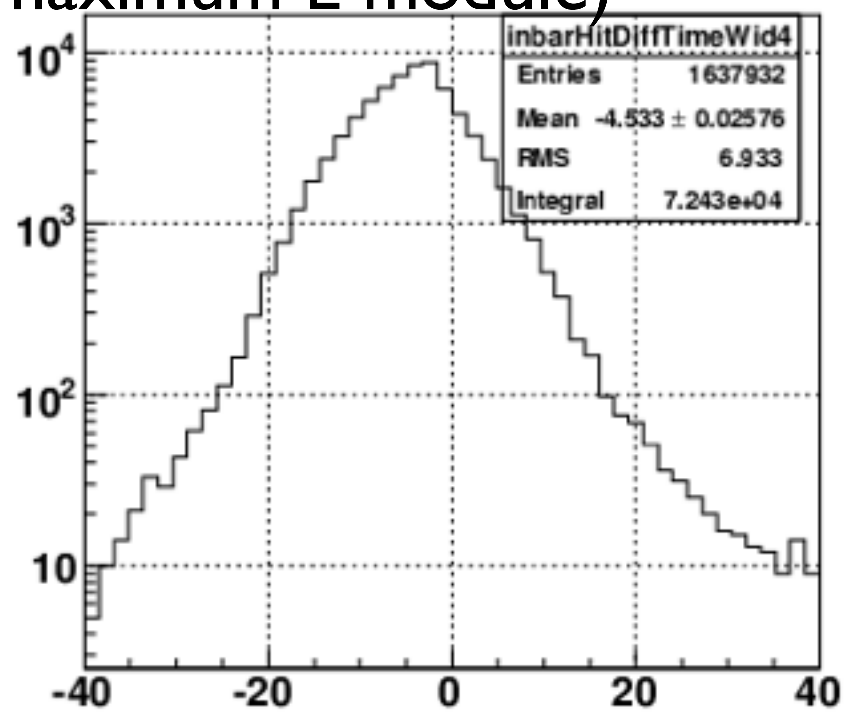
- Estimate the difference of # backgrounds
  - applied punch through probability in Geant4 function to proposal version inefficiency.
  - F($E_\gamma$, atomic number, proton number, path length, density)

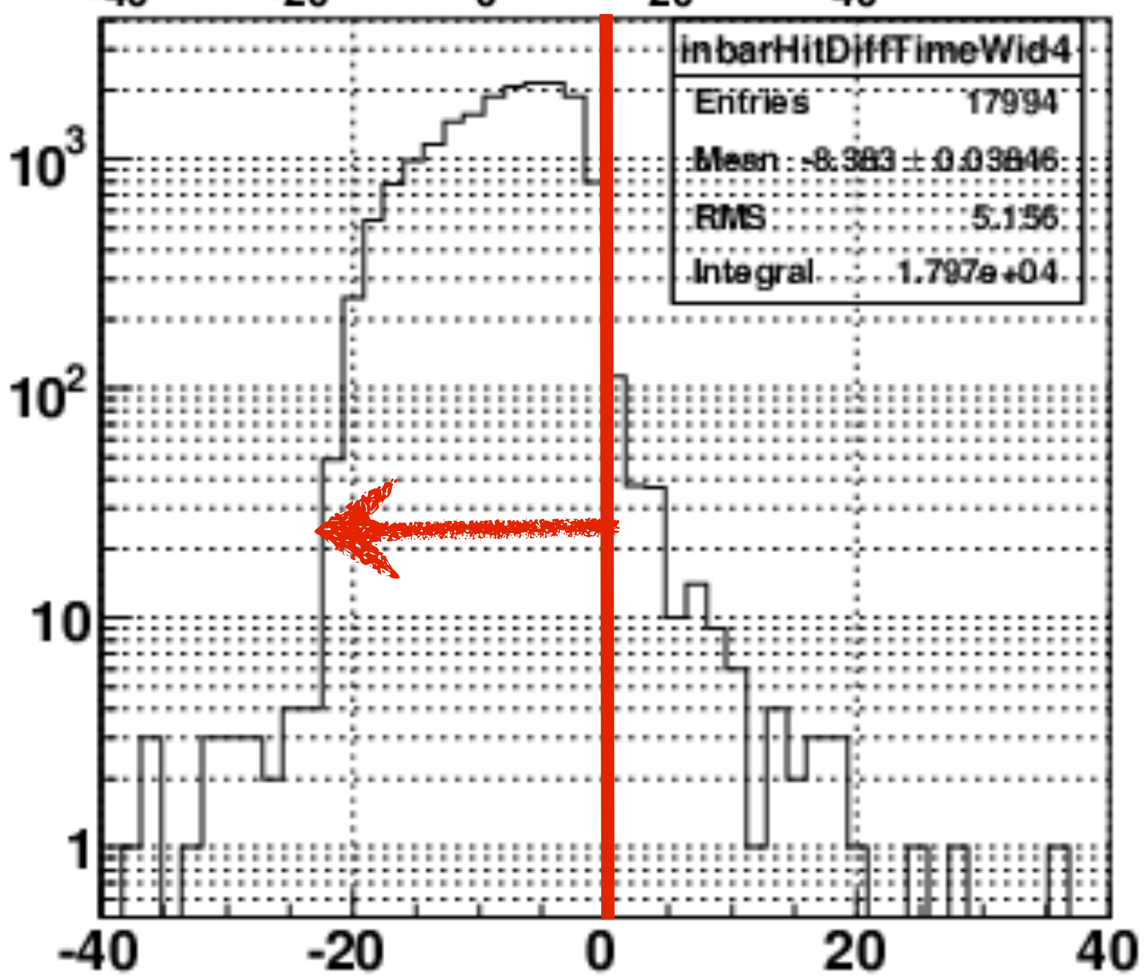
Inefficiency used in MC→



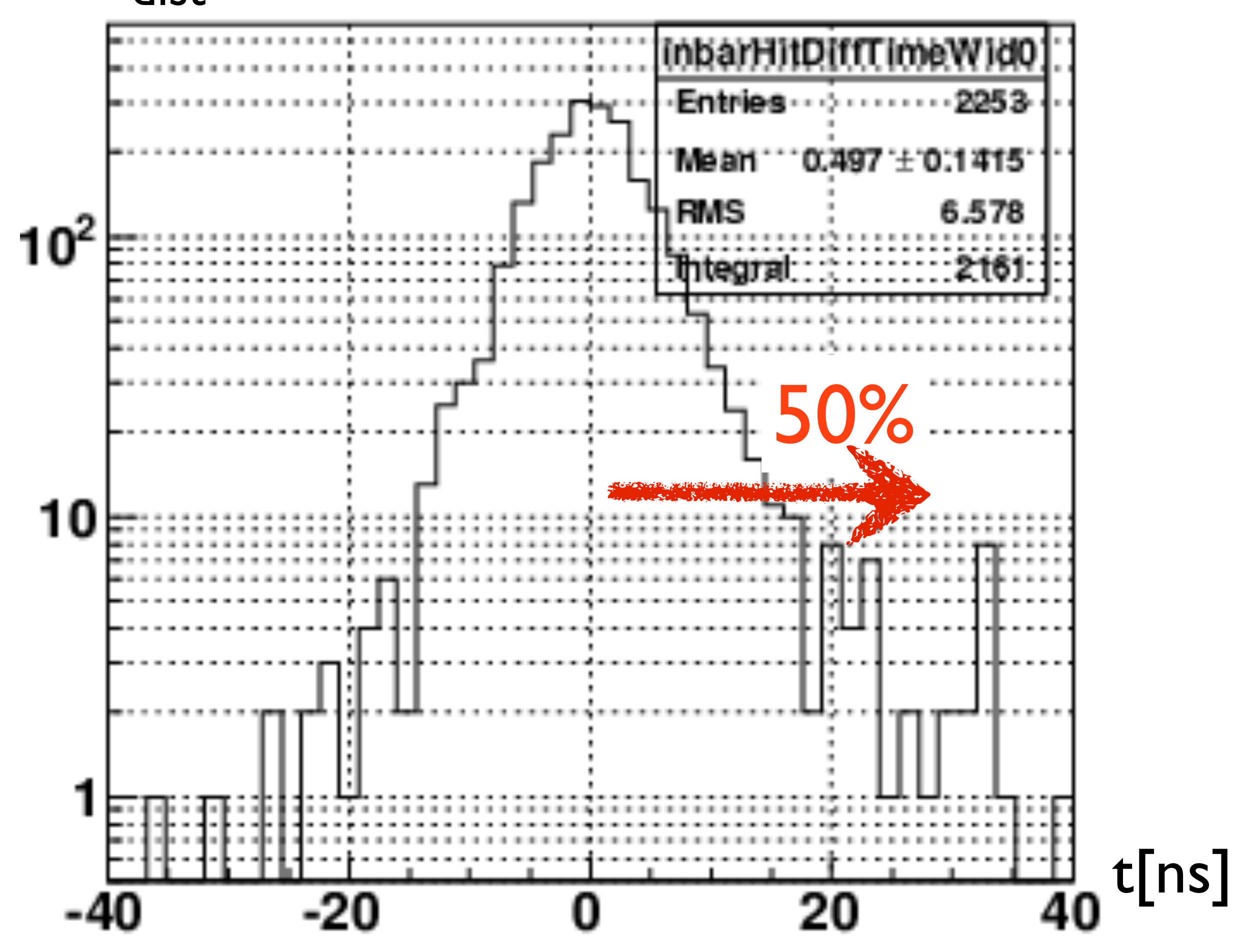
# timing difference

- background($\pi^0\pi^0$)の ($T_{inbar}$-$T_{cal}$ ) -$T_{dist}$ in inner barrel (上: all modules, 下: maximum E module)



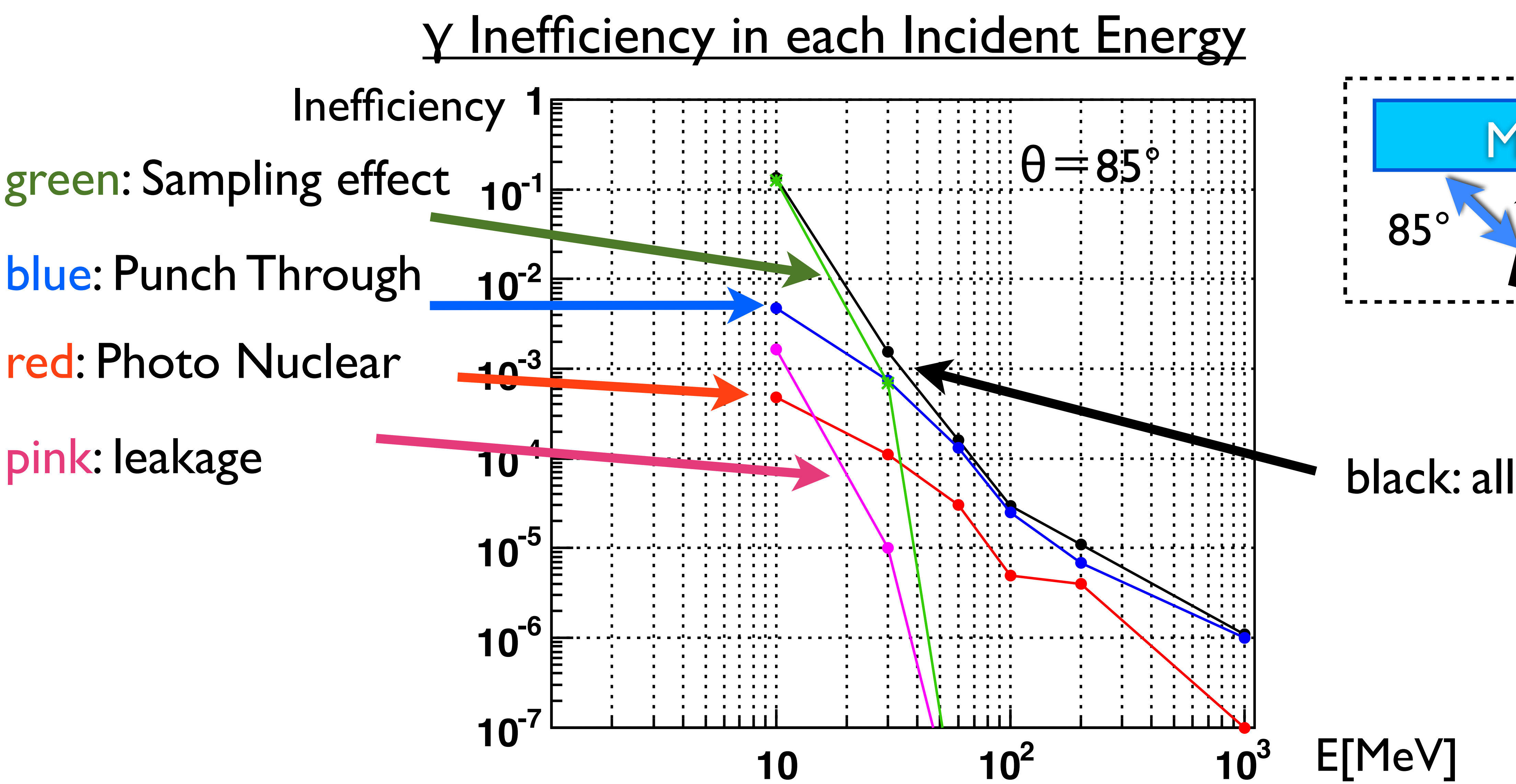



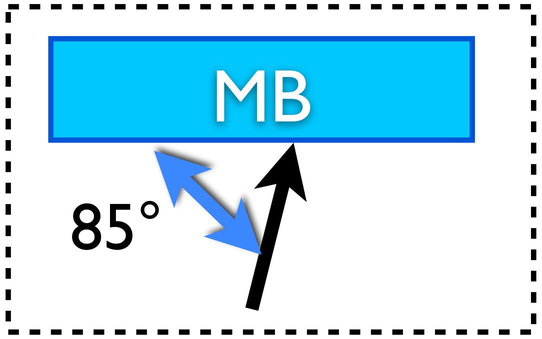

- backsplash($\pi^0\nu\nu$)の ($T_{inbar}$-$T_{cal}$ ) -$T_{dist}$ in inner barrel



# Inefficiency of MB in Proposal (~normal incidence)

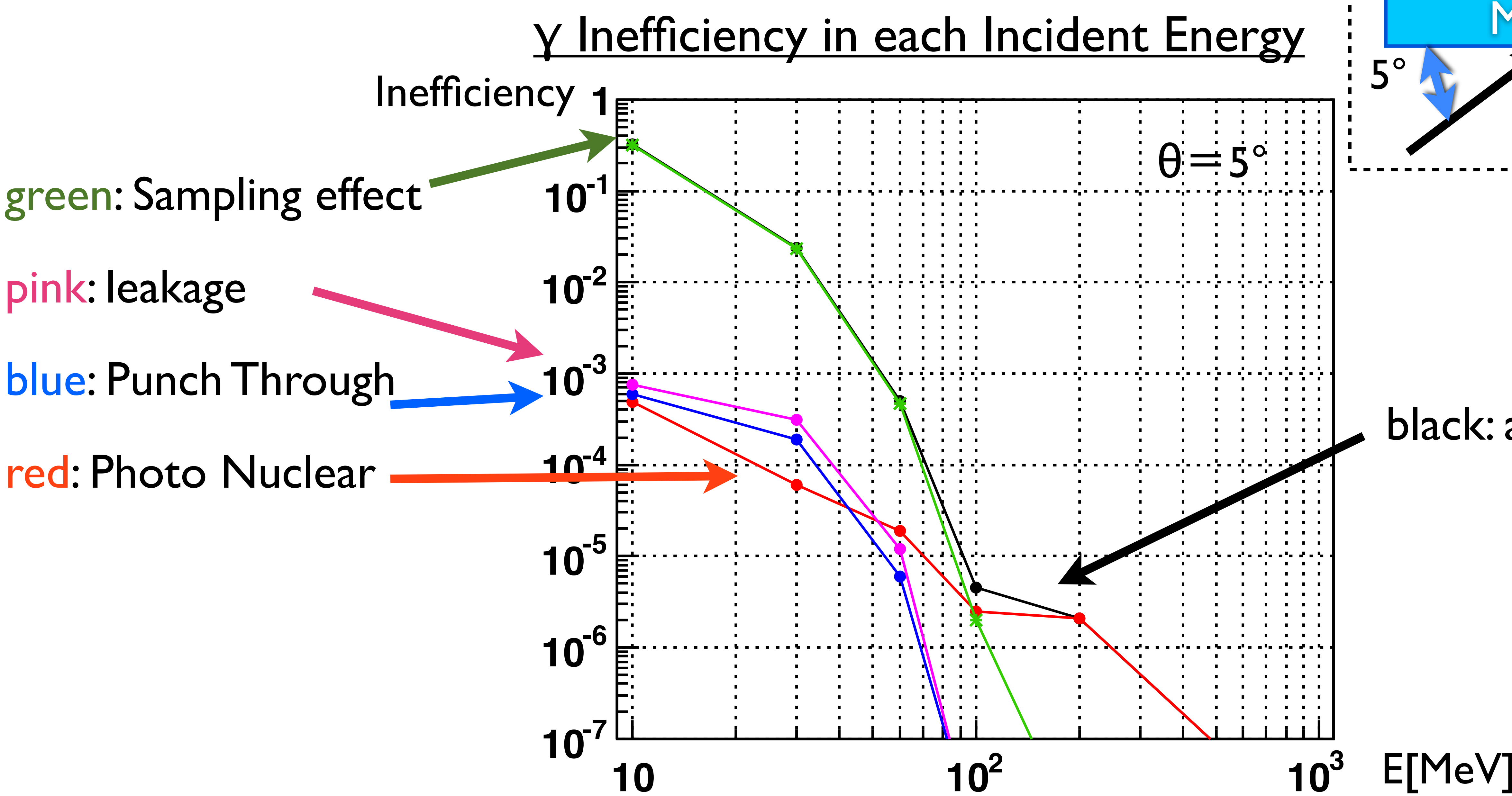
- ~ normal incidence
  - Low Energy ... sampling effect
  - High Energy ... punch through

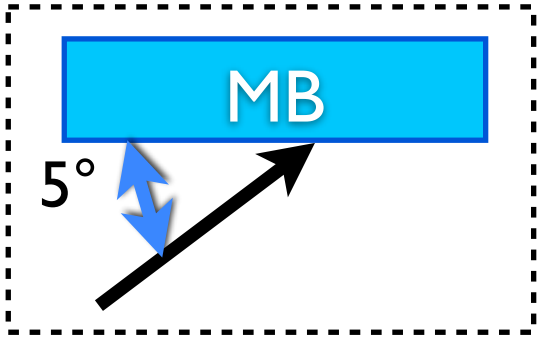


# Inefficiency of MB in Proposal (shallow incidence)

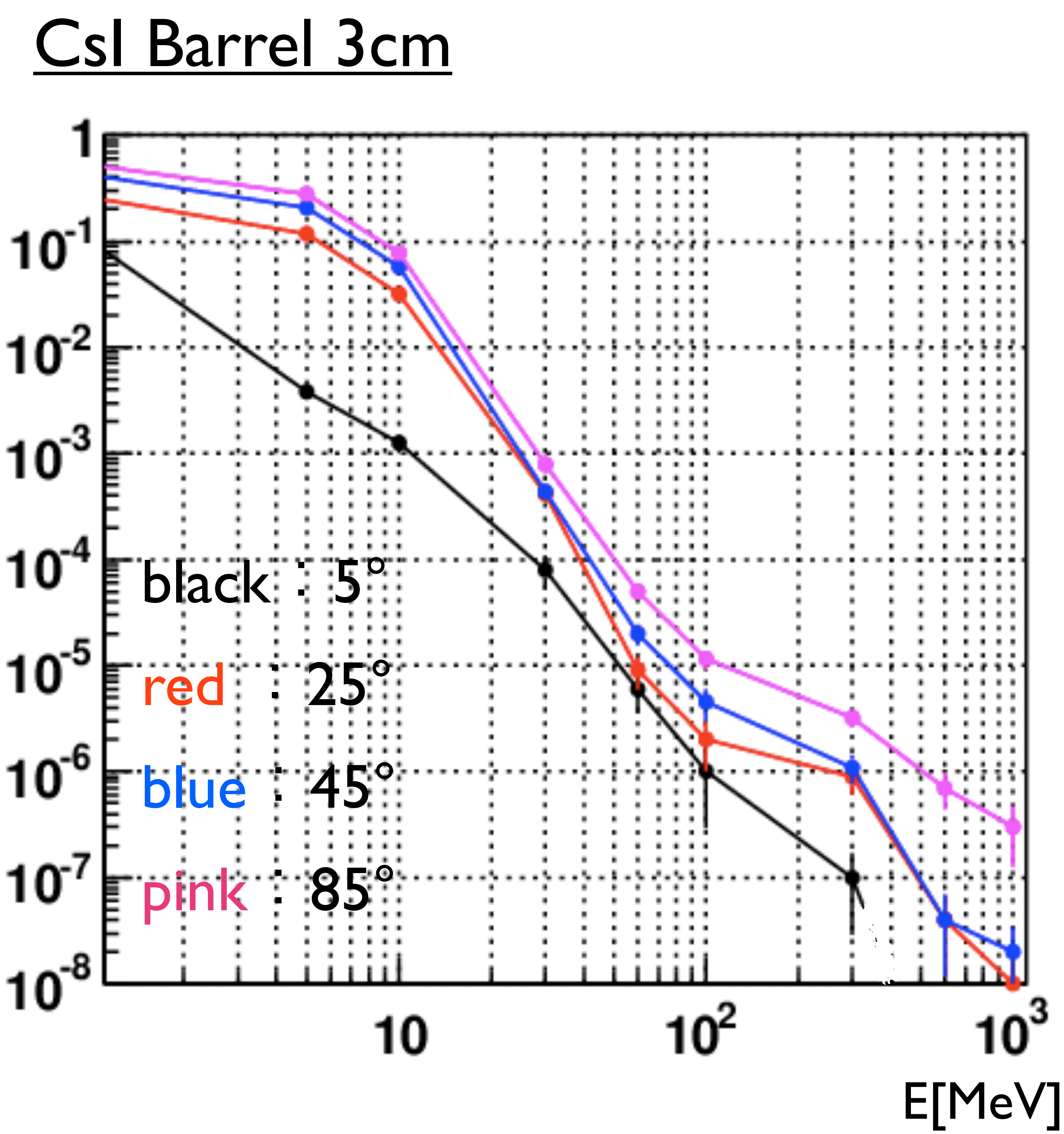
- large incident angle γ to MB surface
    - Low Energy ... sampling effect
    - High Energy ... photo nuclear

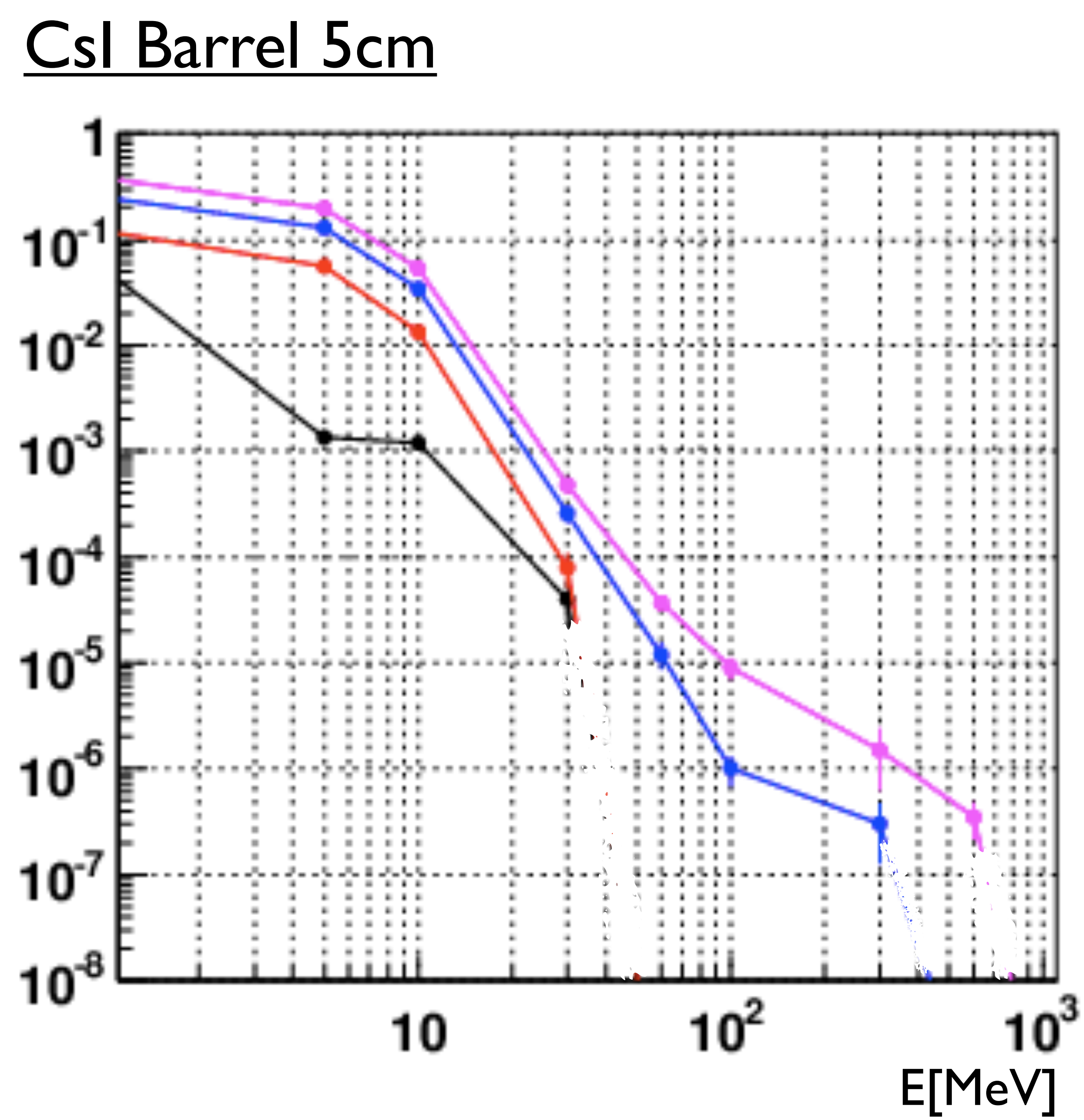



2011年3月25日金曜日

# Inefficiency of CsI Barrel + MB in proposal




memo
5deg5MeV→10MeV......leak→photonucl