Expected performance using Excel calculation

J. Va’vra

Content

- **Do SiPMTs actually work at 5 Tesla ?**
- **Various error contributions to Cherenkov angle resolution**
- **PID performance = f(momentum)**

Do SiPMTs actually work at 5 Tesla ?

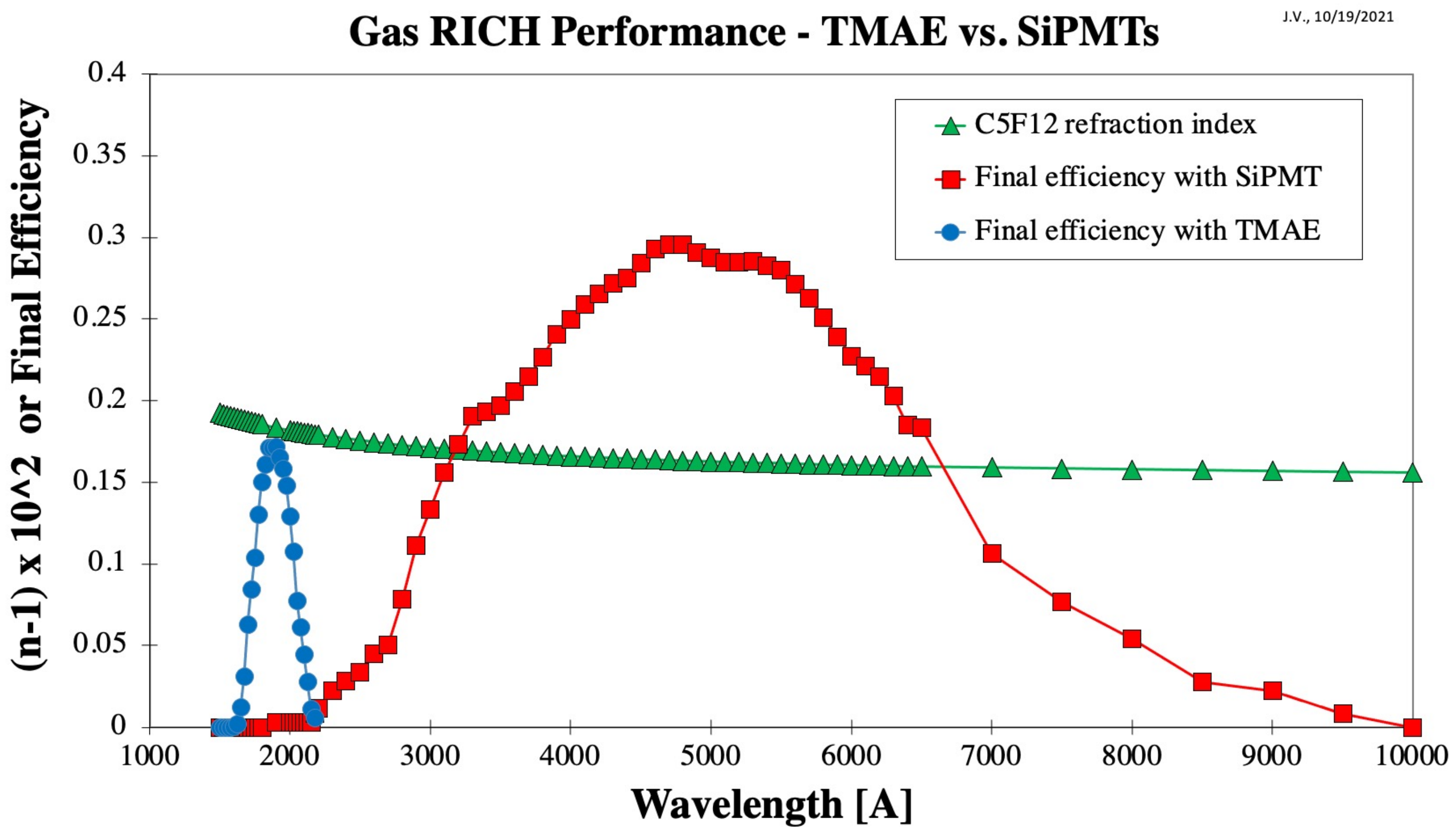
- Contact Robert Klanner.
- **My question to him:** Did anybody tried to run SiPMTs at 4−5 Tesla ? Would they work ? In this application, the field would be tangential to face, i.e., SiPMTs would be placed on a barrel.

- **His answer:** No effects are expected. Measurements at 7 T:
  S. Espan a et al.,
  https://core.ac.uk/download/pdf/30044497.pdf (NIM)

  Greetings,
  Robert

Chromaticity: TMAE vs SiPMTs

J. Va'vra



- **Although CRID operated in a region where refraction index changed more rapidly, its wavelength acceptance was very narrow and therefore the chromatic error was smaller than in case of SiPMTs – see later.**

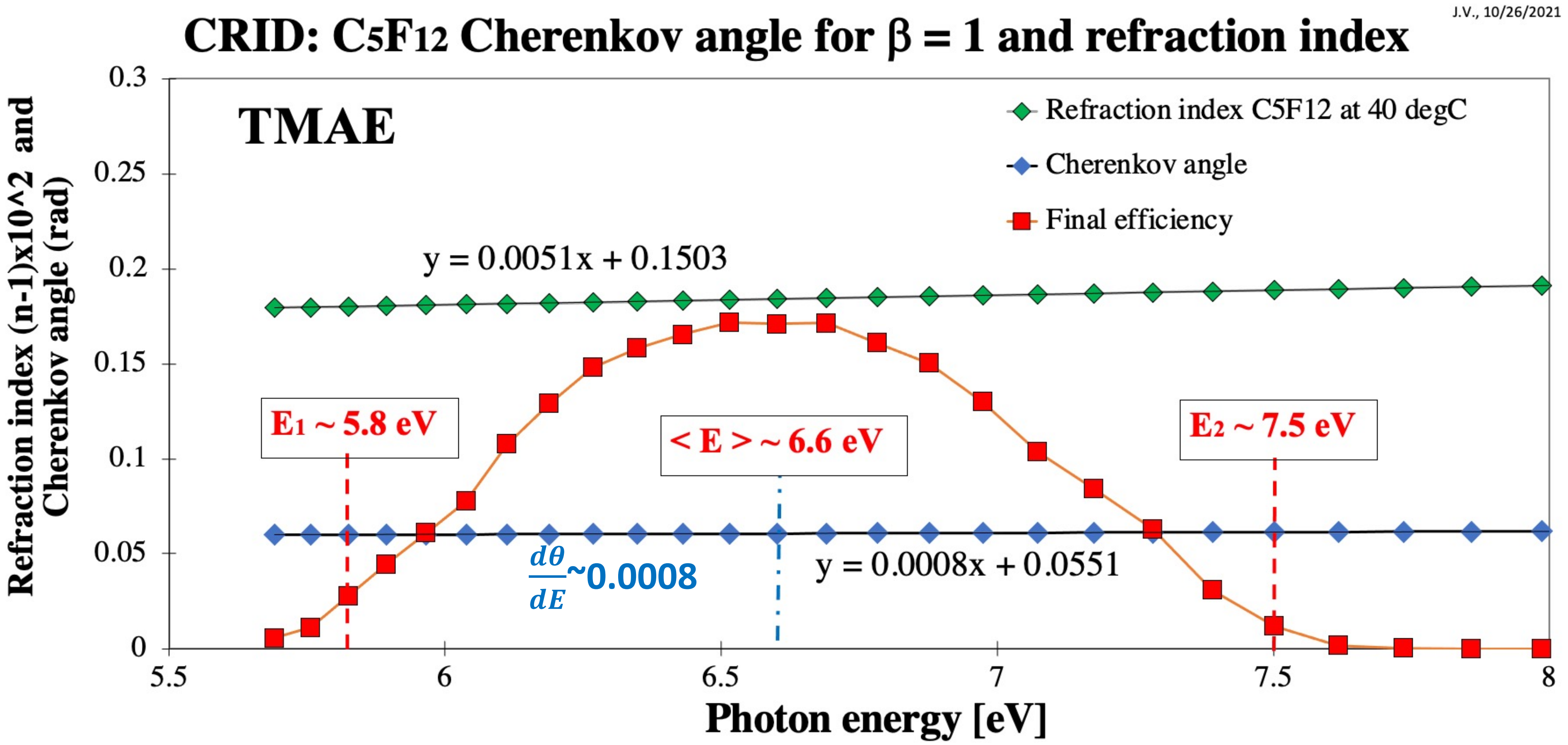
Chromatic error

- $\boldsymbol{\sigma_{\theta_c}}|_{\text{single photon}} \sim \frac{\mathbf{d\theta_c}}{\mathbf{dE}}\,(\boldsymbol{E_2} - \boldsymbol{E_1})\frac{\mathbf{1}}{\sqrt{\mathbf{12}}}$ **=** f(gas choice, detector)

- Cherenkov angle: $\theta_c = \arccos(\frac{1}{n\beta}) = f(E) \sim \arccos(\frac{1}{n})$ for $\beta \sim 1$
- E is photon energy,
- E_2 & E_1 are bandwidth acceptance limits

CRID: Chromatic error = f(n(E))

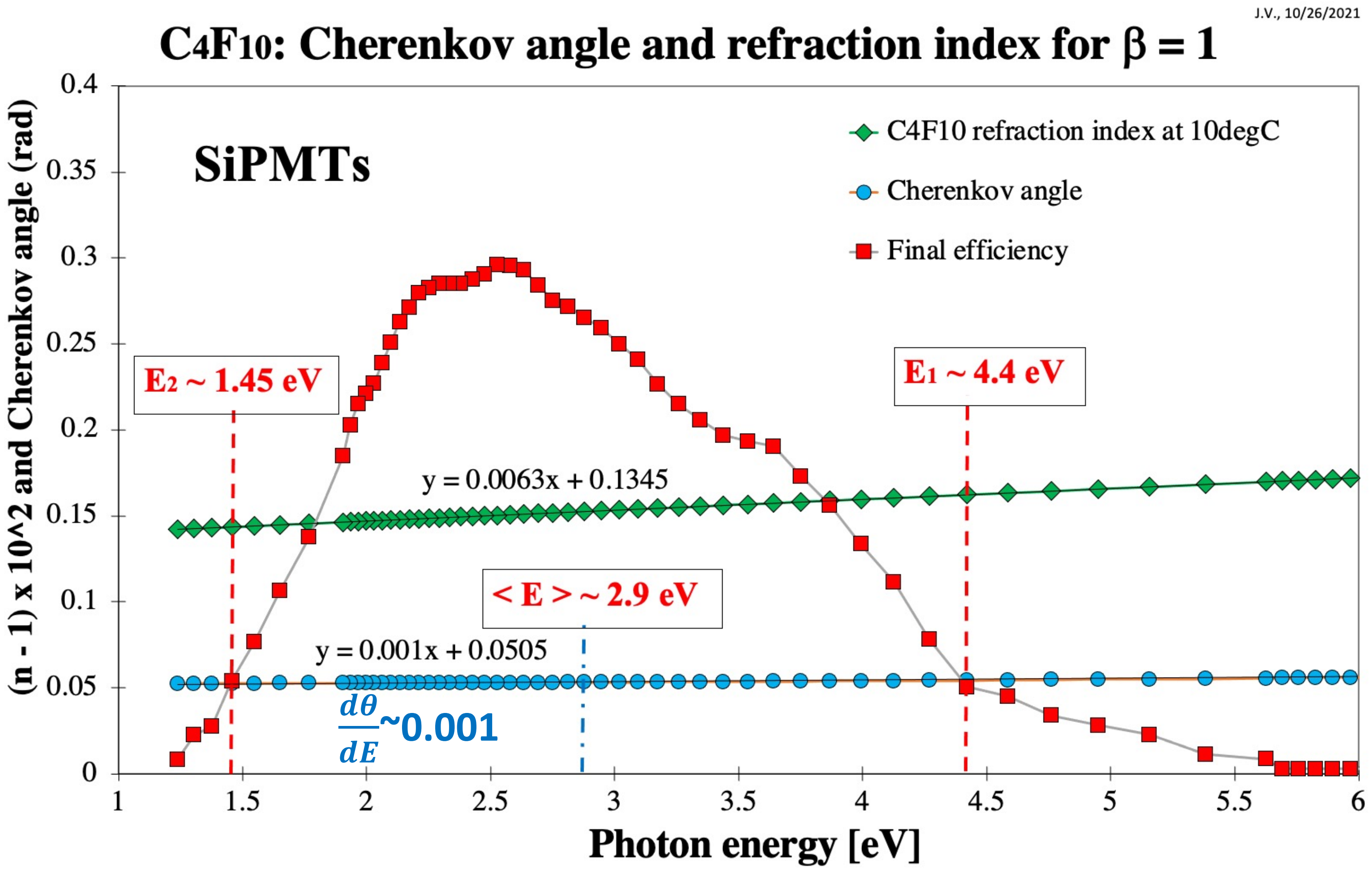
J. Va'vra



$\sigma_{\theta_c} \sim \frac{d\theta_c}{dE}(E_2 - E_1)\frac{1}{\sqrt{12}} \sim$ **0.4 mrad**, $\theta_c(E_{mean}) \sim 60$ mrad, $\frac{\sigma_{\theta_c}}{\theta_c}\Big|_{Chromatic} \sim$ **0.65%**

SiD: Chromatic error error = f(n(E))

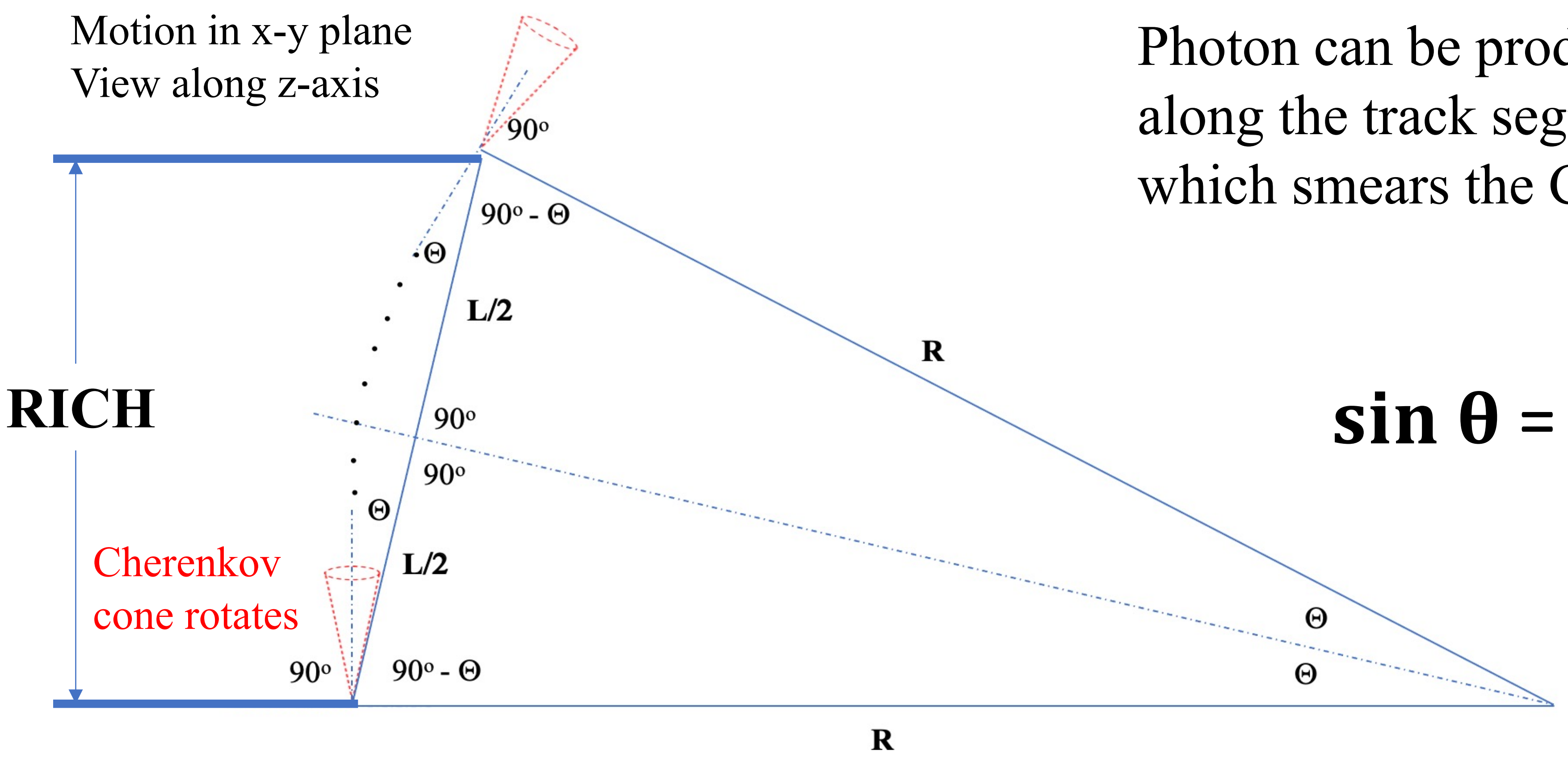
J. Va'vra



$\sigma_{\theta_c} \sim \frac{d\theta_c}{dE}(E_2 - E_1)\frac{1}{\sqrt{12}} \sim$ **0.85 mrad**, $\theta_c(E_{mean}) \sim 53.4$ mrad, $\frac{\sigma_{\theta_c}}{\theta_c}|_{Chromatic} \sim$ **1.6%** !!

Angular error due to track bending

J.Va'vra



Photon can be produced anywhere along the track segment along path L, which smears the Cherenkov angle

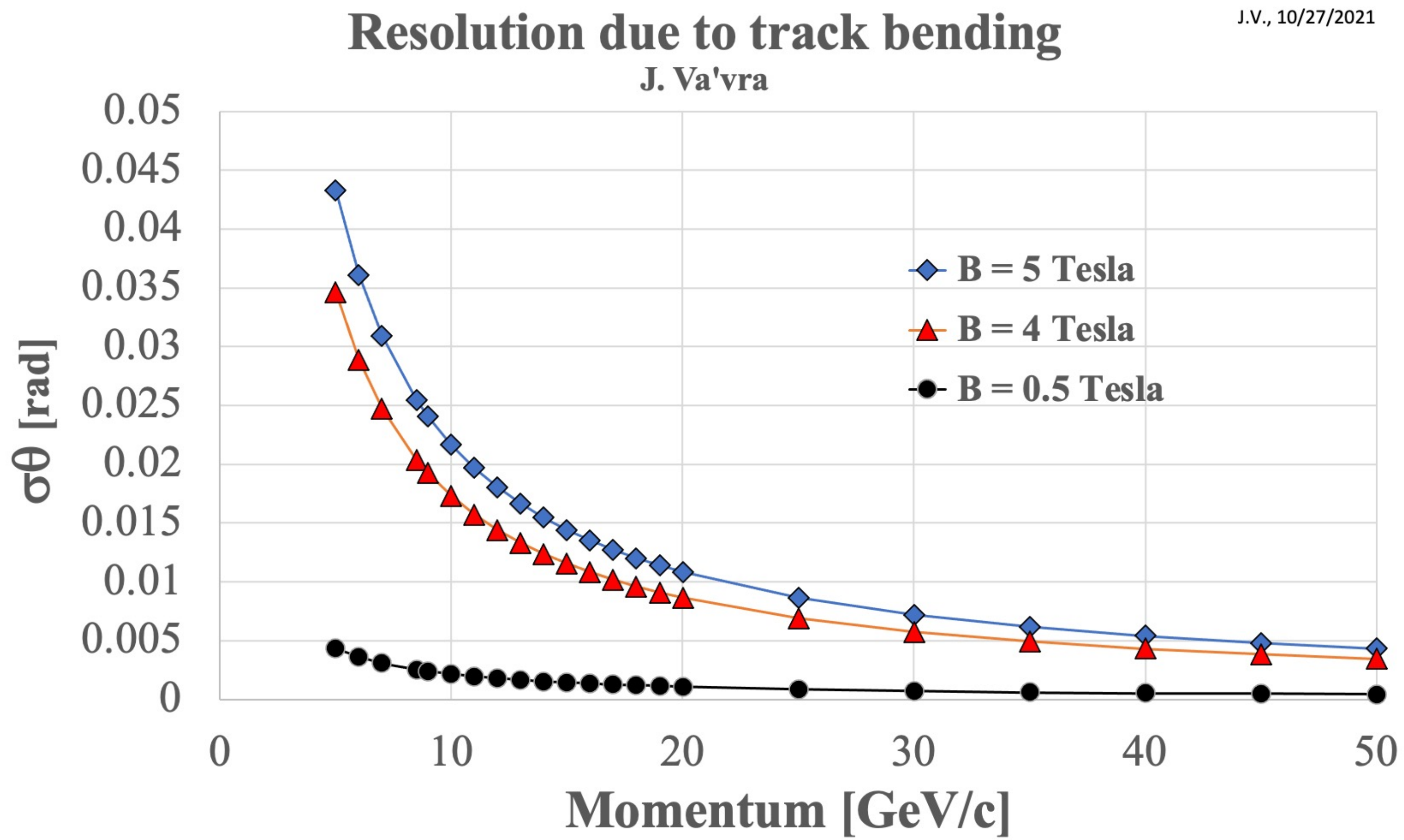
$$\sin\theta = \left[\frac{\left(\frac{L}{2}\right)}{R}\right]$$

$$\sigma_\theta \sim \frac{2\,\theta}{\sqrt{12}} \sim \{2\,\text{arsin}\left[\frac{\left(\frac{L}{2}\right)}{R}\right]\}\frac{1}{\sqrt{12}}\;,\; R = \frac{p}{300\,B},\; L = 0.25\text{ m},\; p\ [\text{MeV/c}],\; R\ [\text{m}]$$

SiD: Angular error due to track bending = f(B)

J. Va'vra

$$\sigma_\theta \sim \frac{2\,\Theta}{\sqrt{12}} \sim [2\ \mathrm{arsin}[\frac{\left(\frac{L}{2}\right)}{R}]\ \frac{1}{\sqrt{12}}$$



- **The angular resolution due to track bending is significant above ~2-3 Tesla**

Total Cherenkov angle error in CRID for L = 45 cm

- Chromatic error with C_5F_{12}/N_2 gas and TMAE: ~0.4 mrad
- Pixel size effect: ~(0.15cm/√12)/(1.5 x 45 cm) ~0.48 mrad
- Error due to track bending: ~1-2 mrad
- Mirror misalignment: ~0.5 mrad
- Gas pressure variations, flow changes, distortions, etc.: a few mrad

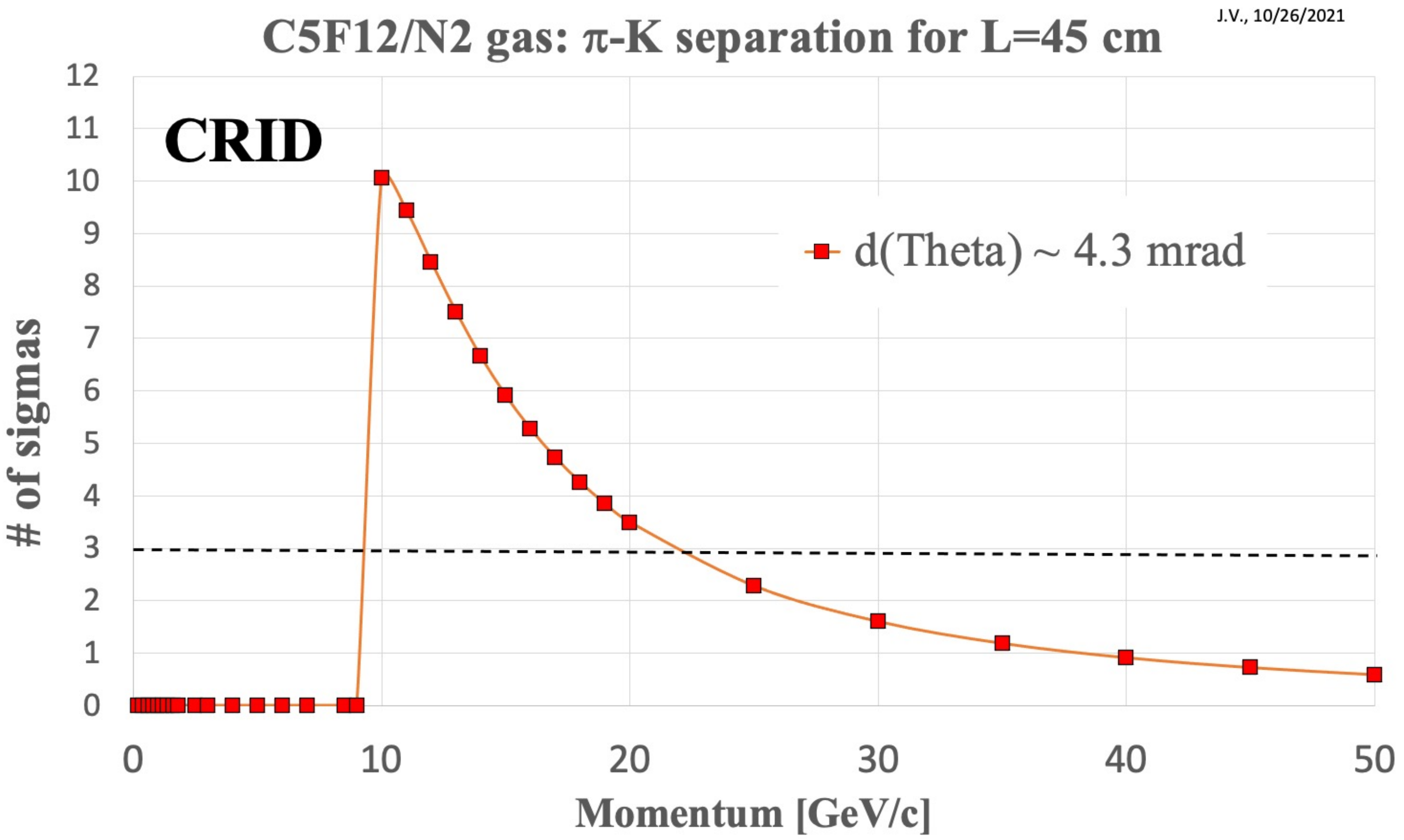
- **Total: σ_θ ~ 4.3 mrad (per single photoelectron)**

CRID: PID performance = f(momentum)

J. Va'vra

# of sigmas = $\frac{\theta_{\pi}-\theta_{K}}{\sigma_{\theta}/\sqrt{N}}$

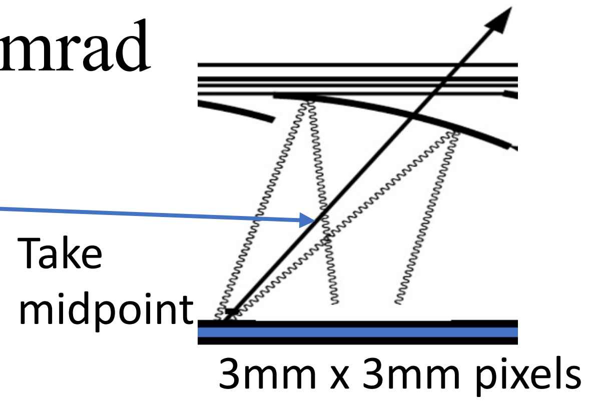
σ_{θ} is total Cherenkov angle resolution



- **CRID had 3 sigma π/K separation up to ~24 GeV/c.**

Cherenkov angle error in SiD for L= 25 cm

- Chromatic error with C_4F_{10} gas and SiPMT PDE: ~0.85 mrad
- Pixel size effect: ~(0.3cm/√12)/(1.5 x 25 cm) ~2.3 mrad
- Error due to track bending: >10 mrad at 3-5 Tesla
- Mirror misalignment: ~0.5 mrad
- Gas pressure variations, flow changes, distortions, etc.: ?



- **Total: σ_θ can be >10 mrad at larger magnetic field !!**

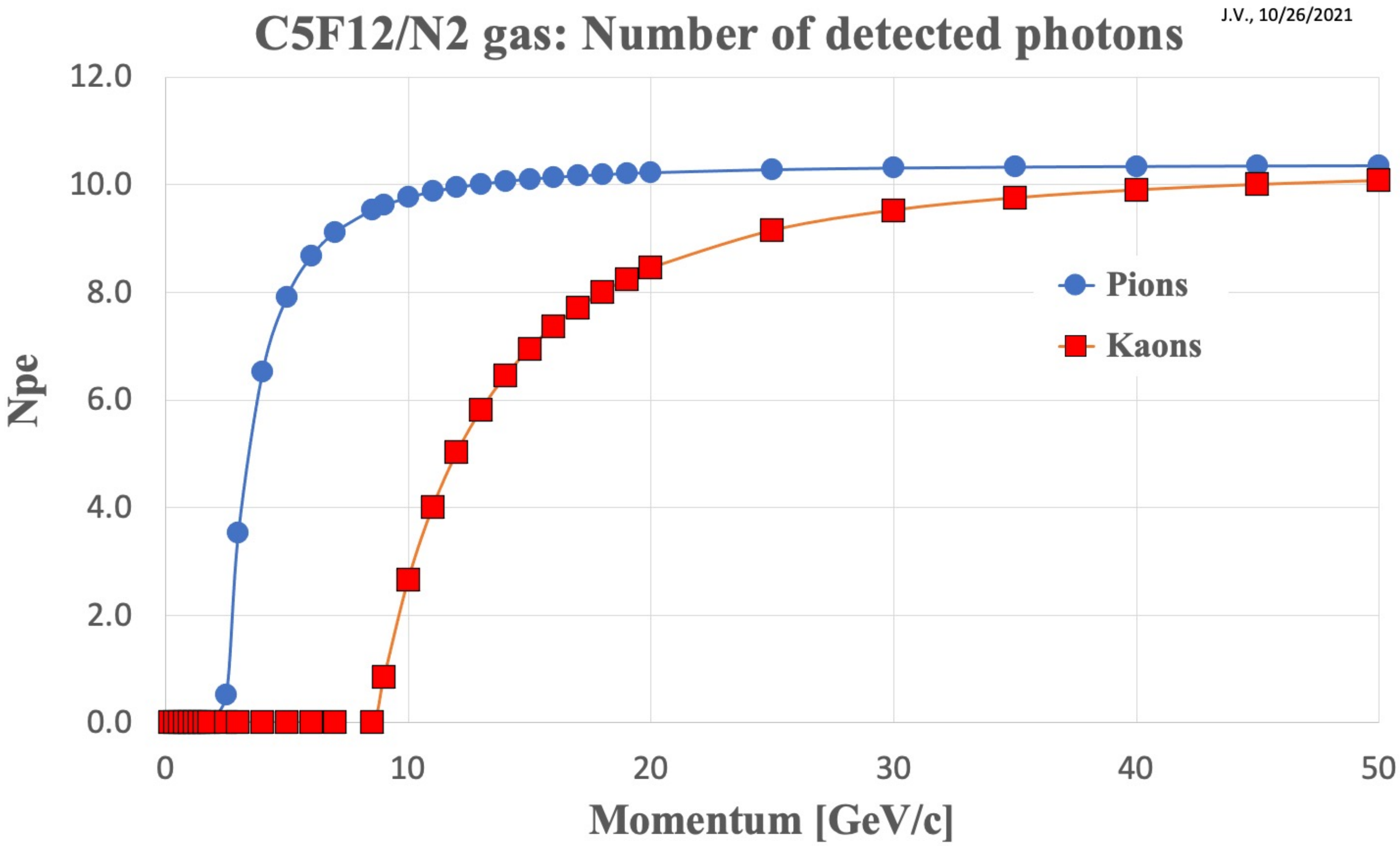
CRID: Threshold behavior

J. Va'vra

$$N_o = \frac{\left(\frac{\alpha}{hc}\right) \int \mathrm{Eff(E)}[\sin(\theta_c)]^2 dE}{[\sin(<\theta_c>)]^2}$$

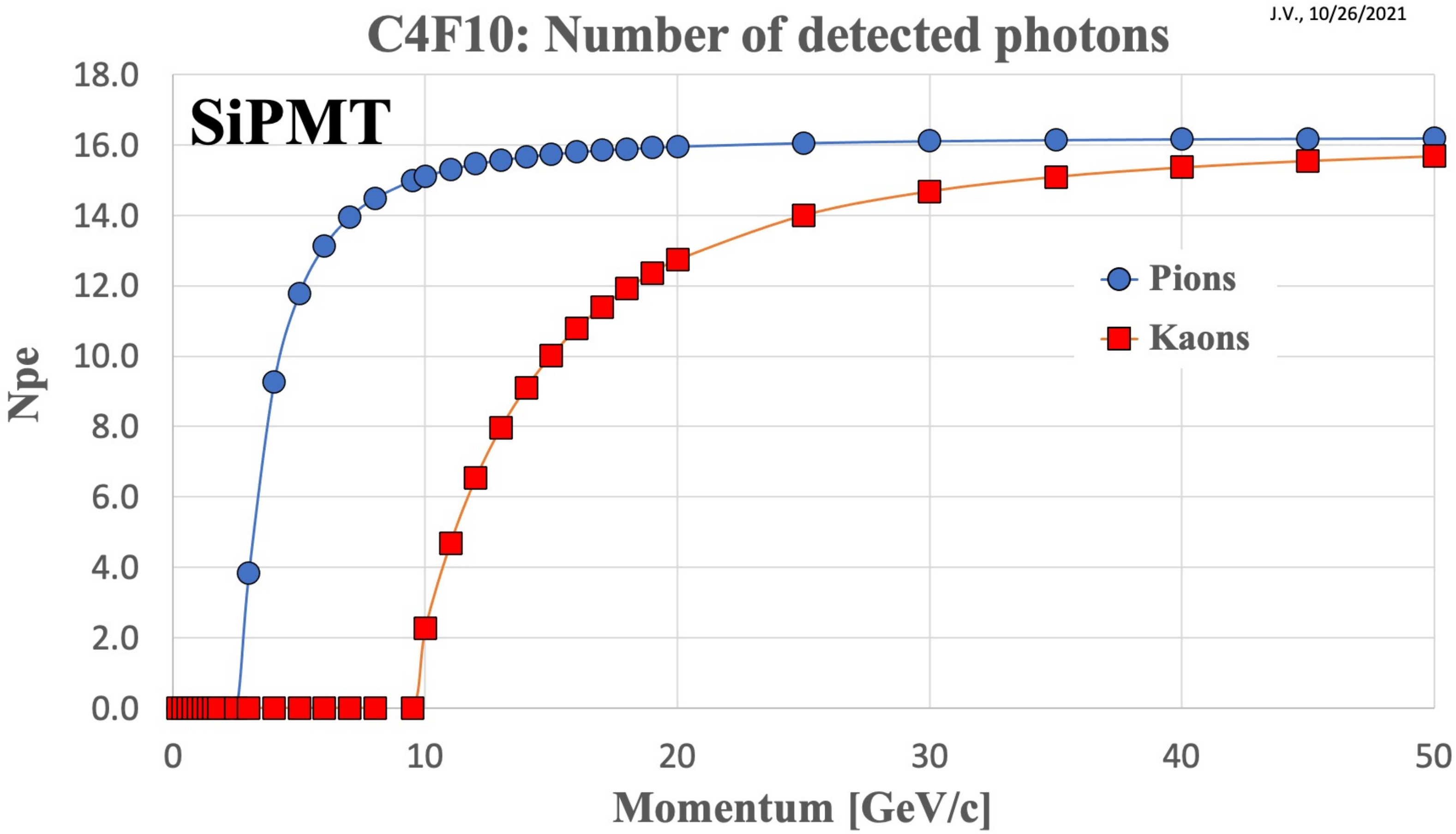
$$N_{pe} = N_o \, L \, [\sin <\theta_c>]^2$$

$<\theta_c>$ is mean Cherenkov angle



- **Below ~9 GeV/c Kaons do not produce light, Pions below ~2.5 GeV/c.**
- **Between 10 and 15 GeV/c Kaons produce small number of photoelectrons.**

SiD: Threshold behavior (25 cm)

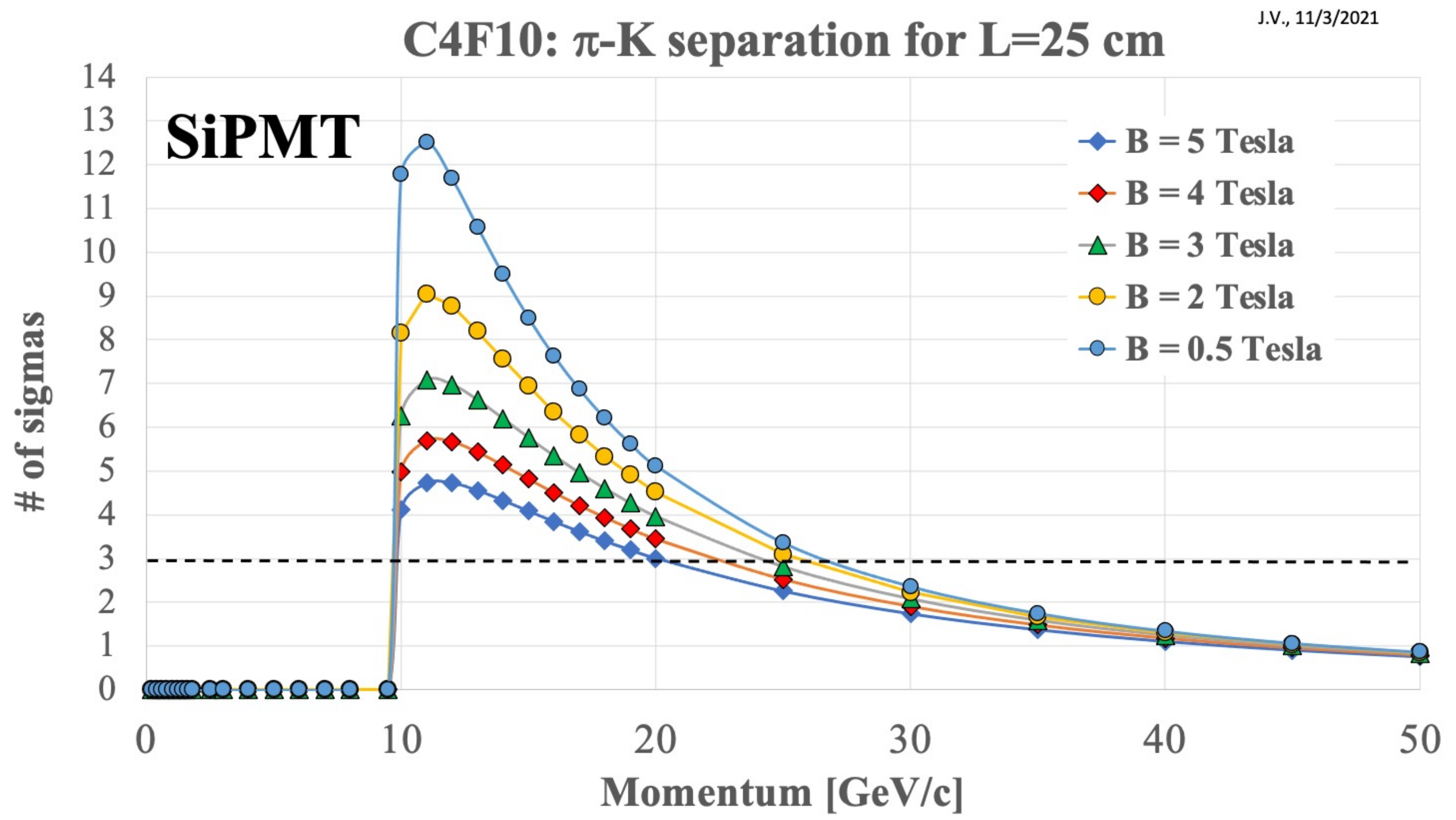


- Below 10 GeV/c Kaons do not produce light in this gas, Pions below ~3 GeV/c.

SiD: PID performance = f(momentum, B)

# of sigmas = $\dfrac{\theta_\pi - \theta_K}{\sigma_\theta/\sqrt{N}}$

σ_θ is total Cherenkov angle resolution = f(p); it is a total error, which included chromatic effect, bending effect, pixel size effect and other expected systematic effects



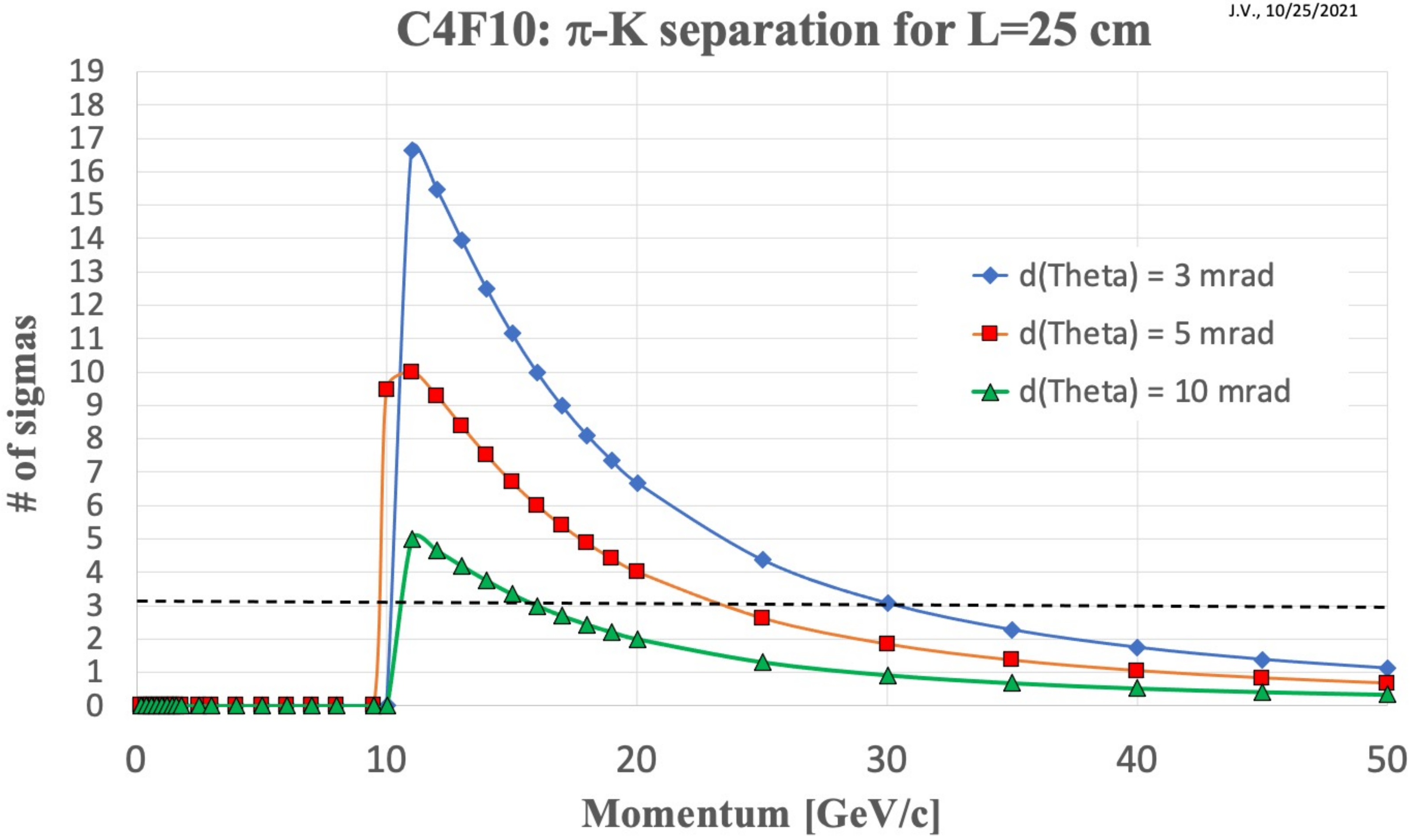
- **Maximum field we might think about in this particular design is 3 Tesla.**

SiD: PID performance = f(momentum,σ_θ)

# of sigmas =

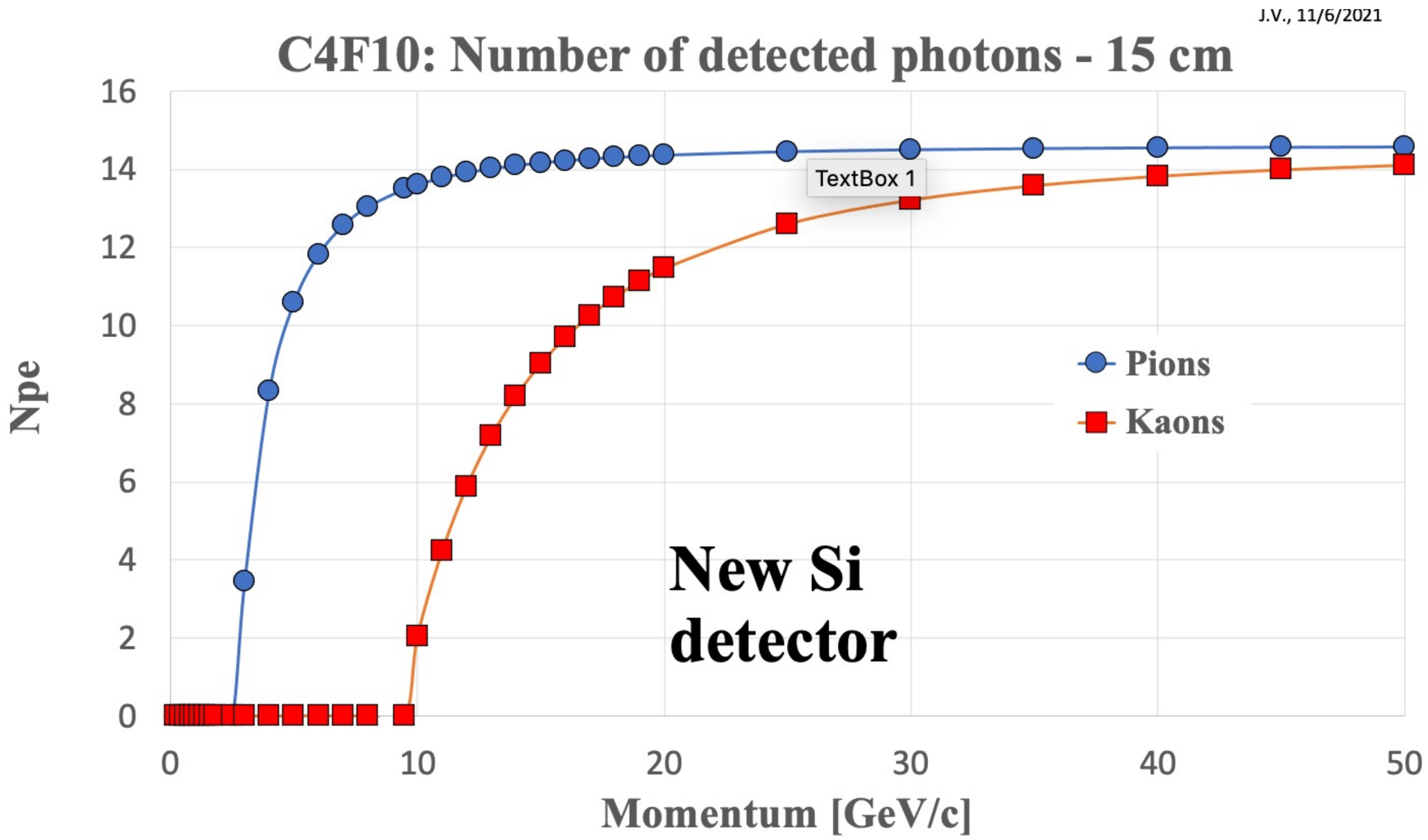
$$\frac{\theta_\pi - \theta_K}{\sigma_\theta/\sqrt{N}}$$

σ_θ is total Cherenkov angle resolution



- **Goal: One should not exceed Cherenkov error above ~5 mrads !!**

SiD: Threshold behavior

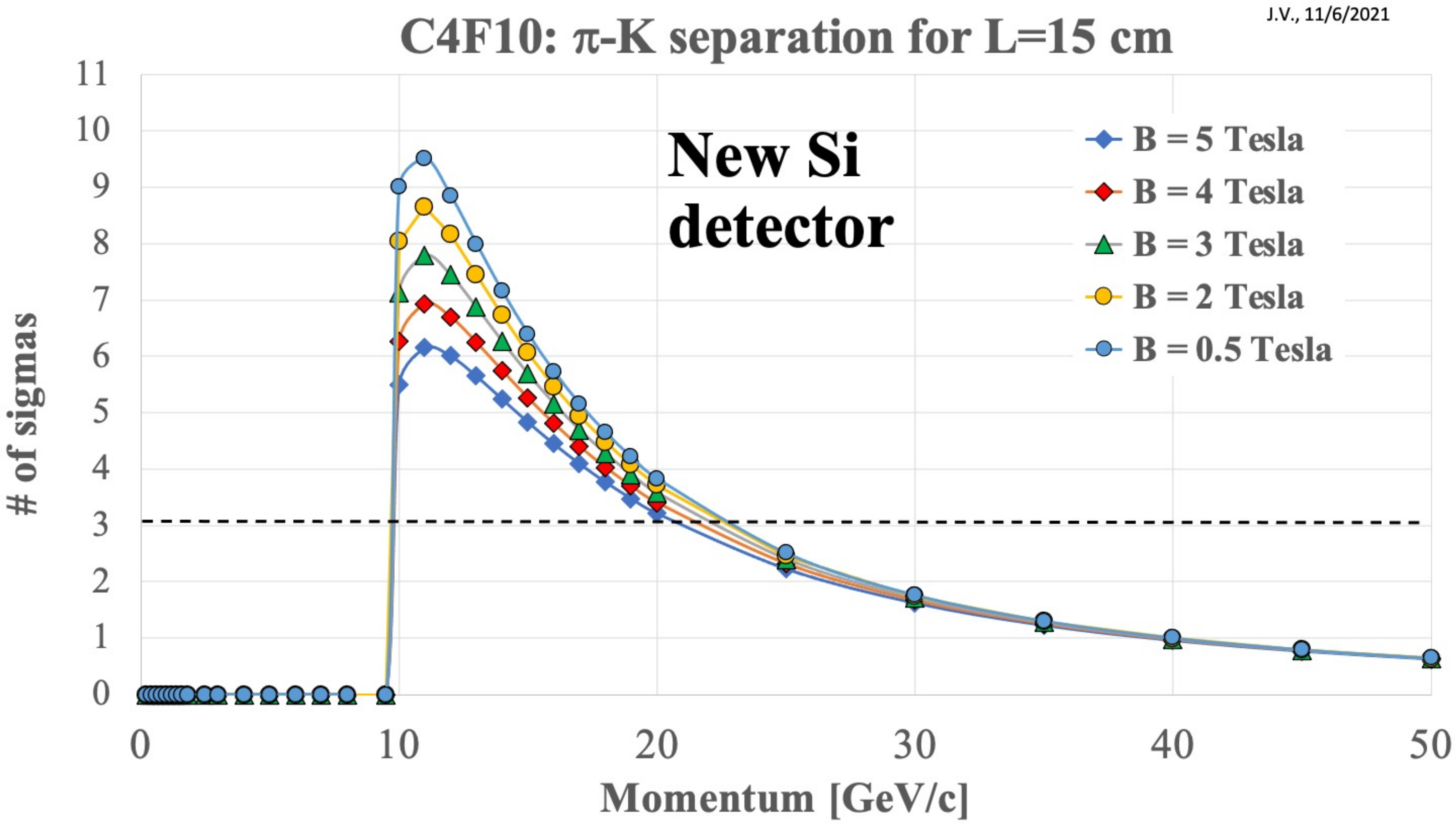


- 15 cm long radiator; PDE of a <u>hypothetical</u> Si detector has 1.5 x PDE_{SiPMT}.

SiD: PID performance = f(momentum, B)

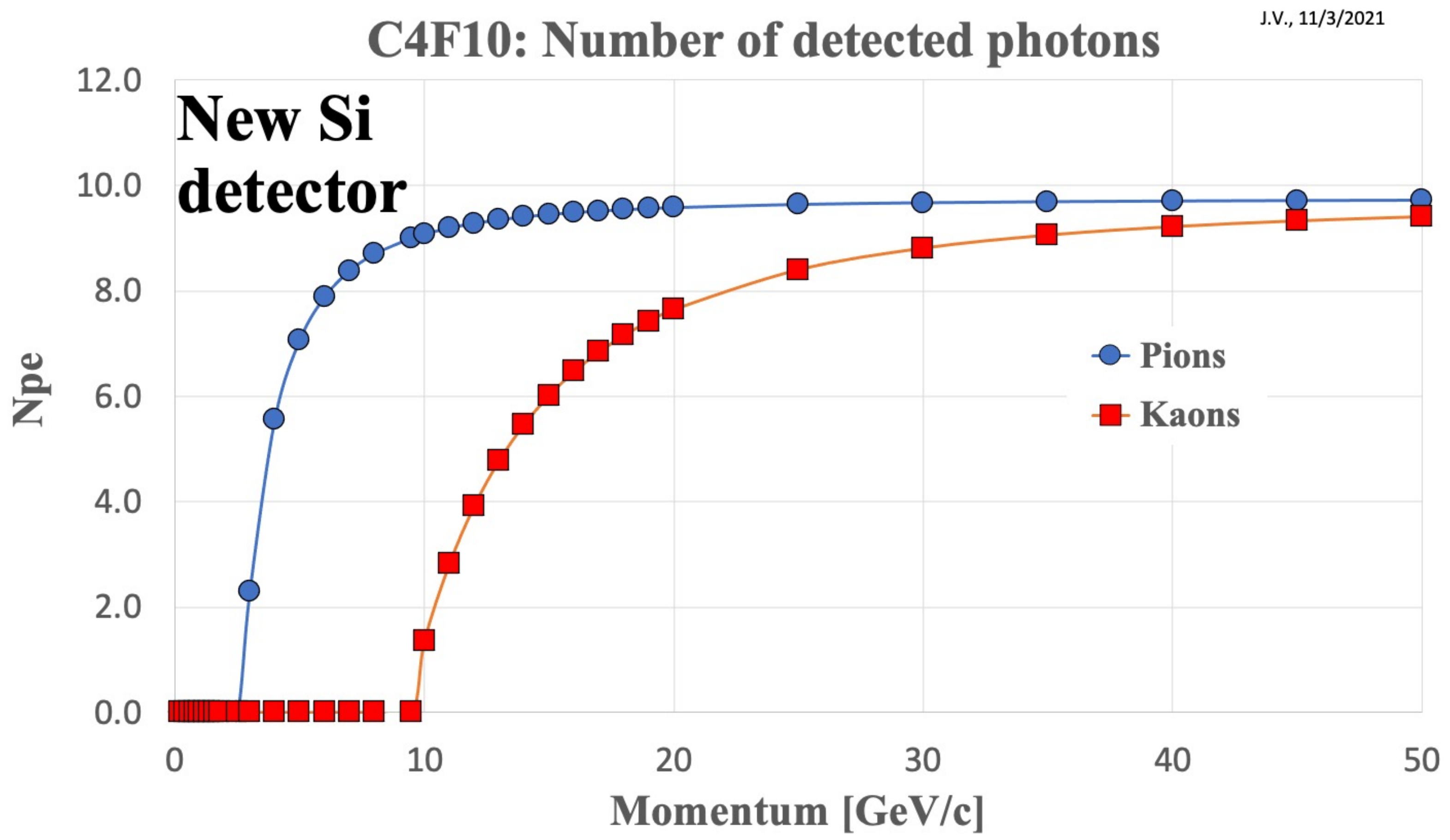
# of sigmas = $\dfrac{\theta_\pi - \theta_K}{\sigma_\theta / \sqrt{N}}$

σ_θ is total Cherenkov angle resolution = f(p); it is a total error, which included chromatic effect, bending effect, pixel size effect and other expected systematic effects



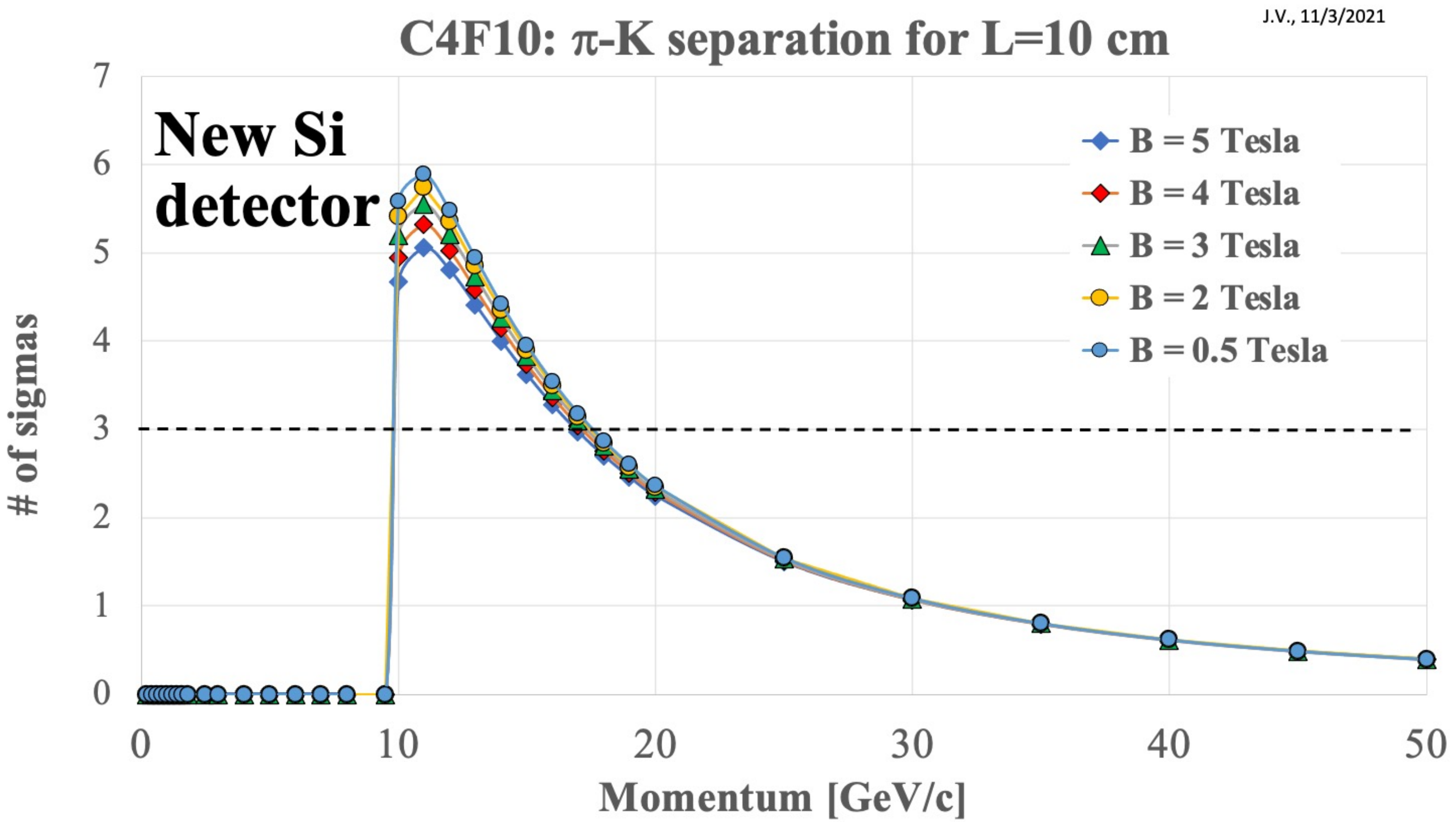
- **15 cm long radiator; PDE of a <u>hypothetical</u> Si detector has 1.5 x PDE$_{SiPMT}$.**
- **This detector does not exist yet.**

SiD: Threshold behavior



- **10 cm long radiator; PDE of a <u>hypothetical</u> Si detector has 1.5 x PDE$_{SiPMT}$.**

SiD: PID performance = f(momentum, B)



- 10 cm long radiator; PDE of a <u>hypothetical</u> Si detector has 1.5 x PDE_{SiPMT}.
- Not good enough + This detector does not exist yet.