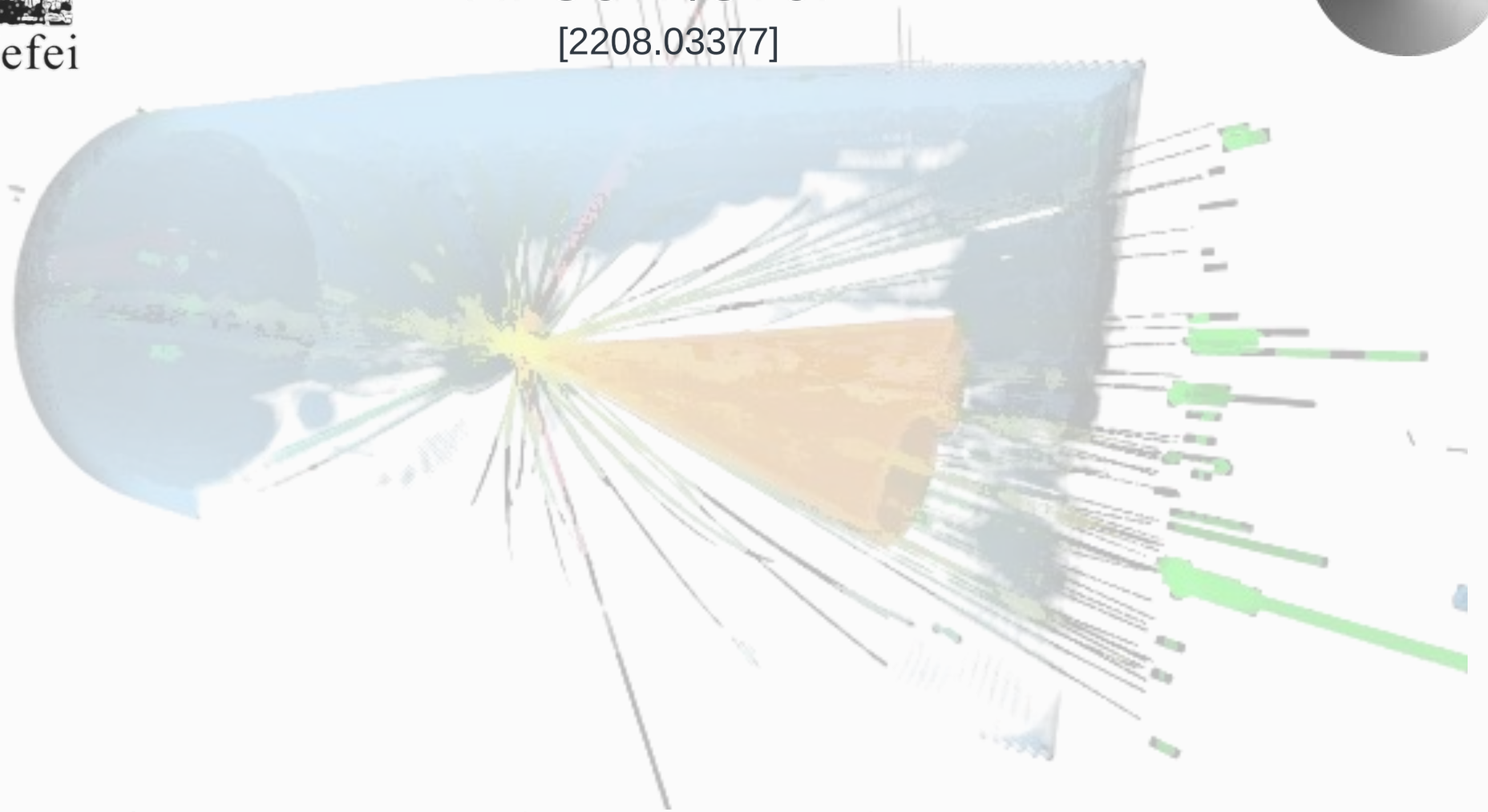
FTCF2024

USTC Hefei

MILLICHARGED PARTICLES AT SCTF/STCF

[2208.03377]



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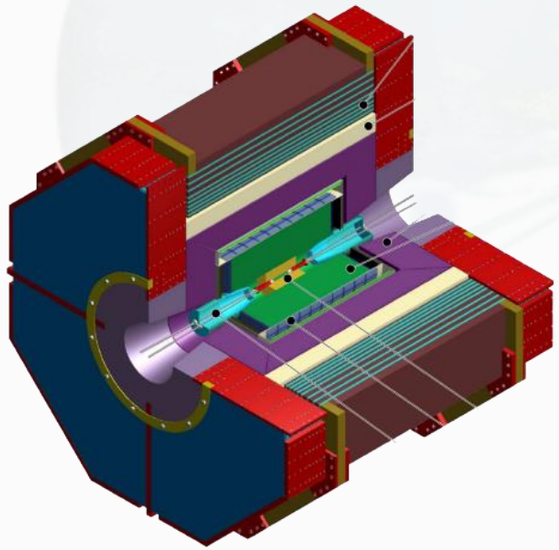
MILLICHARGED PARTICLES
Super Tau-Charm Factory

e^+e^- - collider

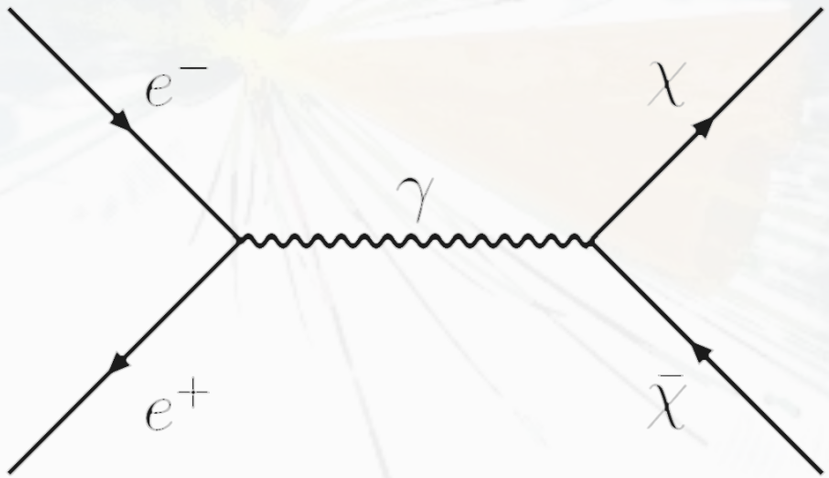


$\sqrt{s}, GeV$	L, fb^{-1}
3.097	*300*
3.554	*50*
3.686	*150*
3.770	*300*
4.110	*100*
4.650	*100*

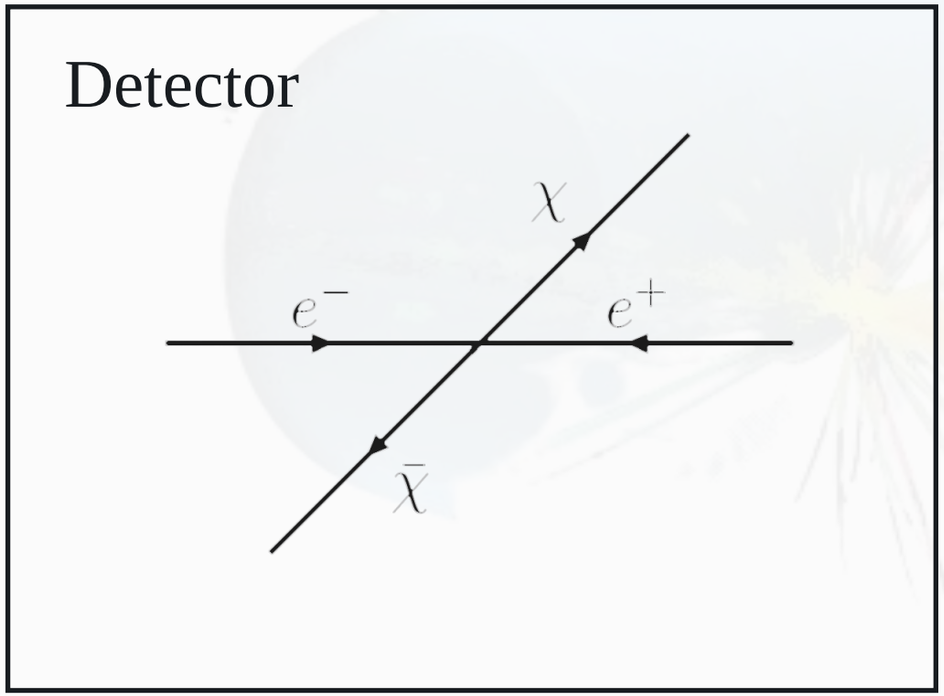
\+ Scan over collision energies with 10 MeV step and 1/fb

MILLICHARGED PARTICLES
Model

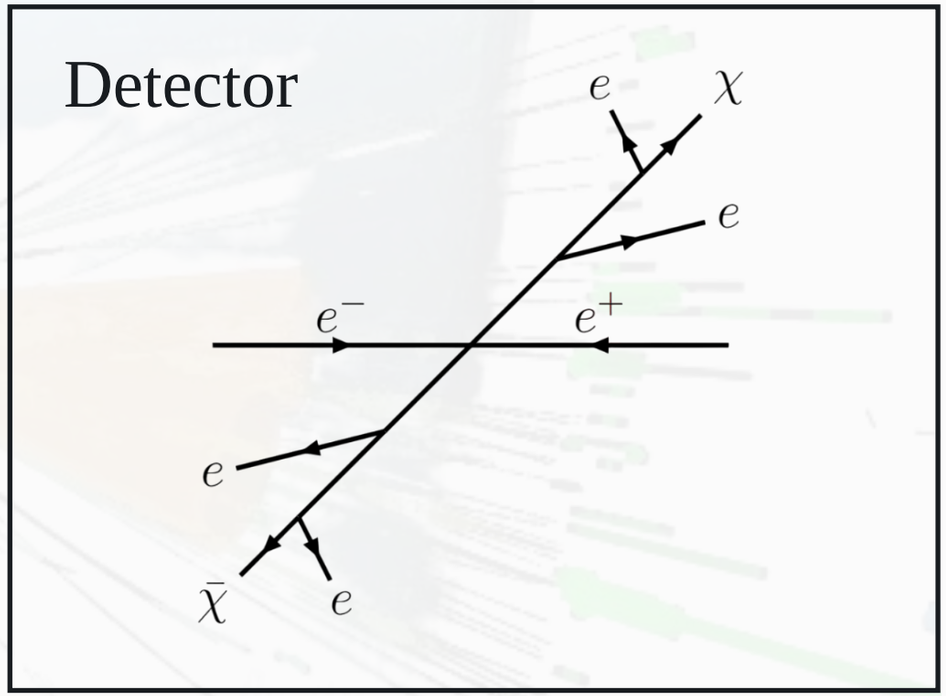
$$\mathcal{L} = \epsilon e\, A_\mu \bar{\chi} \gamma^\mu \chi\,, \qquad \epsilon = \frac{Q_\chi}{e}$$



MILLICHARGED PARTICLES
Signal for direct searches



Energy loss



δ-electrons

MILLICHARGED PARTICLES
Energy loss

$$N(\delta x) = \frac{\rho K}{2}\frac{Z}{A}\delta x \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times \int_I^{T_{max}} dT \frac{1-\beta^2 T/T_{max}}{T^2}$$

$m_\chi \gg m_e$

$\beta \ll 1$

$T_{max} = 2m_e\beta^2$

$$\Rightarrow \quad N(\delta x) = \frac{\rho K}{2}\frac{Z}{A}\delta x \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times \left(\frac{1}{I} - \frac{1}{T_{max}}\right)$$

Gas: propane

$$\Rightarrow \quad N(\delta x) = 0.5 \times \left(\frac{\delta x}{1cm}\right)\left(\frac{\epsilon}{1.8\cdot 10^{-3}}\right)^2\left(\frac{10^{-2}}{\beta}\right)^2$$

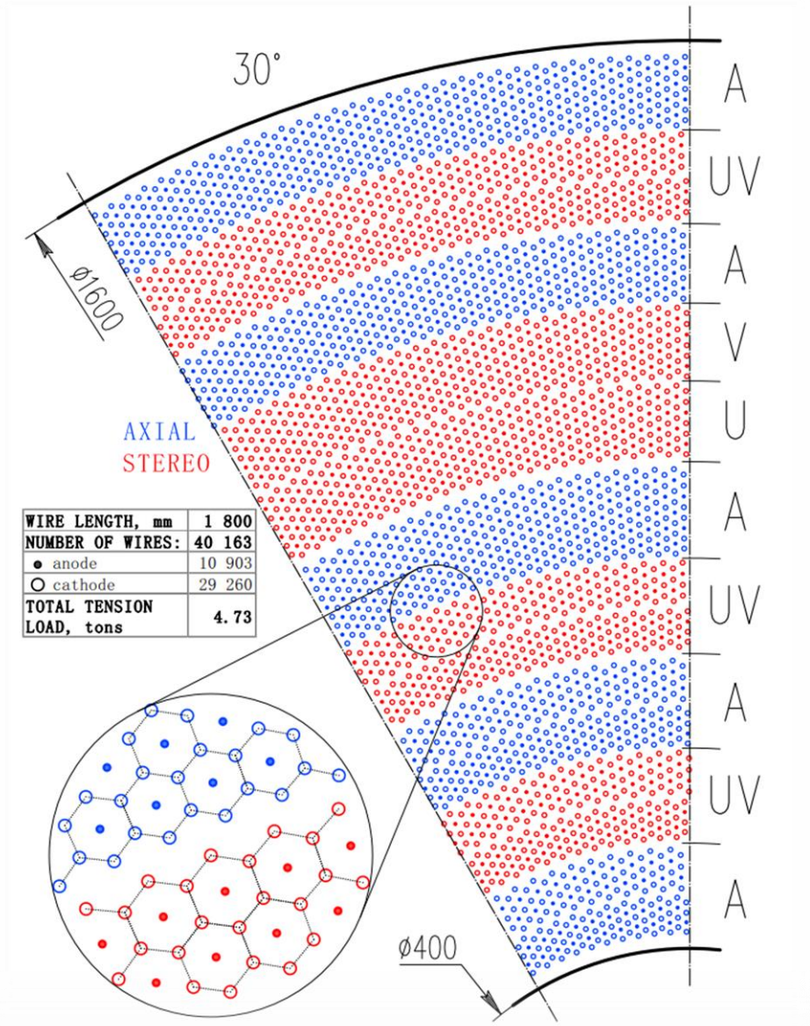
MILLICHARGED PARTICLES
Number of hits

Drift Chamber consist
of 41 sense layers, $n_c = 41$

Cell size $\approx 1\ cm \Rightarrow N(1\ cm)$

Probability to lighten up
more than n_0 cells is:

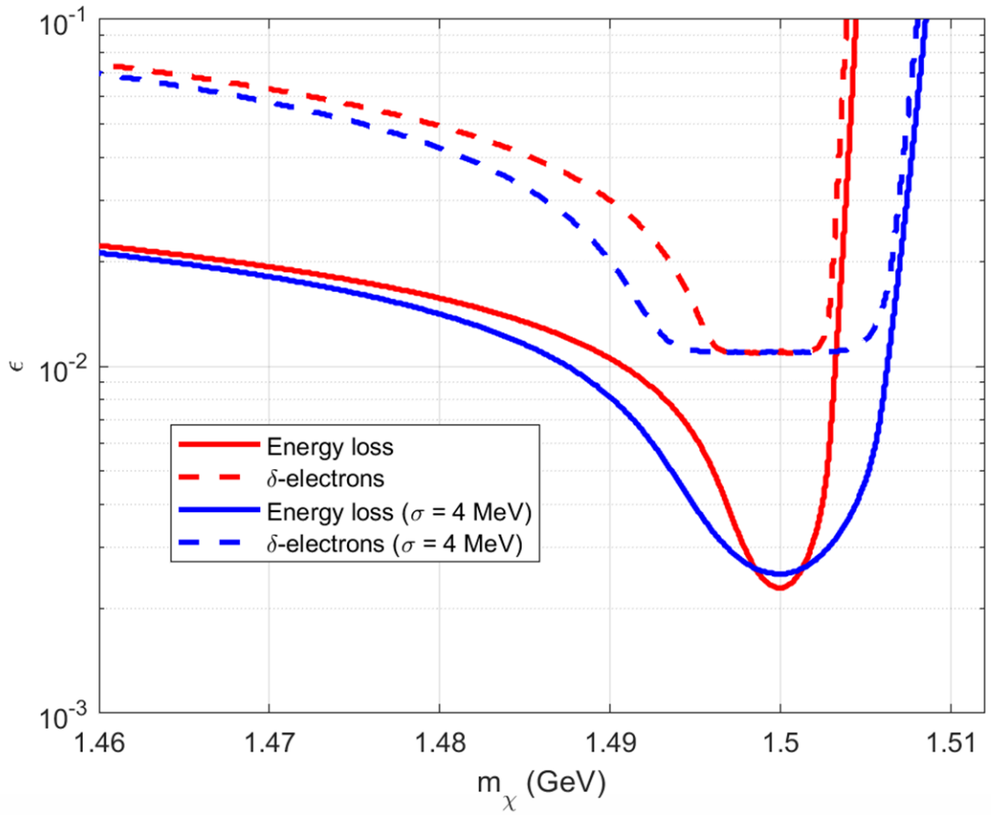
$$P_s(n_0, N) = \sum_{n=n_0}^{2n_c} \left[\begin{matrix} \left(e^{-N}\right)^{2n_c - n} \times \\ \left(1 - e^{-N}\right)^{n} \times \\ \dfrac{2n_c!}{n!\,(2n_c - n)!} \end{matrix} \right]$$



MILLICHARGED PARTICLES
Non-monochromatic energy

$$\frac{\mathrm{d}L}{d\sqrt{s}} = \frac{L_0}{\sqrt{2\pi}\sigma} \times exp\left(-\frac{\left(\sqrt{s}-\sqrt{s_0}\right)^2}{2\sigma^2}\right)$$

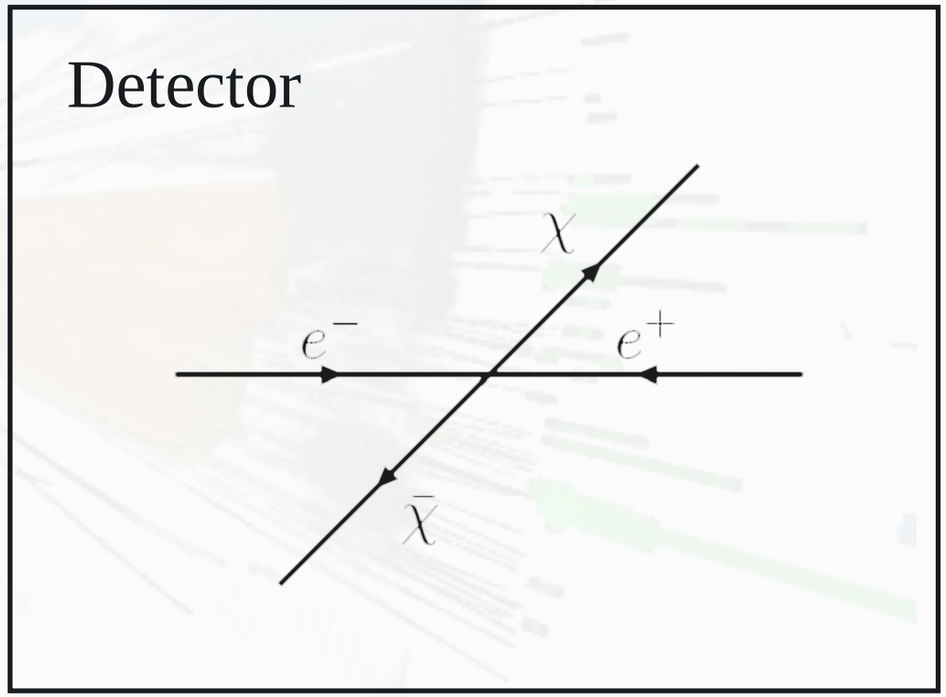
$$\sigma = \sqrt{2} \times 0.01\% \ \frac{\sqrt{s}}{2}$$



MILLICHARGED PARTICLES
Energy loss

$$\sigma(e^+e^- \to \chi\bar{\chi}) = \frac{2\pi\alpha^2\epsilon^2\beta}{s}$$

$$N(\sqrt{s_0}) = \int d\sqrt{s} \times \frac{dL}{d\sqrt{s}} \times \sigma(e^+e^- \to \chi\bar{\chi}) \times P_s(n_0, N)$$



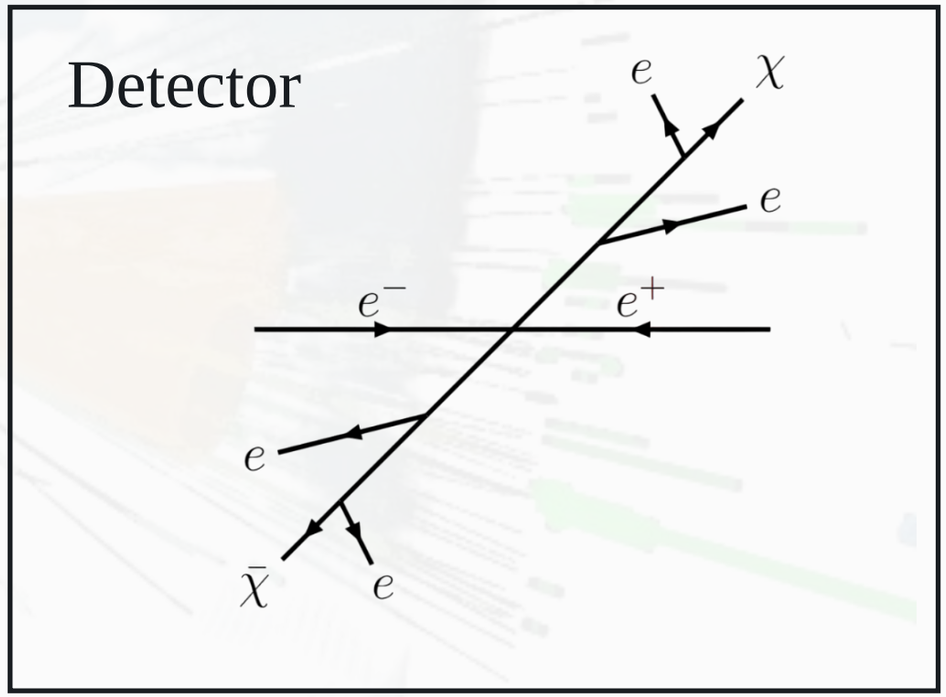
MILLICHARGED PARTICLES
δ-electrons

$$\frac{d^2 N_\delta}{dx\, dT_e} = \frac{\rho K}{2}\frac{Z}{A} \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times \frac{F(T_e)}{{T_e}^2}$$

$$F(T_e) \approx 1$$

$$T_e > T_{min} = 1\ keV$$

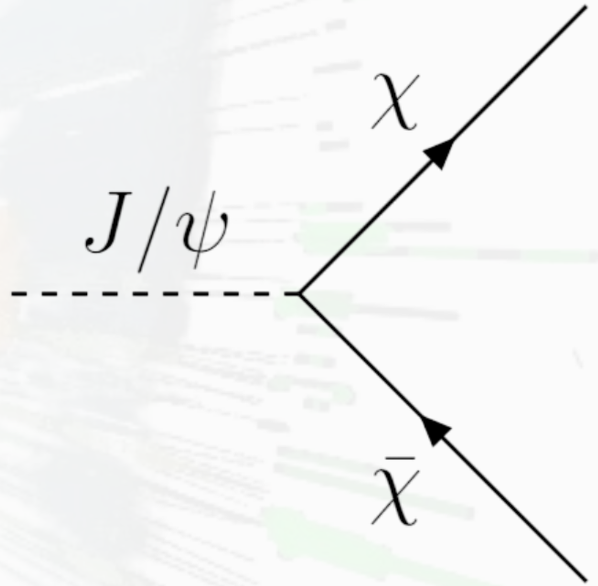
$$N_\delta = \frac{\rho K}{2}\frac{Z}{A} \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times L\left(\frac{1}{T_{min}} - \frac{1}{T_e}\right)$$



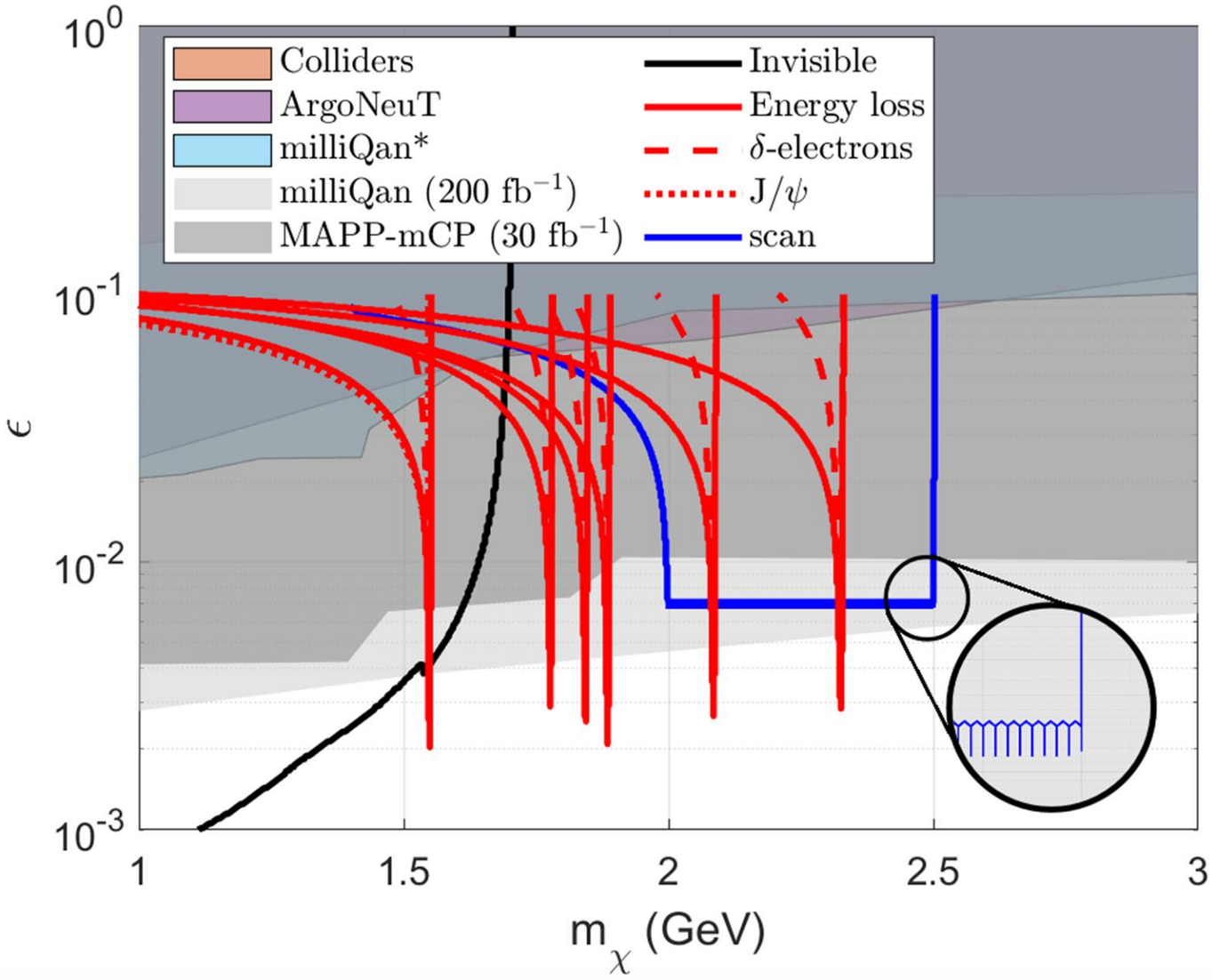
MILLICHARGED PARTICLES
J/ψ decays

$$N = N_{J/\psi} \times \epsilon^2 \times Br_{\chi\bar{\chi}} \times P_s(n_0, N)$$

$$Br_{\chi\bar{\chi}} = Br_{\mu\mu} \frac{\sqrt{1 - 4m_\chi^2/m_{J/\psi}^2}\left(1 + 2m_\chi^2/m_{J/\psi}^2\right)}{\sqrt{1 - 4m_\mu^2/m_{J/\psi}^2}\left(1 + 2m_\mu^2/m_{J/\psi}^2\right)}$$



MILLICHARGED PARTICLES



MILLICHARGED PARTICLES AT SUPER CHARM-TAU FACTORY

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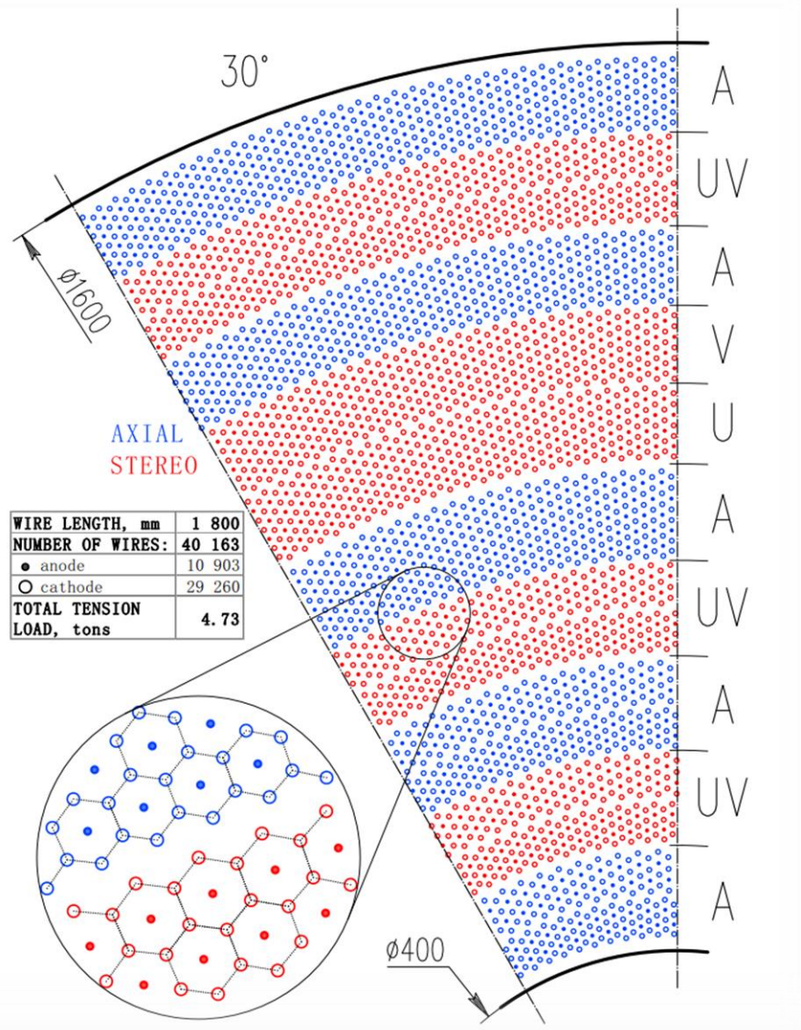
MILLICHARGED PARTICLES
Larmor radius

$$r \approx 97\ cm \left(\frac{1\ T}{B}\right) \times \left(\frac{m_\chi}{1\ GeV}\right)\left(\frac{\beta}{\epsilon}\right)$$

$$r > 20\ cm$$

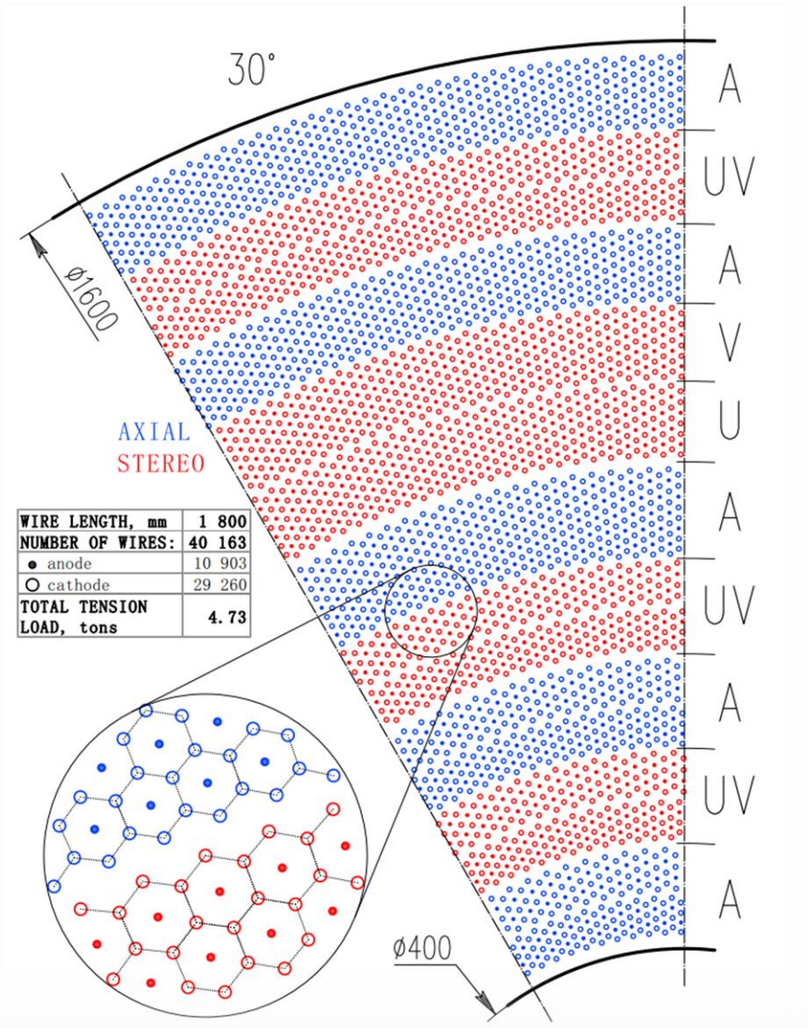


Kalashnikov Dmitry

MILLICHARGED PARTICLES
Number of hits

$$P_b(n_0) = \sum_{n=n_0}^{2n_c} \left[\frac{(1-0.05)^{2n_c-n} \times (0.05)^n \times 2n_c!}{n!\,(2n_c-n)!} \right]$$

$$n_0 > 29, \qquad n_0 = 30$$



MILLICHARGED PARTICLES
Initial State Radiation

$$\sigma_{corr} = \int_0^{x_{max}} \sigma\big((1-x)s\big)\, H(x,s)dx$$

$$E_\gamma < 25\ MeV$$

O. Nicrosini, Luca Trentadue.
Phys.Lett.B 196 (1987), 551