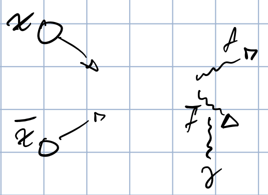
Ok, cool, what about annihilation? $\chi \cdot \bar{\chi} \longrightarrow f\bar{f} \rightarrow f\bar{f} + \gamma\gamma \ldots$

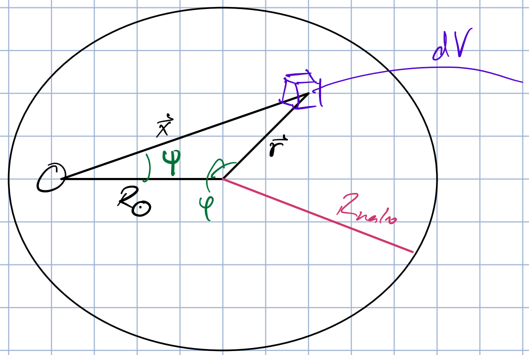
(χ could be its own antiparticle)



$$\sum_f E_f = 2 m_\chi$$

if 2 body annihilation: $E_i \approx 2 m_\chi$

$E_f = E_f + E_{\bar{f}} \longrightarrow E_f = E_{\bar{f}} = m_\chi$ $\quad |\vec{p}|_f = |\vec{p}|_i$



$\varphi = \pi - \psi \qquad dN_\chi = n\,dV$

interested in local flux: $\frac{dN_\gamma^{obs}}{dA_{det}}$

$$\frac{dN_\gamma^{obs}}{dA_{det}} = \frac{1}{4\pi x^2} \cdot dN_\chi \cdot \underbrace{P_{ann}}_{\text{annihilation probability}} \cdot N_\gamma^{ann}$$

$$P_{ann} = \overbrace{\langle\sigma v\rangle\, n_\chi[r(x)]}^{\text{rate}} \cdot dt \cdot \underbrace{\tfrac{1}{2}}_{\text{don't double count}}$$

want γ-spectrum

for one dV region:

$$\frac{dN_\gamma^{obs}}{dA_{det} \cdot dt \cdot dE_\gamma} = \frac{\langle\sigma v\rangle}{8\pi \cancel{x^2}} \cdot \overbrace{\left(\cancel{x^2}\, dx\, d\Omega_\psi\right)}^{dV} \cdot n_\chi^2[r(x)] \cdot \frac{dN_\gamma^{ann}}{dE_\gamma}$$

integrate over dV

$$\frac{d\Phi}{dE_\gamma} = \frac{\langle\sigma v\rangle}{8\pi m_\chi^2} \cdot \frac{dN_\gamma^{ann}}{dE_\gamma} \cdot \int d\Omega_\psi \cdot \int_0^{x_{max}} dx\, \rho_\chi[r(x)]^2$$

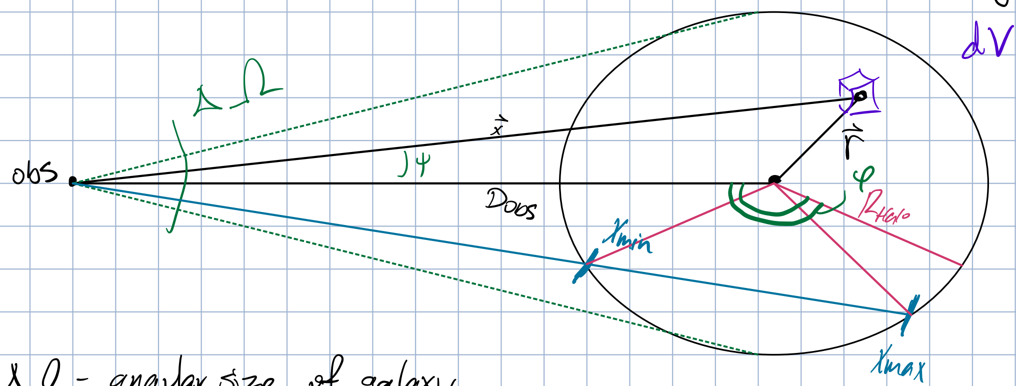
much more sensitive to distribution of stuff same as decay: $x_{max}^2 = R_\odot^2 + R_{Halo}^2 - 2 R_\odot R_{Halo} \cdot \cos\varphi$

$\varphi = \varphi(\psi)$

$$\frac{d\Phi}{dE_\gamma} = \frac{\langle \sigma v \rangle}{8\pi m_\chi^2} \cdot \frac{dN_\gamma}{dE_\gamma} \cdot J$$

$$J \equiv \int d\Omega_\psi \cdot \int dx \, \rho_\chi[r(x)]^2$$

ok cool, but what for distant objects outside our galaxy?



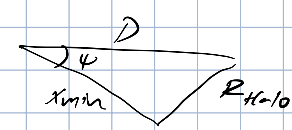
$\Delta\Omega$ - angular size of galaxy

everything stays same except J factor

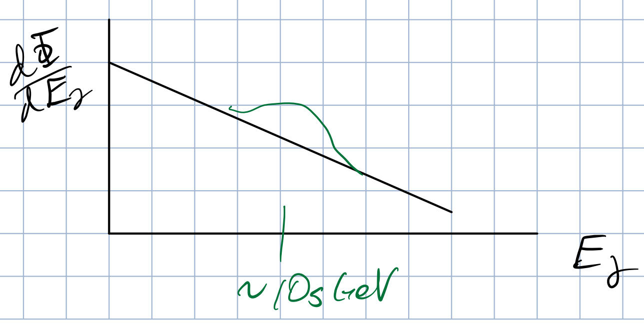
$$J(\Delta\Omega) = \int_{\Delta\Omega} d\Omega_\psi \int_{x_{min}(\psi)}^{x_{max}(\psi)} dx \, \rho_\chi[r(x)]^2$$

$$x_{max}^2 = D_{obs}^2 + R_H^2 - 2 D_{obs} R_H \cos\varphi$$

$$R_{halo}^2 = D_{obs}^2 + x_{min}^2 - 2 D_{obs} x_{min} \cos\psi$$



Galactic Center Excess



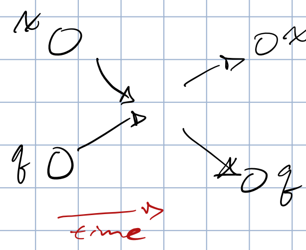
Dan Hooper

Lisa Goodenough

$\langle \sigma v \rangle \sim \langle \sigma v \rangle_{therm}$

In QFT

if you can scatter

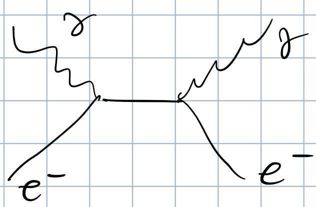


direct detection

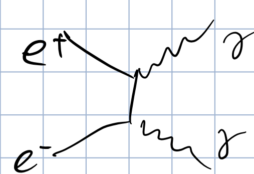
then you can annihilate

then you can be produced

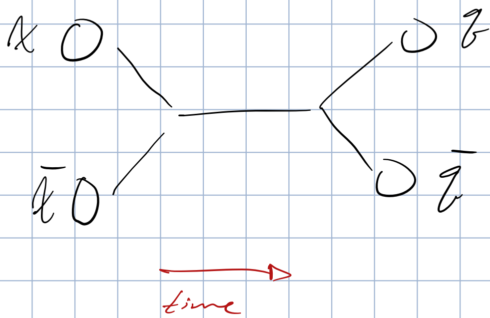
compton scattering $\sigma \sim \frac{\alpha^2}{m_e^2}$



annihilation $\sigma_{ann} \sim \frac{\alpha^2}{m_e^2}$

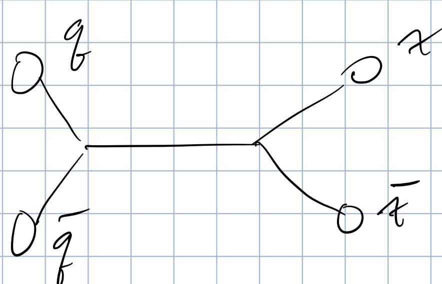


DM



annihilation

indirect detection

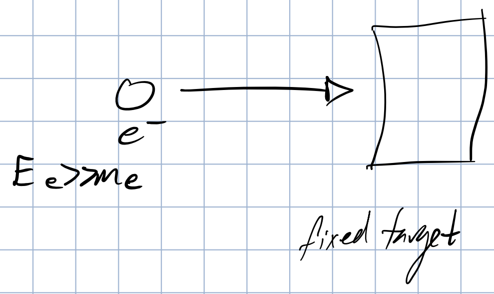


produce

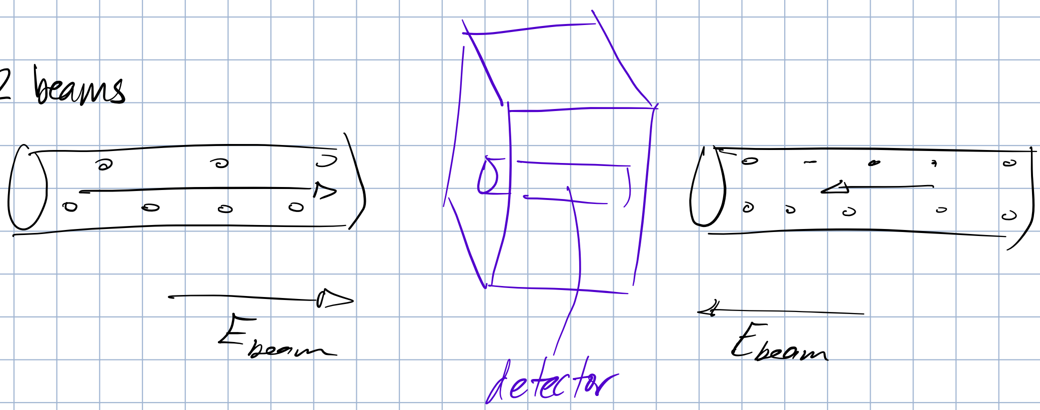
collider production

ok, so what about collider production?

accelerators $\Longrightarrow$ colliders



collider: 2 beams



$$E_{centermass} = E_{CM} = 2E_{beam}$$

LHC: $E_{CM} = 14$ TeV

$pp \to$ stuff (protons)

luminosity

number density in beam (n_{beam}) w/ length (l)

$$\mathcal{L} = n_{beam} \cdot \underbrace{V}_{\approx c = 0.999c}$$

$$[\mathcal{L}] = (\text{area})^{-1}(\text{time})^{-1}$$

$$N_{event} = \underbrace{\Delta t}_{\text{observation time}} \cdot \mathcal{L} \cdot \sigma_{event}$$

"integrated luminosity" $\left[\int \mathcal{L}\, dt\right] = [\text{area}]^{-1}$

can calculate σ_{event} for DM, but can't see it

need visible component, missing energy

LHC $\quad p\bar{p} \longrightarrow \chi\bar{\chi} + \gamma$

LEP $\quad e^+e^- \longrightarrow \underbrace{\chi\bar{\chi}}_{\not{E}} + \gamma$

distinguish from others like $\quad e^+e^- \longrightarrow \gamma + \underbrace{\nu\bar{\nu}}_{\not{E}}$