

① LHC

• ATLAS, CMS, LHCb, ALICE, LHCf, TOTEM, MoEDAL

① 1 ② 5 ③ 8 ④ 2 ⑤ 1 ⑥ 5 ⑦ 8

• Beam: Injection \rightarrow Ramp \rightarrow Squeeze \rightarrow STABLE \rightarrow Dump
 450 GeV \rightarrow 4 TeV $\beta^* \rightarrow 0.6\text{m}$ { Scheduled
accidental

• Bunch train: $26.658\text{km} / 24.95\text{ns} = 3564\text{ slots}$
 (filled: $\lesssim 2808$)

[2012 run: 49.90ns spacing, ≤ 1380 filled.]

• Instantaneous Lumi:

$$\begin{array}{lcl} \left\{ \begin{array}{l} \# \text{ bunches} \\ \text{intensity} \sim \beta^* \end{array} \right. & \begin{array}{l} 1380 \\ \sim 0.6\text{m} \end{array} & \begin{array}{l} [\text{nom: } 2808] \\ [\text{nom: } 0.55\text{m}] \end{array} \\ & \downarrow & \downarrow \\ & 7 \times 10^{33} / \text{cm}^2 \text{s} & 1 \times 10^{34} / \text{cm}^2 \text{s} \end{array}$$

* LHC filling scheme: "333 334 334 334" = $2808 / 3484 + 0 / 80$

$$333 = (216/270) \times 3 + (0/1) = 648/811$$

\downarrow

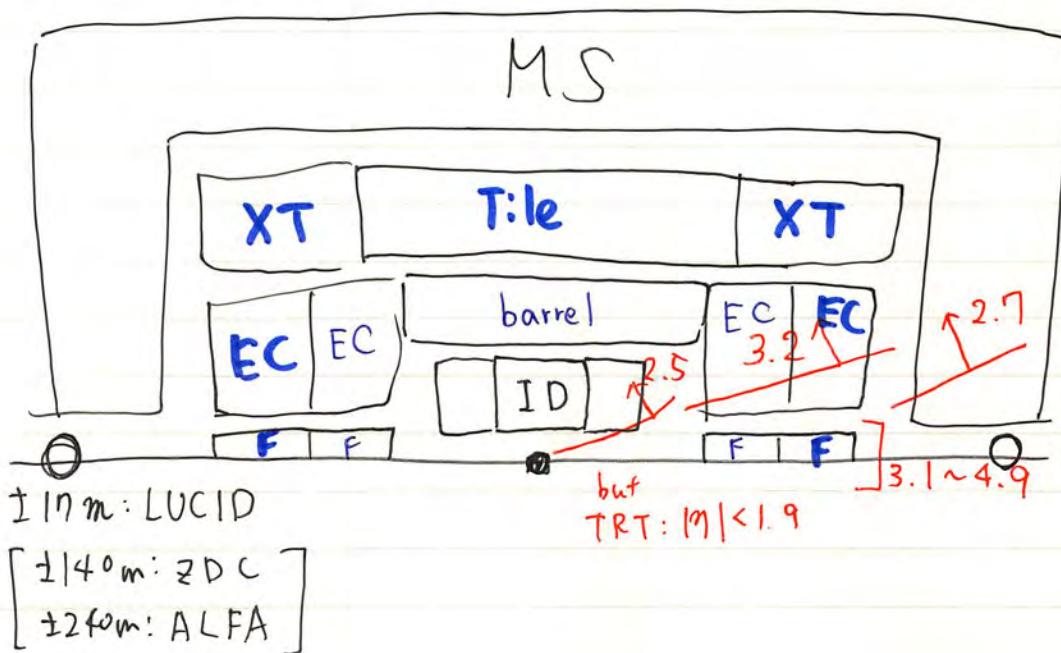
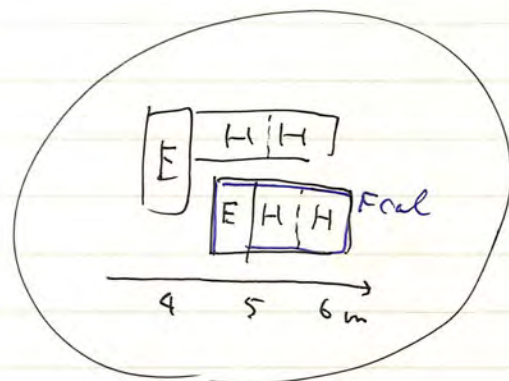
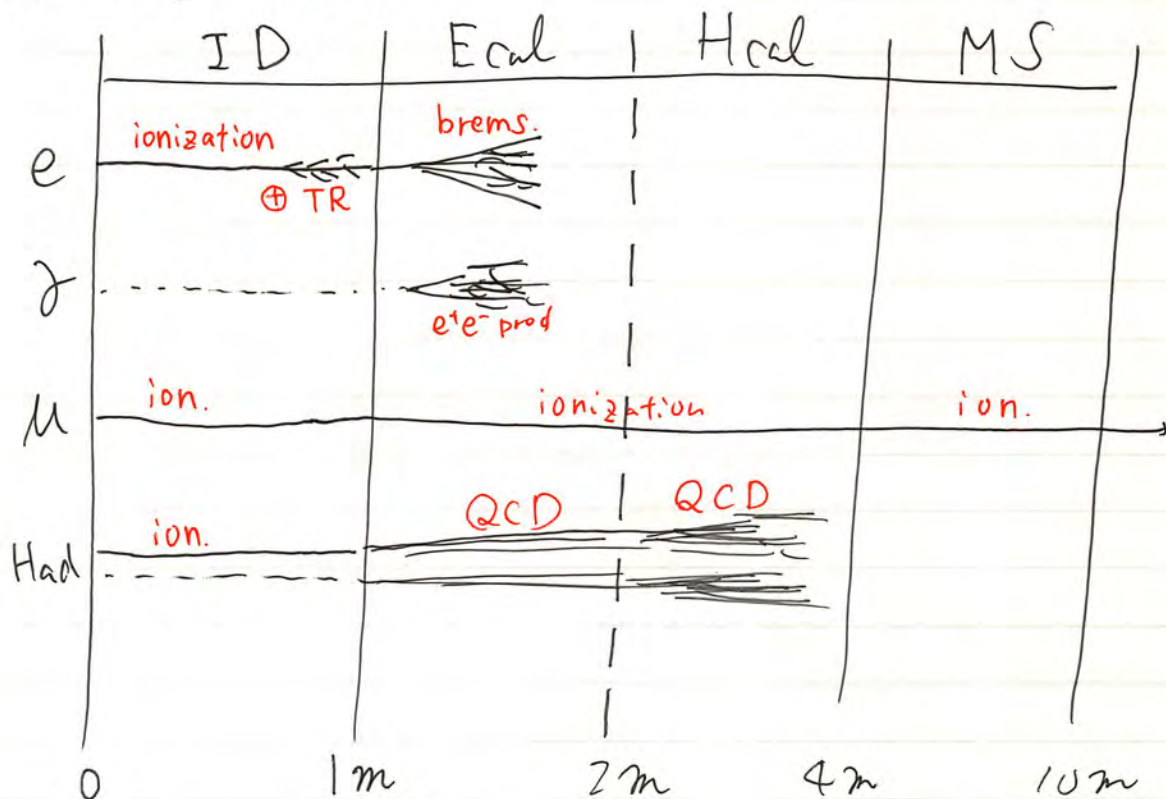
$$\overline{\text{nnnn}} = (\underline{72} + 8 + \underline{72} + 8 + \underline{72} + 8 + 30) = 270/216$$

sp: $\underline{72} + 12$

$$334 = 720/891$$

\downarrow
 3564
 2808
 filled

ATLAS Overview

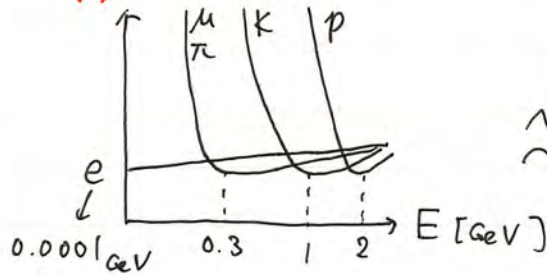


• Ionization

$$\frac{dE}{dx} = \frac{N_A Z}{A} \frac{4\pi Q^2 \alpha^2}{m} \left[\frac{1}{\beta^2} \ln \frac{2m\beta^2 \gamma^2}{I} - 1 \right]$$

P_e/P

$= \rho L$



I : Ionization Potential
 $\sim 2 \text{ MeV} / g \text{ cm}^2 \sim 16 Z^{0.9} \text{ eV}$

$$\sim 2 \text{ MeV} \cdot \rho \left[\frac{g}{\text{cm}^2} \right] L_{\text{cm}}$$

Minimum ionization

ex. 50 GeV μ -like particle

$$m = 0.1 \text{ GeV} \Rightarrow \beta \gamma \sim 0(100)$$

$$m = 100 \text{ eV} \Rightarrow \sim 0.5$$

• Bremsstrahlung

$$\frac{dE}{dx} = \frac{N_A}{A} \frac{4Z(Z+1)\alpha^3}{m^2} E \ln \frac{183}{Z^{1/3}} =: \frac{E}{X_0} \Rightarrow \text{RADIATION LENGTH}$$

ONLY for electrons
 (or μ with $E \gtrsim \text{TeV}$)

$$E(x) = E_0 e^{-x/X_0}$$

• Photon + material

- photoelectric $\sim \text{keV}$
 - Compton $\sim \text{MeV}$
 - e^+e^- prod. $> \text{MeV}$
- length $\sim X_0$ ($= \frac{9}{7} X_0$)

• Hadronic scattering

($\lambda_\pi > \lambda_{\text{Nuc}}$, but similar.)

$$\lambda = \frac{A}{\sigma N_A \rho}$$

$\sim \rho_{\text{Nucleus}}$

Total - Elastic - diffractive
 = inelastic = absorption

* ex. Fe 132.1

$$\lambda_{\text{inter.}} = \frac{132.1}{16.7} \text{ g/cm}^2 = 7.9 \text{ cm}$$

$$\lambda_{\text{total}} = 81.7 \text{ g/cm}^2 = 10.4 \text{ cm}$$

• Transition Radiation (vacuum \leftrightarrow medium)

$$I \sim \alpha Q^2 \gamma \omega_p / 3$$

plasma freq. $\omega_p \sim 0(10) \text{ eV}$

ATLAS calorimetry

ECAL Barrel LAr + Pb } 20-30 X_0 ($\sim 2\lambda_I$)
 EC " } ($\oplus 2-5X_0$ in front.)
 Forward LAr + Cu

HCAL Tile Scintille + Fe } 8-10 λ_I
 XT " } ($\oplus 2-3\lambda_I$ in front
 Forward LAr + W = ECAL etc.)

(FCAL: 0.5 λ in front $\oplus 2\lambda_I$ (EM)
 $\oplus 5\lambda_I$ (Had))

	X_0		λ_I NUCL
Pb	6.37 g/cm ² = 0.6 cm	199.6 g/cm ²	= 18 cm
Cu	12.86 = 1.4 cm	137.3	= 15 cm
Fe	13.84 = 1.8 cm	132.1	= 17 cm
W	6.76 = 0.4 cm	191.9	= 10 cm
(C _{graphite} 42.72 = 19.3 cm 85.8 = 38.8 cm)			

o ~~Energy Resolution (Test Beam 10-245 GeV electron)~~

• ATLAS calorimetry Energy Resolution

$$\frac{\sigma(E)}{E} = \frac{S^{(a)}}{\sqrt{E}} \oplus \frac{N^{(c)}}{E} \oplus C^{(b)}$$

(Statistical
particle $\propto E$)

 \nwarrow detector nonuniformity
calibration uncertainty

J/NST 3

• Test beam result (~~0.90 ± 0.05~~)

EM barrel: ~~S = 0.10 ± 0.01~~, ~~b = 0~~

S = 10.1%, C = 0.17% (e-beam, 10-180 GeV)

EC ~ similar

S = 10.0 ~ 12.5%, C = 0.6% (")

HEC: S = (10.6 ± 1.5)%, C = (5.8 ± 0.2)%

(π -beam, < 200 GeV)

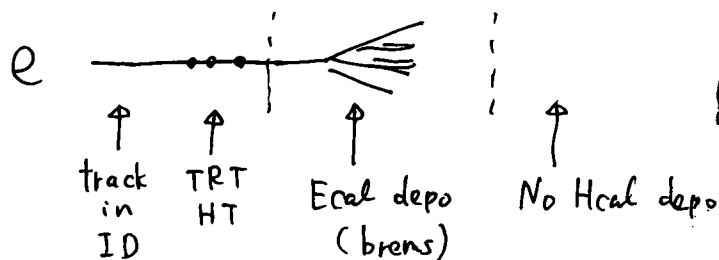
FCal_E: S = 28.5 ± 1.0%, C = 3.5 ± 0.1% (e-beam)

H: S = 94.2 ± 1.6%, C = 7.5 ± 0.4% (π -beam)

LAr+Tile / π -beam: ~~S = 0.520%~~

$$\frac{\sigma}{E} = \frac{0.520\%}{\sqrt{E}} \oplus \frac{1.5\%}{E} \oplus 3.02\%$$

Electron



• Reconstruction

- Ecal cluster

- loose matching to tracks

← Energy calibration
(Brms in ID etc...)

• Identification (criteria)

- loose : Calo only

- Ecal depo + little Hcal depo

↓ tightened

- medium: ⊕ SCT ⊕ Pixel

- # hits in ID

- track quality (do)

- track-cluster matching

↓ tightened

- tight : ⊕ TRT

- # hits, # HT hits in TRT

- Not converted (γ -veto)

$$\left(\begin{array}{l} \epsilon \sim 90\% / 80\% / 65\% \\ P_i \sim 500 / 2000 / 10^5 \end{array} \right)$$

- efficiency ?

$$C = \epsilon_{ev} \times \underbrace{\epsilon_{trig} \times \epsilon_{reco} \times \epsilon_{ID} \times \epsilon_{iso}}_{\text{Electron efficiency}}$$

- event quality
- must be triggered (esp. e-trigger)
- must be reconstructed
- must pass criteria
- avoid overlap-removal

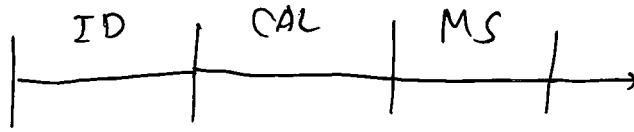
- tag & probe - method

e : tight criterion

e : • loose criterion
• opposite charge

↳ whether pass, or not? $\Rightarrow \epsilon_{ID}$
⊖ background (MC)

③ Muon



- ID track \oplus MS track.

* $|n| < 2.5$: ID coverage
(< 1.9 : TPT)

3 criteria

- Stand-Alone : ID only
- ② Combined : ID track \wedge MS track : successful combination
- Segment-Tagged : ID track \rightarrow MS track segment exists

2 algorithms :
Staco (Chain 1)
MuId (2)

$$\mathcal{E}^{CB} = \mathcal{E}_{ID} \times \mathcal{E}_{MS} \times \mathcal{E}_{match}$$