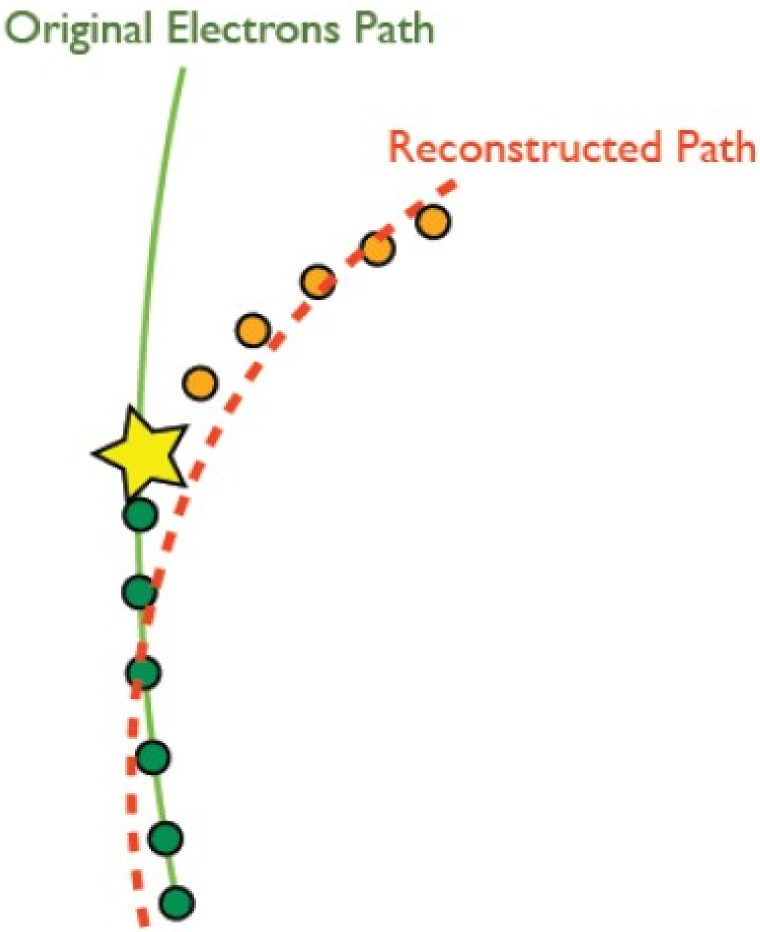
Brem electrons

Require "loose truth matching" for Monte Carlo

- If (el_origin == 12) isDirectMatch = true;
- If (el_origin == 12) ||

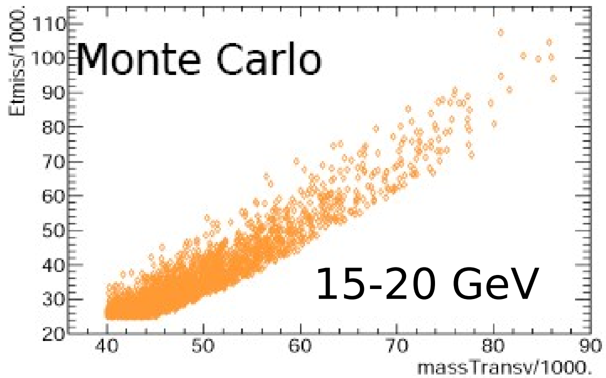
(el_type == 4 && el_originbkg == 40) ||

(el_type == 4 && el_originbkg == 12)) isLooseMatch = true;

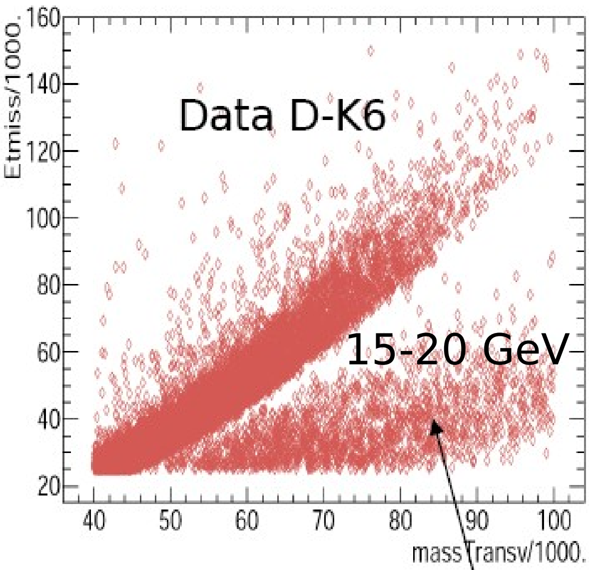


D-K6: final selection

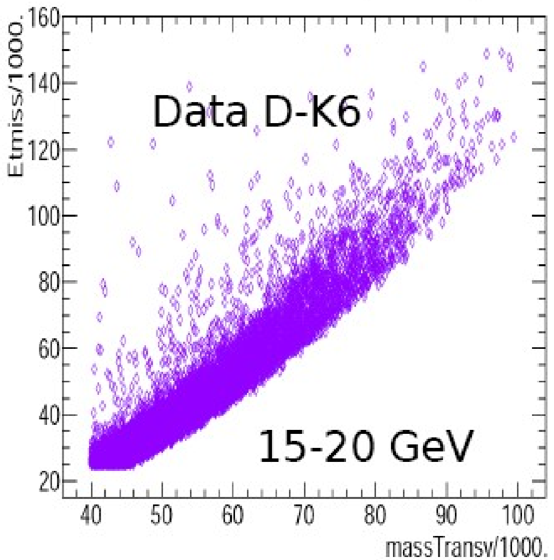
- Kinematical distribution spans esonable wide range, we can play with kinematical cuts



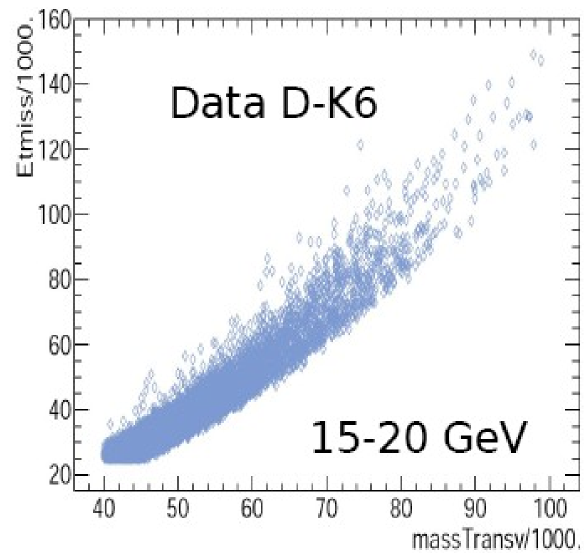
Baseline cut flow



+ track quality

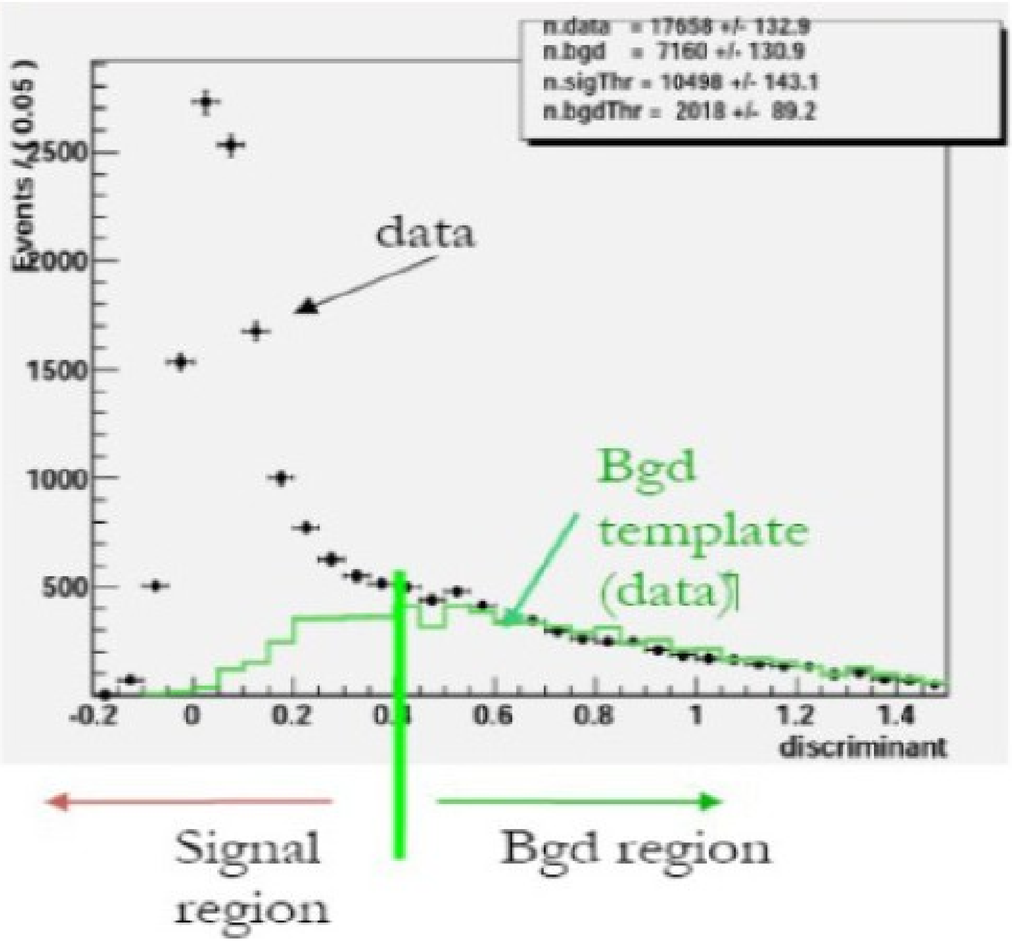


+ METisol > 2.0



Beam-halo bgd, suppressed by track quality

Simple subtraction method



IsEM bits

Used for tight
Used for medium
Used for loose

Bit number	Bit name
Bit 1	ConversionMatch
Bit 2	HadronicLeakage
Bit 4	ClusterMiddleEratio37
Bit 6	ClusterMiddleWidth
Bit 11	ClusterStripsWtot
Bit 15	ClusterStripsDEmaxs1
Bit 16	TrackBLayer
Bit 19	TrackA0
Bit 20	TrackMatchEta
Bit 21	TrackMatchPhi
Bit 22	TrackMatchEoverP
Bit 24	TrackTRThits
Bit 25	TrackTRTratio
Bit 26	TrackTRTratio90
Bit 27	TrackA0Tight
Bit 28	TrackMatchEtaTight
Bit 29	IsolationElectron
Bit 30	ClusterIsolationElectron
Bit 31	TrackIsolationElectron

LOOSE identification

Hadronic leakage	⋆ Ratio of E_T in the first layer of the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| < 0.8$ and $\|\eta\| > 1.37$) ⋆ Ratio of E_T in the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| > 0.8$ and $\|\eta\| < 1.37$)	R_{had1} R_{had}
Second layer of EM calorimeter	⋆ Ratio in η of cell energies in 3×7 versus 7×7 cells. ⋆ Lateral width of the shower.	R_η $w_{\eta 2}$

MEDIUM identification

Medium cuts (includes Loose)		
First layer of EM calorimeter.	⋆ Total shower width. ⋆ Ratio of the energy difference associated with the largest and second largest energy deposit over the sum of these energies	w_{stot} E_{ratio}
Track quality	⋆ Number of hits in the pixel detector (≥ 1). ⋆ Number of hits in the pixels and SCT (≥ 7). ⋆ Transverse impact parameter (<5 mm).	d_0
Track matching	⋆ $\Delta\eta$ between the cluster and the track (< 0.01).	$\Delta\eta_1$

TIGHT identification

Tight cuts (includes Medium)		
b-layer	⋆ Number of hits in the b-layer (≥ 1).	
Track matching	⋆ $\Delta\phi$ between the cluster and the track (< 0.02). ⋆ Ratio of the cluster energy to the track momentum ⋆ Tighter $\Delta\eta$ cut (< 0.005)	$\Delta\phi_2$ E/p $\Delta\eta_1$
Track quality	⋆ Tighter transverse impact parameter cut (<1 mm).	d_0
TRT	⋆ Total number of hits in the TRT. ⋆ Ratio of the number of high-threshold hits to the total number of hits in the TRT.	
Conversions	⋆ Electron candidates matching to reconstructed photon conversions are rejected	

Efficiency: simple counting

The simplest case is just counting the number N_0 of candidate events and the number N_p that pass a cut. The efficiency is then given by

$$\epsilon = \frac{N_p}{N_0}. \tag{1}$$

Since N_p and N_0 are correlated, using equation 1 with propagation of uncorrelated Poisson errors does not give the correct uncertainty on the efficiency. Usually, this is handled by noting that this is equivalent to a binomial problem with total events N_0 and a probability ϵ for each event to pass. The uncertainty on ϵ is then given by

$$(\Delta\epsilon)^2 = \frac{\epsilon(1-\epsilon)}{N_0}. \tag{2}$$

Efficiency: simple counting

An equivalent, alternative method is to consider the number N_p of events that pass and the number N_f that fail (see pages 46-48 of **Statistics for Nuclear and Particle Physicists** by Louis Lyons, Cambridge University Press, 1986). These two are uncorrelated and hence easier to use in error propagation. Note that in this approach, the total number of events $N_0 = N_p + N_f$ is not a fixed number, but is itself Poisson distributed. The efficiency is

$$\epsilon = \frac{N_p}{N_p + N_f}. \tag{3}$$

Standard error propagation then gives

$$\begin{aligned}
(\Delta\epsilon)^2 &= \left(\frac{\partial\epsilon}{\partial N_p}\right)^2 (\Delta N_p)^2 + \left(\frac{\partial\epsilon}{\partial N_f}\right)^2 (\Delta N_f)^2 && (4)\\
&= \left(\frac{N_f}{N_0^2}\right)^2 (\Delta N_p)^2 + \left(\frac{-N_p}{N_0^2}\right)^2 (\Delta N_f)^2 && (5)\\
&= \frac{(1-\epsilon)^2 N_p + \epsilon^2 N_f}{N_0^2} && (6)\\
&= \frac{\epsilon(1-\epsilon)}{N_0}. && (7)
\end{aligned}$$

Note that this is exactly the same result as obtained by considering it as a binomial problem, as it should be since they are equivalnet. The reason for considering the second method is that it is easier to extend to the cases considered below.

Efficiency: fits

Instead, suppose that the fit number that pass the cut is $N_p \pm \Delta N_p$ and the fit number that fail the cut is $N_f \pm \Delta N_f$. The efficiency is

$$\epsilon = \frac{N_p}{N_p + N_f}. \tag{8}$$

Standard error propagation gives

$$\begin{aligned}
(\Delta\epsilon)^2 &= \left(\frac{\partial\epsilon}{\partial N_p}\right)^2 (\Delta N_p)^2 + \left(\frac{\partial\epsilon}{\partial N_f}\right)^2 (\Delta N_f)^2 && (9)\\
&= \frac{(1-\epsilon)^2(\Delta N_p)^2 + \epsilon^2(\Delta N_f)^2}{N_0^2}, && (10)\\
& && (11)
\end{aligned}$$

where we assume $N_0 = N_p + N_f$ (which is not exactly true in each case since each of these numbers comes from a fit, but is a hopefully good approximation).

Efficiency: fits

Instead, suppose that the fit number that pass the cut is $N_p \pm \Delta N_p$ and the fit number that fail the cut is $N_f \pm \Delta N_f$. The efficiency is

$$\epsilon = \frac{N_p}{N_p + N_f}. \tag{8}$$

Standard error propagation gives

$$\begin{aligned}
(\Delta\epsilon)^2 &= \left(\frac{\partial\epsilon}{\partial N_p}\right)^2 (\Delta N_p)^2 + \left(\frac{\partial\epsilon}{\partial N_f}\right)^2 (\Delta N_f)^2 && (9)\\
&= \frac{(1-\epsilon)^2(\Delta N_p)^2 + \epsilon^2(\Delta N_f)^2}{N_0^2}, && (10)\\
& && (11)
\end{aligned}$$

where we assume $N_0 = N_p + N_f$ (which is not exactly true in each case since each of these numbers comes from a fit, but is a hopefully good approximation).

Efficiency: fits

If we also assume that $(\Delta N_0)^2 = (\Delta N_p)^2 + (\Delta N_f)^2$, then we can rewrite $(\Delta\epsilon)^2$ completely in terms of results of fits to the total number before the cut and the number that pass the cut, that is,

$$(\Delta\epsilon)^2 = \frac{(1-\epsilon)^2(\Delta N_p)^2 + \epsilon^2(\Delta N_f)^2}{N_0^2} \quad (12)$$

$$= \frac{(1-2\epsilon)(\Delta N_p)^2 + \epsilon^2((\Delta N_p)^2 + (\Delta N_f)^2)}{N_0^2} \quad (13)$$

$$= \frac{(1-2\epsilon)(\Delta N_p)^2 + \epsilon^2(\Delta N_0)^2}{N_0^2}. \quad (14)$$

Note that if we replace $(\Delta N_p)^2$ and $(\Delta N_0)^2$ by their Poisson values of N_p and N_0, respectively, we get back the usual binomial formula.

Efficiency: side-band subtraction

We define a signal region and a side band region. Let N_p and N_f, be the numbers of events in the signal region that pass and fail the cut, respectively. Let $N_{p,SB}$ and $N_{f,SB}$ be the corresponding numbers in the side bands. Define $N_0 = N_p + N_f$ and $N_{0,SB} = N_{p,SB} + N_{f,SB}$. We want to include the fact that the side bands may not have the same number of expected background events as the signal region by defining the ratio of expected events to be α, that is, if there are N_{SB} side band events, we expect αN_{SB} events in the signal region. In this derivation, it is assumed that α is the same before and after the cut. If this is not the case, the reader is left to extend the derivation.

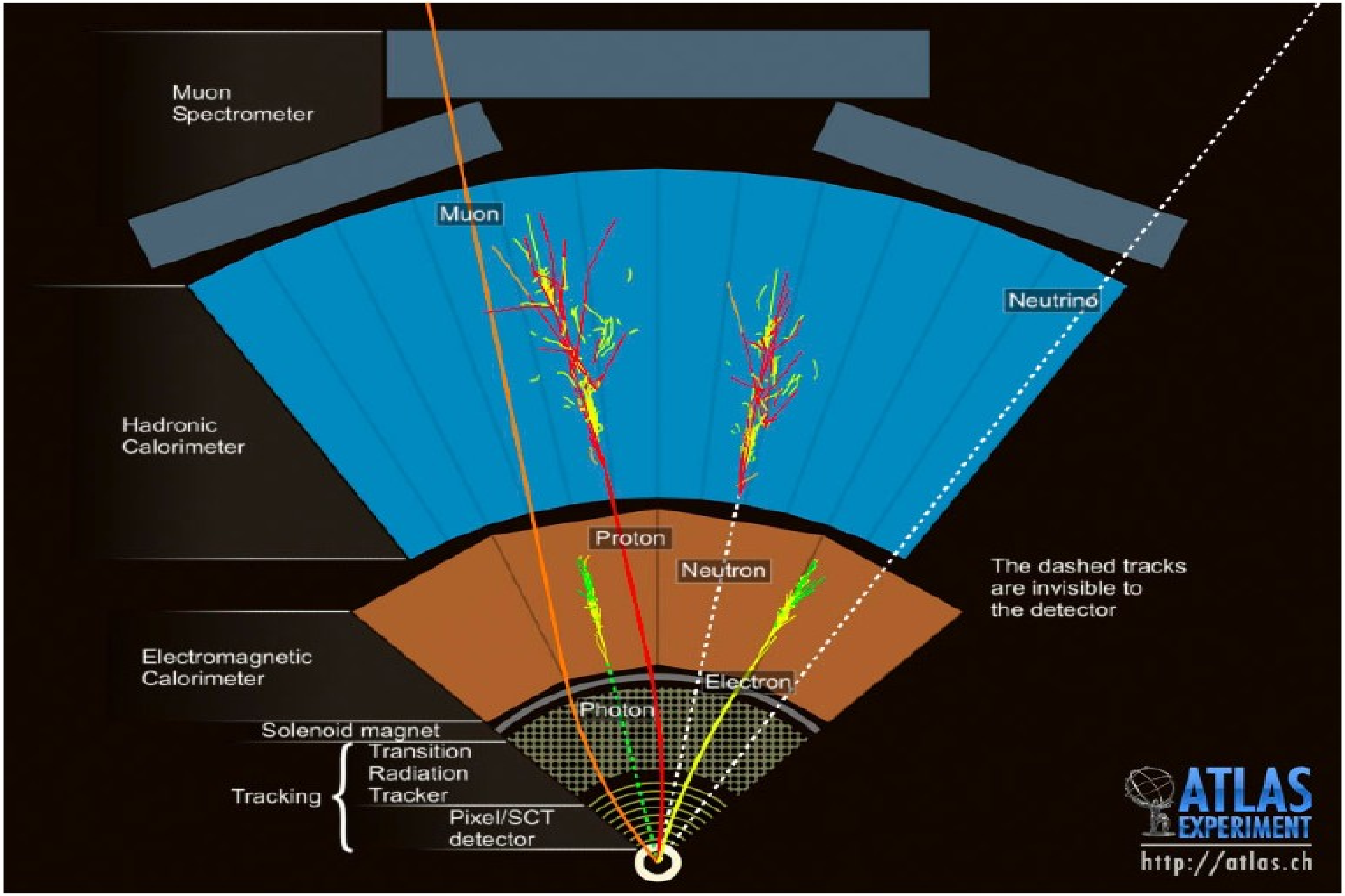
The efficiency is

$$\epsilon = \frac{N_p - \alpha N_{p,SB}}{N_p + N_f - \alpha(N_{p,SB} + N_{f,SB})} \tag{18}$$

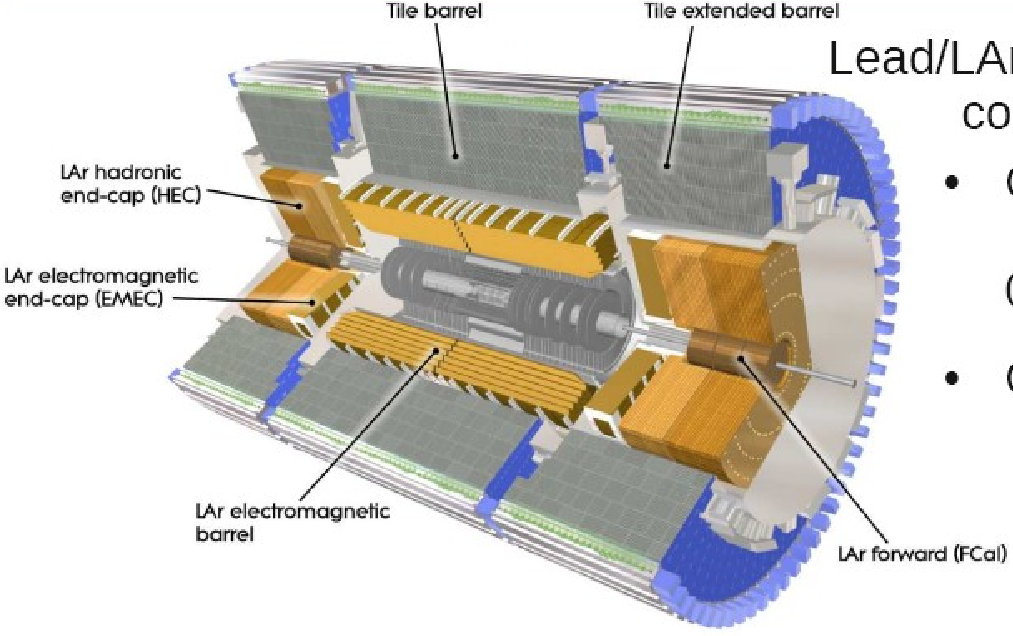
Standard propagation of errors gives

$$\begin{aligned}
(\Delta\epsilon)^2 &= \left(\frac{\partial\epsilon}{\partial N_p}\right)^2 (\Delta N_p)^2 + \left(\frac{\partial\epsilon}{\partial N_{p,SB}}\right)^2 (\Delta N_{p,SB})^2 + \\
&\quad \left(\frac{\partial\epsilon}{\partial N_f}\right)^2 (\Delta N_f)^2 + \left(\frac{\partial\epsilon}{\partial N_{f,SB}}\right)^2 (\Delta N_{f,SB})^2 && (19)\\
&= \frac{(1-\epsilon)^2((\Delta N_p)^2 + \alpha^2(\Delta N_{p,SB})^2) + \epsilon^2((\Delta N_f)^2 + \alpha^2(\Delta N_{f,SB})^2)}{(N_0 - \alpha N_{0,SB})^2} && (20)\\
&= \left[(1-2\epsilon)((\Delta N_p)^2 + \alpha^2(\Delta N_{p,SB})^2) + \epsilon^2((\Delta N_p)^2 + (\Delta N_f)^2) + \right. \\
&\quad \left. \epsilon^2\alpha^2((\Delta N_{p,SB})^2 + (\Delta N_{f,SB})^2)\right] / (N_0 - \alpha N_{0,SB})^2 && (21)\\
&= \frac{(1-2\epsilon)(N_p + \alpha^2 N_{p,SB}) + \epsilon^2(N_0 + \alpha^2 N_{0,SB})}{(N_0 - \alpha N_{0,SB})^2}, && (22)
\end{aligned}$$

Particle identification

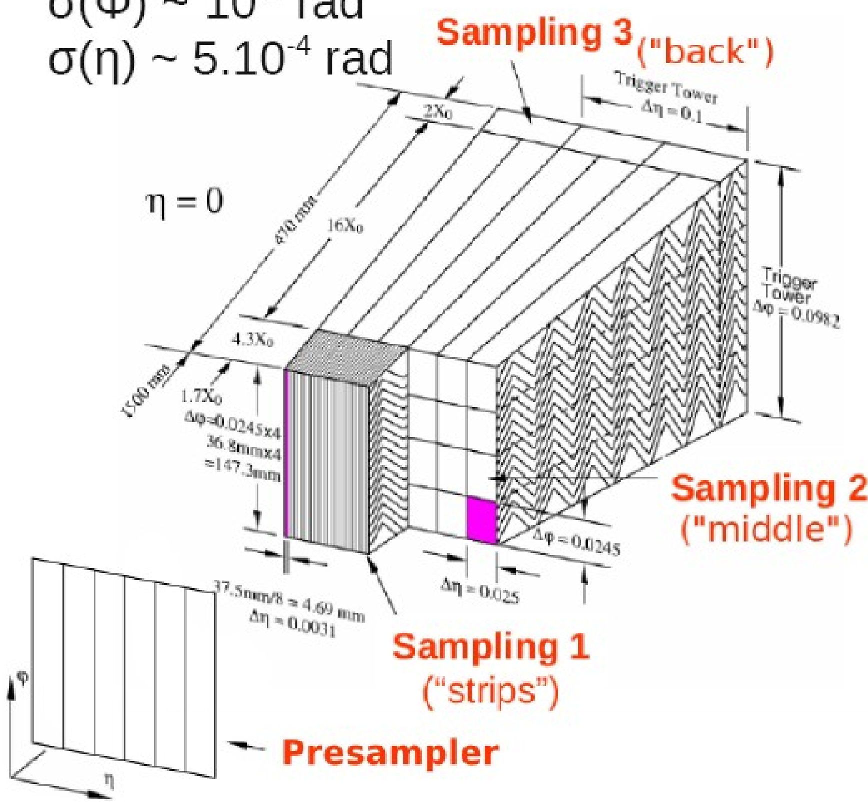


The ATLAS electromagnetic calorimeter



Lead/LAr EM calorimeter divided in 3 longitudinal compartments + Pre-sampler in front

- Good energy resolution :
  $\sigma(E)/E = a/E \oplus b/\sqrt{E} \oplus c$ (with a ~ 0.3 GeV, b ~ 10%, c ~ 0.7%)
- Good angular resolution :
  $\sigma(\Phi) \sim 10^{-3}$ rad
  $\sigma(\eta) \sim 5.10^{-4}$ rad



Layer	Granularity Δη x Δφ	Radiation length
Pre-sampler	0.025 x 0.1	
Strips	0.003 x 0.1	$4.3\ X_0$
Middle	0.025 x 0.025	$16\ X_0$
Back	0.05 x 0.025	$2\ X_0$

The ATLAS Inner Detector

- Hits in Pixel and Silicon detectors
- High and low threhold hits in TRT detector