Update on Photon Identification Methods

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Introduction / Motivation

- Discriminate photons from other (neutral) particles (e.g. neutrons and pions)
  - important for calibration, measurements and searches (e.g. H→4e, H→γγ)
  - test method with CALICE simulation and data
- ATLAS group “electron/photon identification & reconstruction” counts about 20 members
- Results in this presentation are preliminary:
  - still some simplifications
  - work in progress

Longitudinal Shower Shape

- Longitudinal shower shape of electromagnetic cascades

$$f(E,t)=\frac{(bt)^{a-1}e^{-bt}}{\Gamma(a)}$$

– shape normalised to unit area
– t depth in rad. Length
– a,b weakly energy dependent

for 1 to 100 GeV

- Parameters a,b are related to moments of t:

$$\langle t^n\rangle=\int_0^\infty t^n f(E,t)\,dt$$

$$\langle t\rangle=\frac{a}{b} \qquad \langle t^2\rangle=\frac{a^2+a}{b^2}$$

permits robust estimation of profile parameters

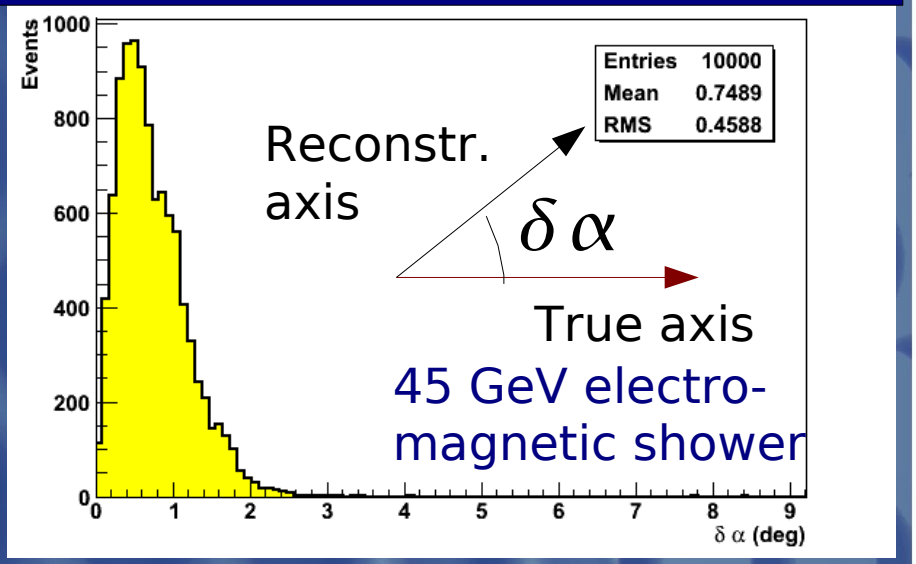
Shower Axis / Tensor of Inertia

- Tensor of inertia

$$I = \sum e_k \begin{pmatrix} y_k^2 + z_k^2 & -x_k y_k & -x_k z_k \\ -x_k y_k & x_k^2 + z_k^2 & -y_k z_k \\ -x_k z_k & -y_k z_k & x_k^2 + y_k^2 \end{pmatrix}$$

(→ my talk @ UTA)

Space angle between reconstructed and true shower direction



non Gaussian: $f(\theta, \phi)\, d\Omega$

- Eigenvector with smallest eigenvalue yields shower axis
- Eigenvalues also useful for particle classification

The Algorithm ...

- Clustering to collect signal hits
- Calculate tensor of inertia and shower axis
- Compute parameters a, b and quality estimator
- Classification based on selected parameters

… and Some Simplifications

- Clustering to collect signal hits
  – include all hits in the calorimeter prototype
- Calculate tensor of inertia and shower axis
  – normally incident beams only
- Compute parameters a, b and quality estimator
  – radiation depth calculation includes only tungsten
  – simple 1:2:3 sampling fraction scheme
- Classification based on selected parameters
  – evaluate with electron / neutron, pion samples

Simulation

- Si-W ECAL simulation based on Mokka

- Signal electromagnetic showers induced by electrons
  Energy fixed at 30 GeV
- Background neutrons
  Energies {5,10,15,20,30,40} GeV
- Background pions
  Energies {5,10,15,20,30,*40} GeV *missing

More samples in preparation...

Variables Used in Classification

- Longitudinal shower profile parameters from statistical computation: a, b
- Longitudinal shape quality:

$$\chi^2 = \sum_k \left(f(a,b)_k - f_k\right)^2 \qquad f_k = \frac{E_{depth(k)}}{E_{tot}}$$

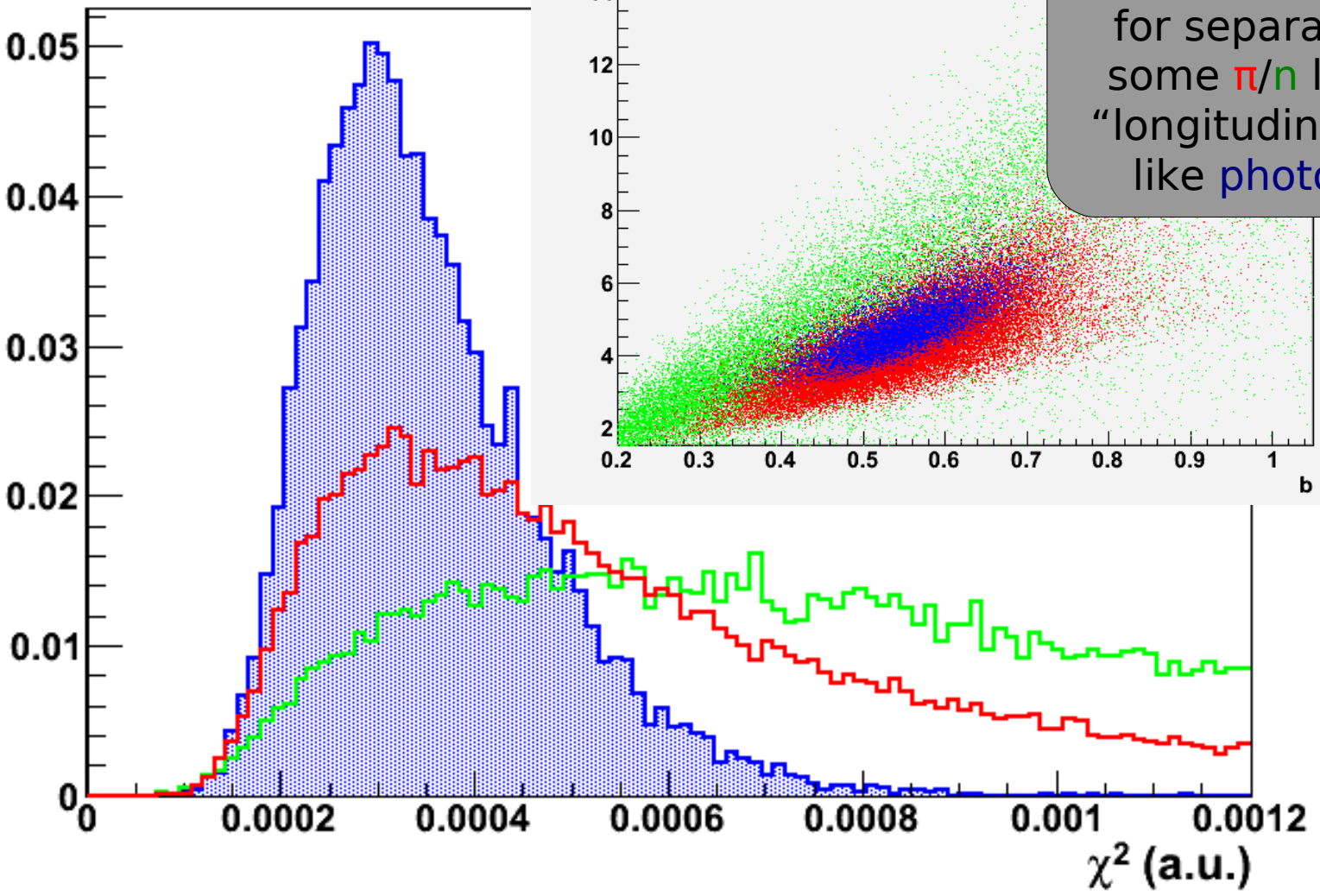
- Tensor of Inertia:

:

$$e = \sqrt{e_1^2 + e_2^2}/e_3$$

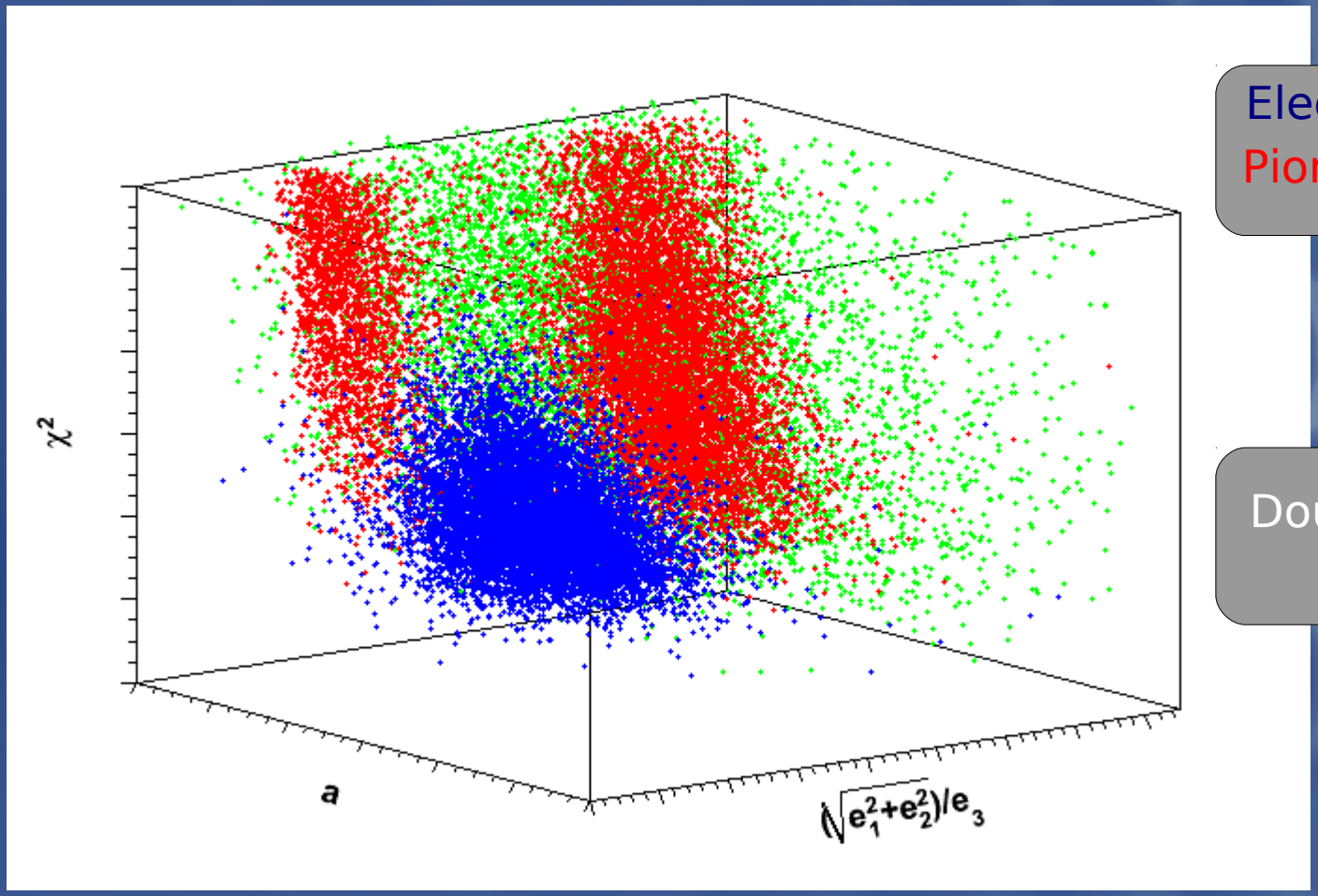
- In total four input parameters used for classification

Profile Parameters a,b and χ^2



a,b insufficient for separation some π/n look "longitudinally" like photons

Signal / Background Separation



Electrons/photons
Pions Neutrons

Double structure for pions?

- Efficient separation when including $e = \sqrt{e_1^2 + e_2^2}/e_3$

Particle Classification

- Use general method for classification!

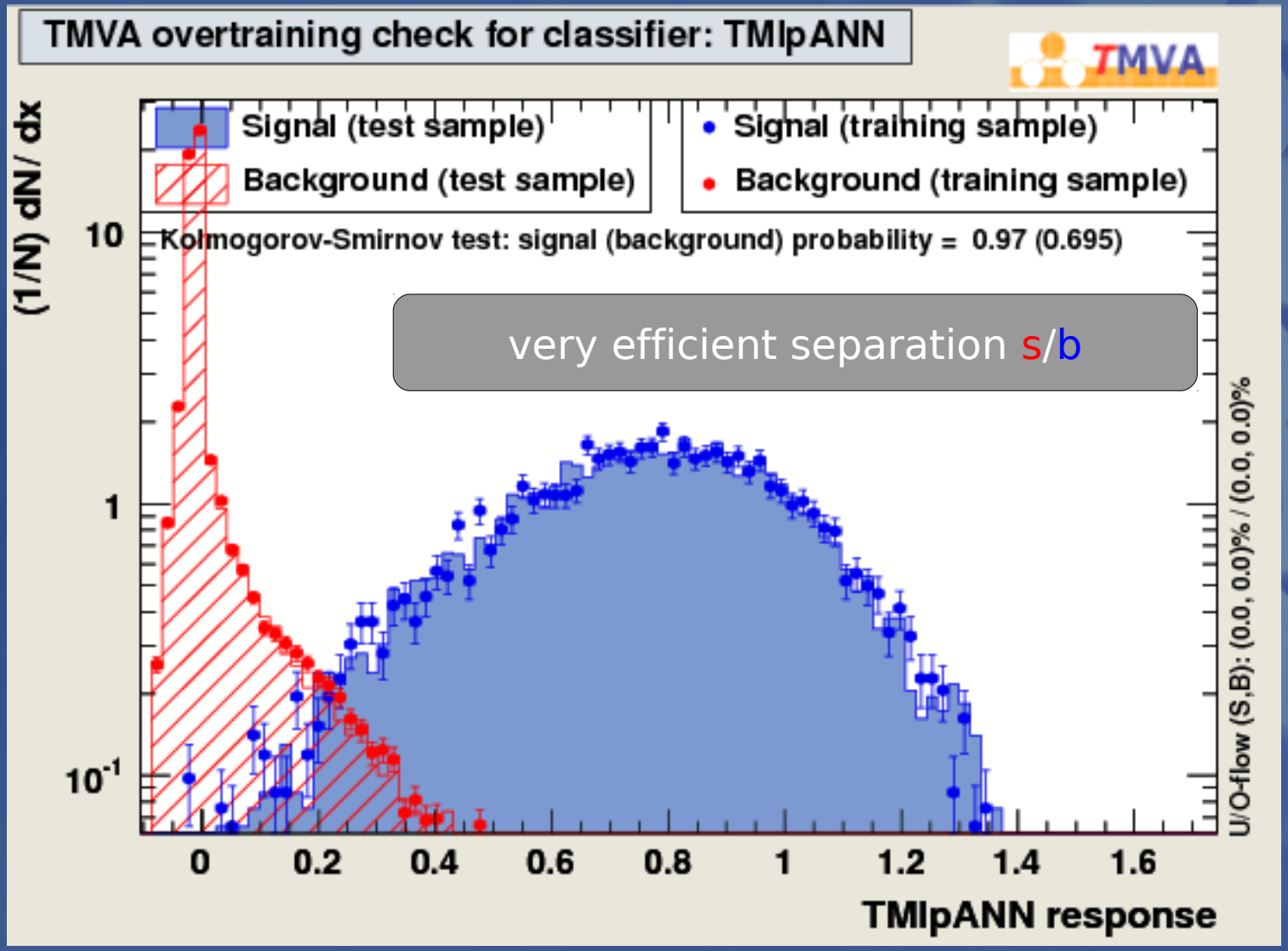
  Toolkit for Multivariate Data Analysis with ROOT (TMVA)
  - version 4.0.3 from http://tmva.sourceforge.net
  - offers a wide choice of algorithms

- Most effective method in this case:

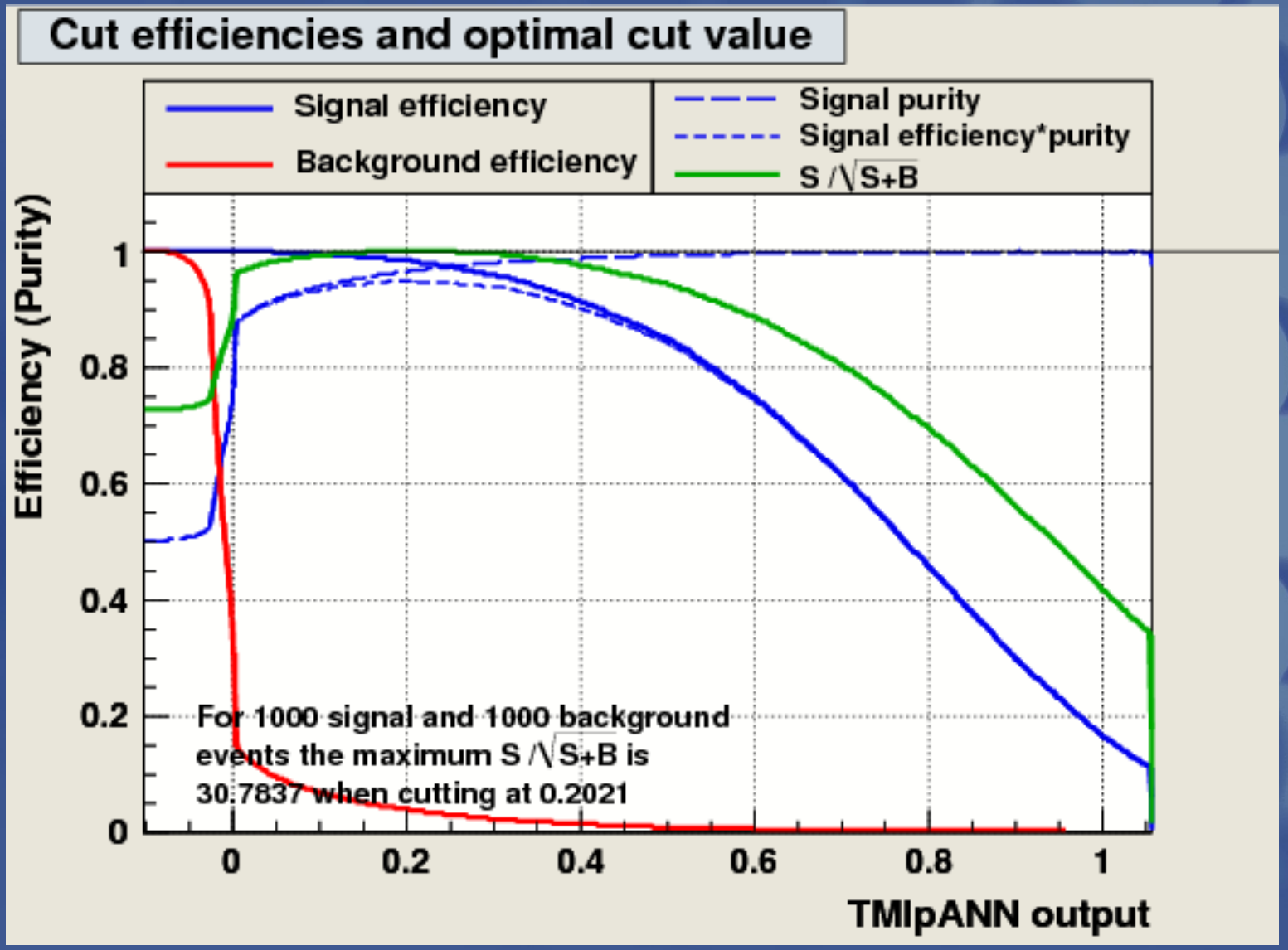
  Artificial Neural Network (TMlpANN)

  Still no extensive tuning of input parameter nor classification options, some more systematic checks (stability, etc.) necessary ...

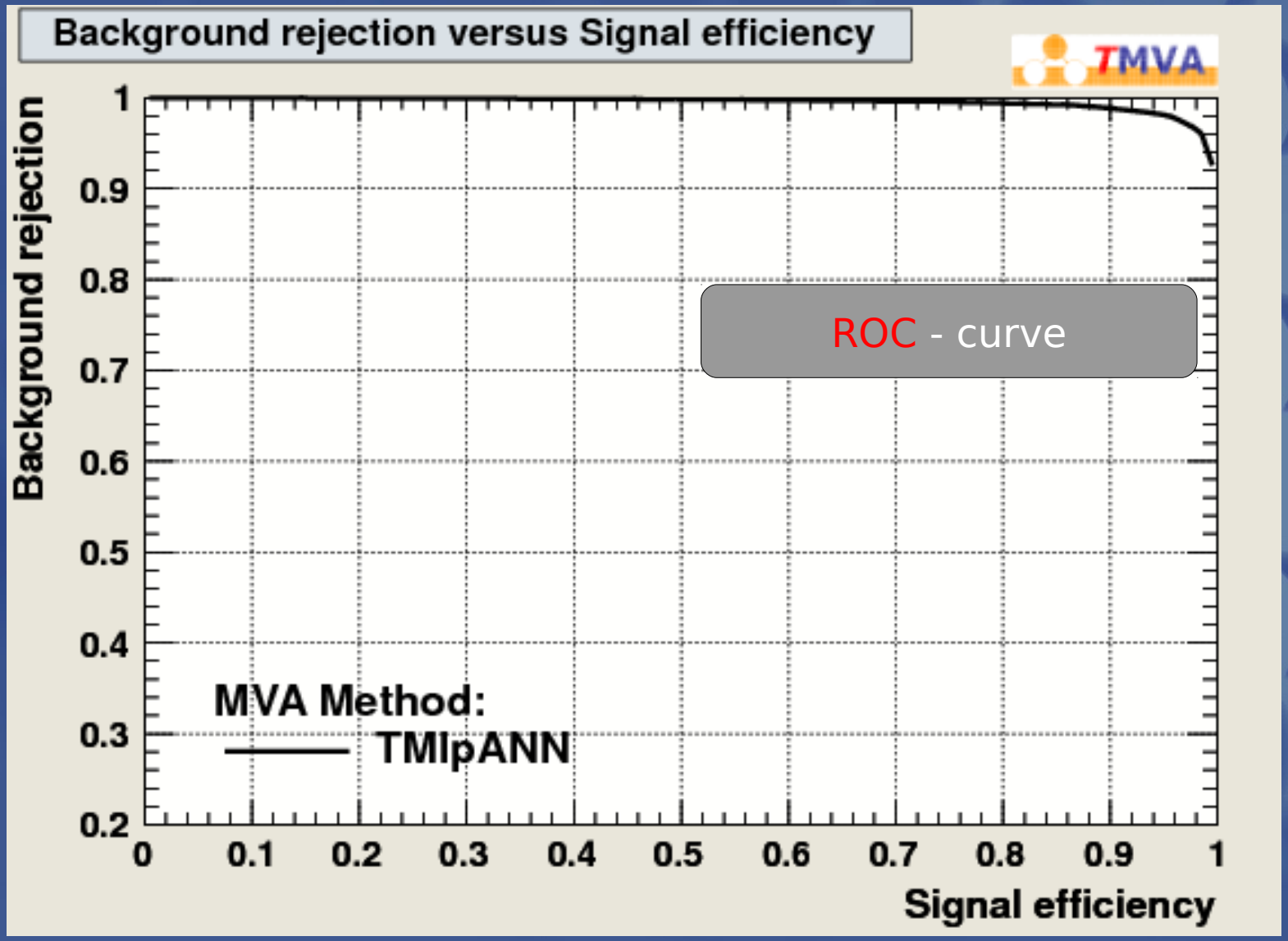
Classifier Distribution



Selection Efficiency and Purity



Receiver Operation Characteristic



Summary / Outlook

- Longitudinal shower profile parameters and tensor of inertia provide input parameters for neural network
- Promising classification results

- Next steps:
  - use clustering algorithm for collection of signal hits to tag photons in presence of background
  - use precise radiation depths and energy dependent sampling fractions
  - compare with test beam data (→ my talk at UTA)

  … write an analysis note/paper on photon ID