Student Lecture

MET + Jet(s) Dark Matter Search
and Other Things You Always Wanted to Know

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Winter Term 2016/2017

Heidelberg

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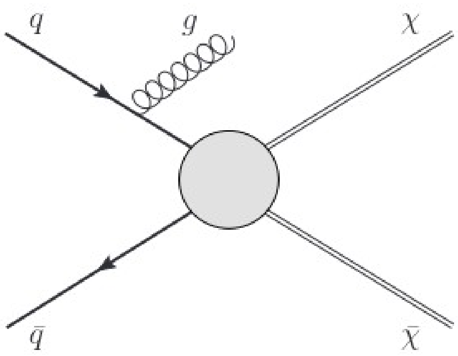
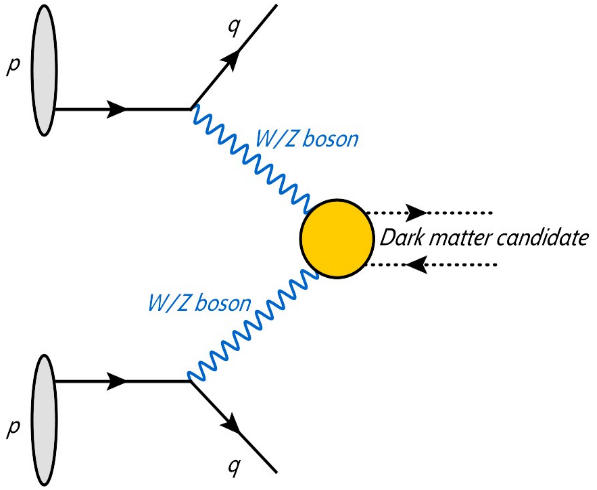
Motivation

- My PhD topic: search for Dark Matter with the ATLAS detector at the LHC





- General signature: MET, some jets, kinematic cuts

What We Want the Search to Be

- Precise
  - Good understanding and treatment of backgrounds
- Have a great reach / be as useful as possible
  - (DM) model independant
  - Results that are easy to use by theorists

What This Is About

1. Experimental Particle Physics is Messy!

   Reconstruction and Identification of Tau Leptons

2. A Very Short Introduction to Unfolding

3. Searching for Dark Matter with ATLAS

Introduction

- Searching for new phyics challenging because of finity of experimental setup
  - Limited statistics
  - Limited energy
  - Finite resolution
  - Fitine acceptance
  - ...

Introduction

- Consequences:
  - Particle „loss“
  - Particle identification and „fakes“
    - τ leptons (← messiest lepton)

Introduction

- Taus often not even considered a lepton in particle physics lingo

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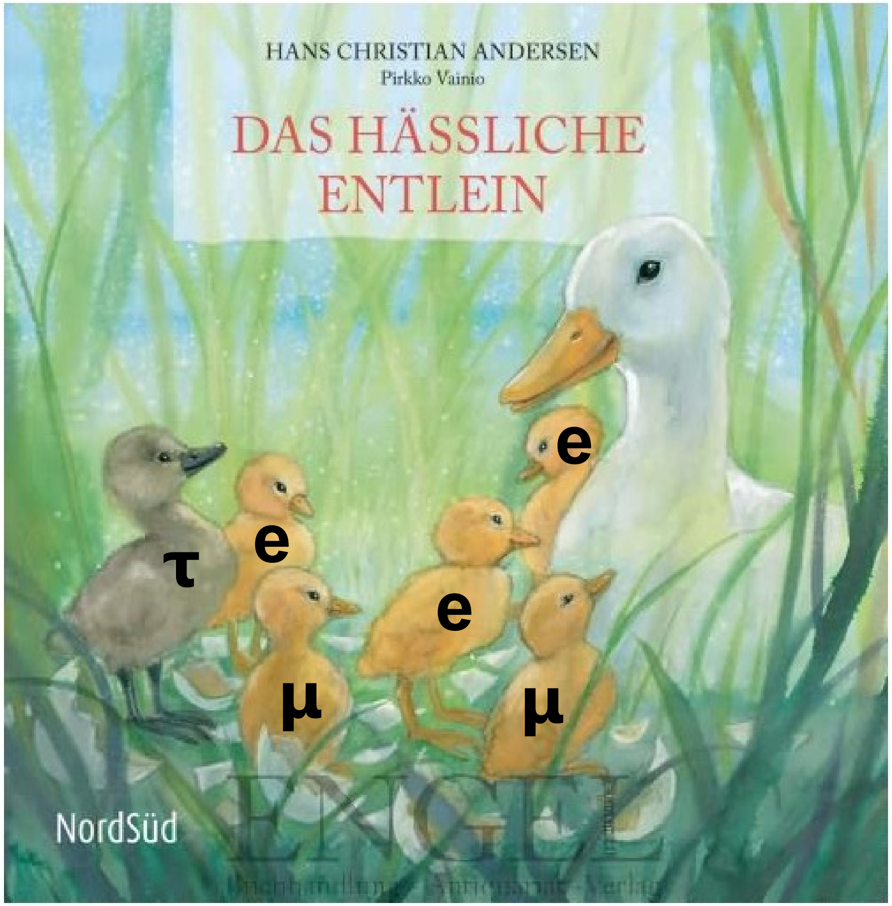
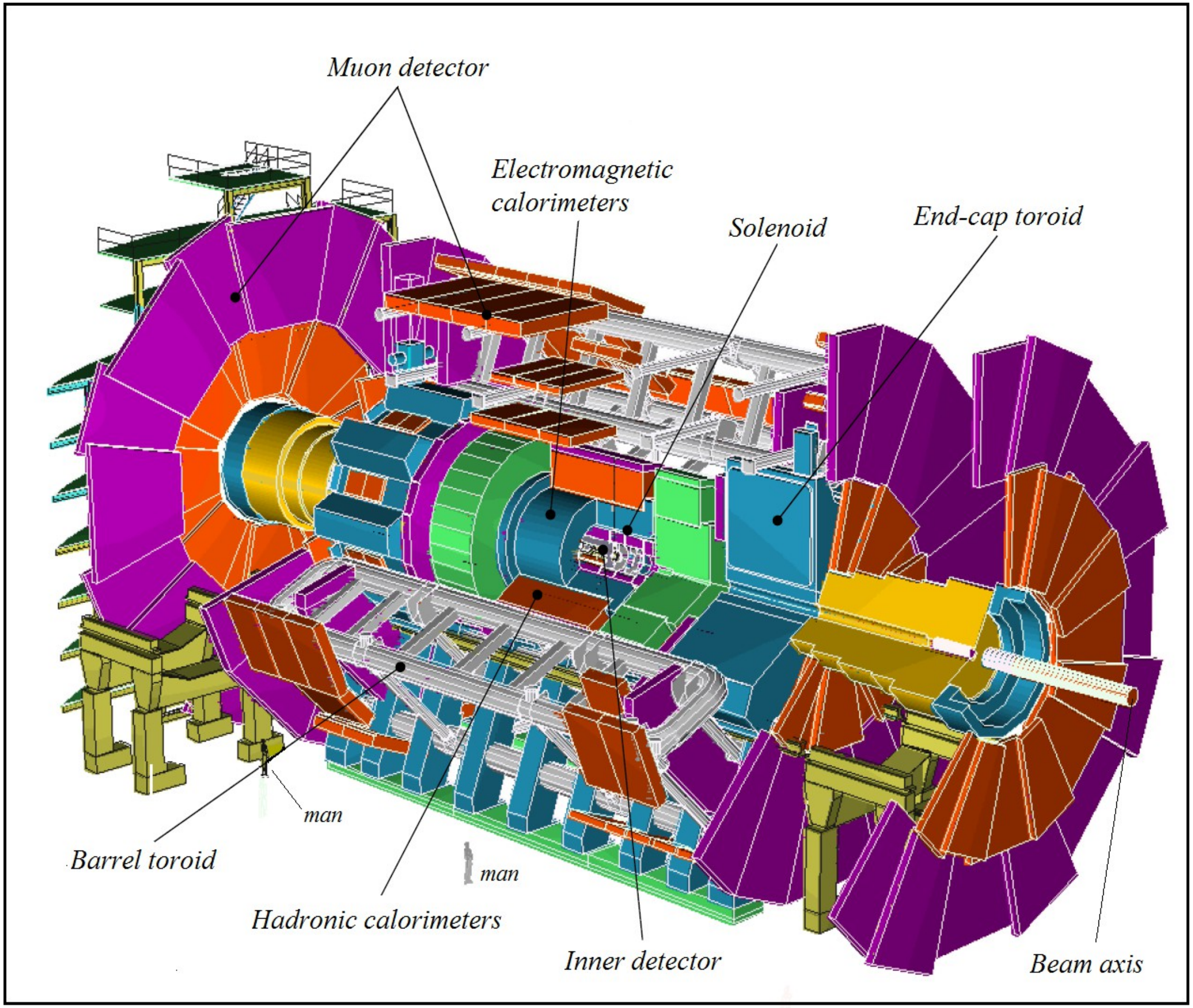
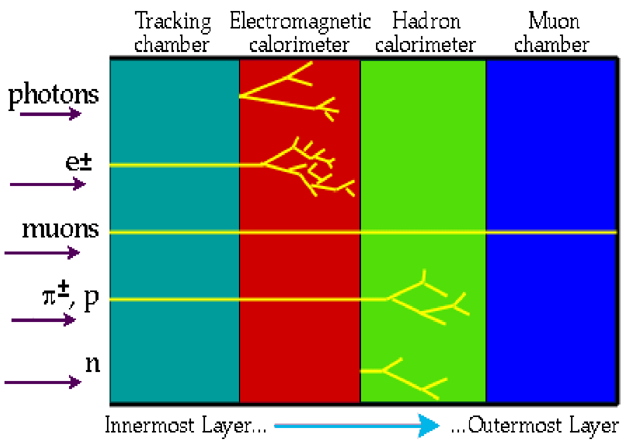
Introduction

- Taus often not even considered a lepton in particle physics lingo
- The „ugly duckling“ of the particle zoo



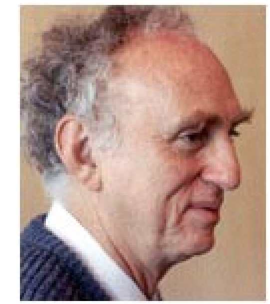
A Quick Reminder





→ Reconstruction, identification, fakes, inefficiencies all depend on properties of your detector

Tau Leptons


Martin Lewis Perl

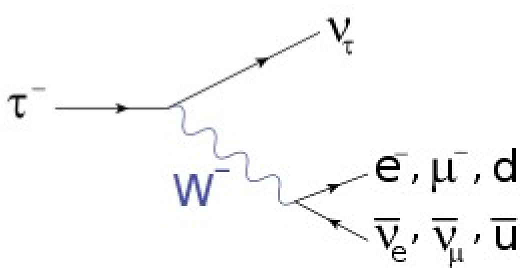
- 3rd generation lepton
- M_τ = 1.78 GeV ↔ 87μm decay length
- Discovered between 1974-1977 at SLAC

We have discovered 64 events of the form

$$e^+ + e^- \rightarrow e^\pm + \mu^\mp + \text{at least two undetected particles}$$

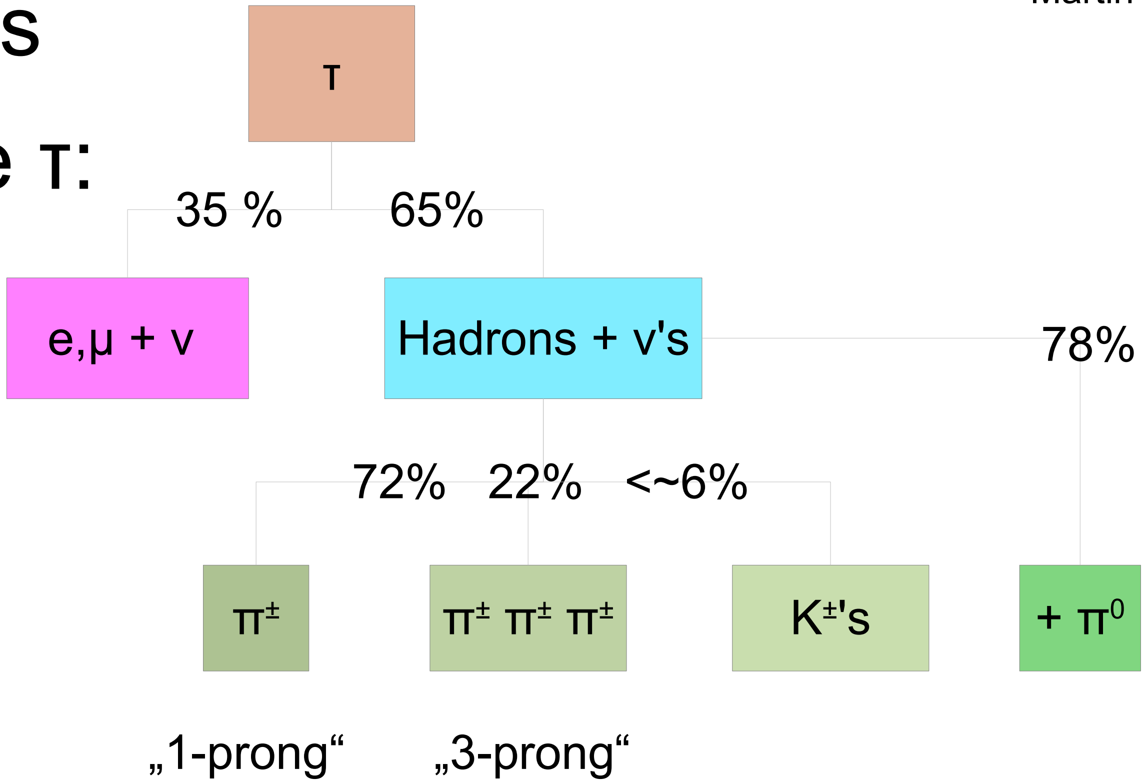
for which we have no conventional explanation.

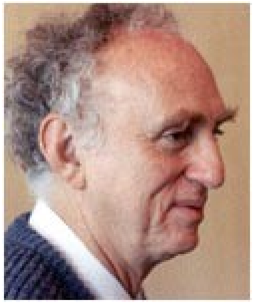
- $e^+ + e^- \longrightarrow \tau^+ + \tau^- \longrightarrow e^\pm + \mu^\mp + 4\nu$



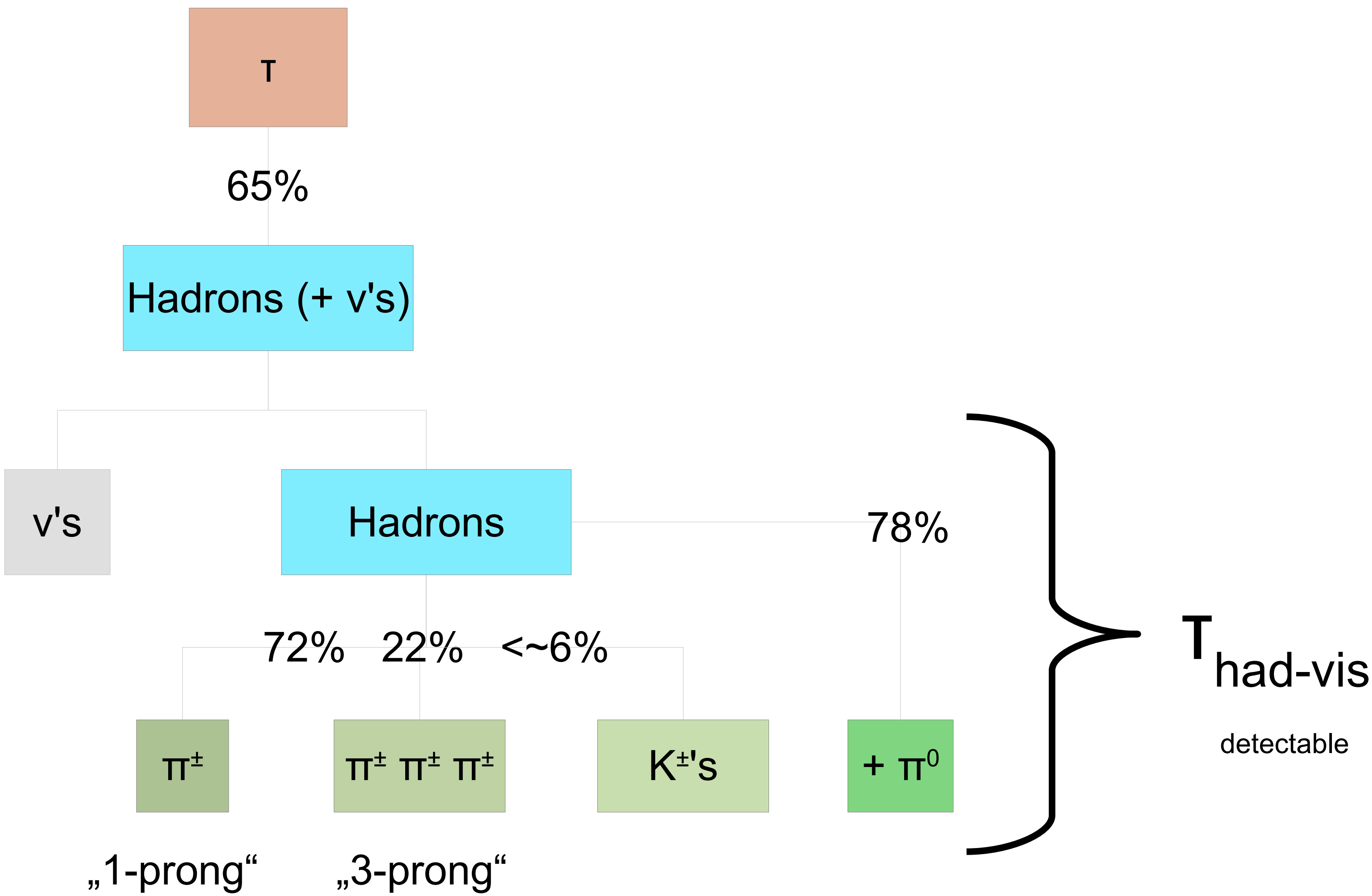
Tau Leptons II

- Nobel prize in 1995
- SPEAR and DESY measured spin and mass
- Decays of the τ:

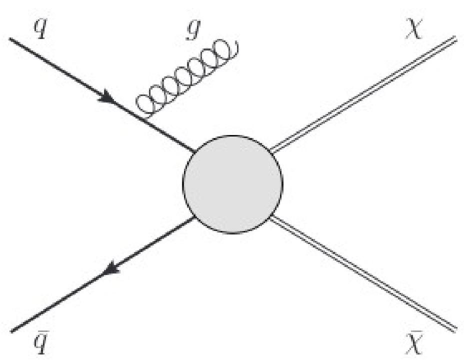


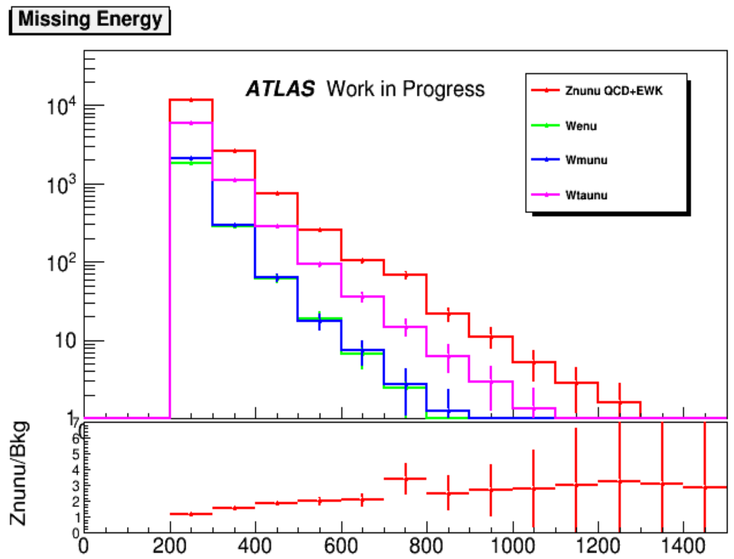


Martin Lewis Perl

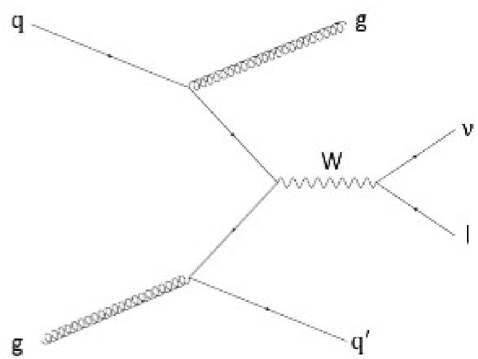

τ
65%
Hadrons (+ ν's)
ν's
Hadrons
78%
72%
22%
<~6%
π±
π± π± π±
K±'s
+ π0
„1-prong“
„3-prong“
τhad-vis
detectable

The Context





- MET > 200 GeV
- At least one jet
- Veto all leptons
  - Leptons can be out of acceptance or fake jets!
  - e,μ vetoes take care of ~35% of τ's
  - Concern is the remaining 65%



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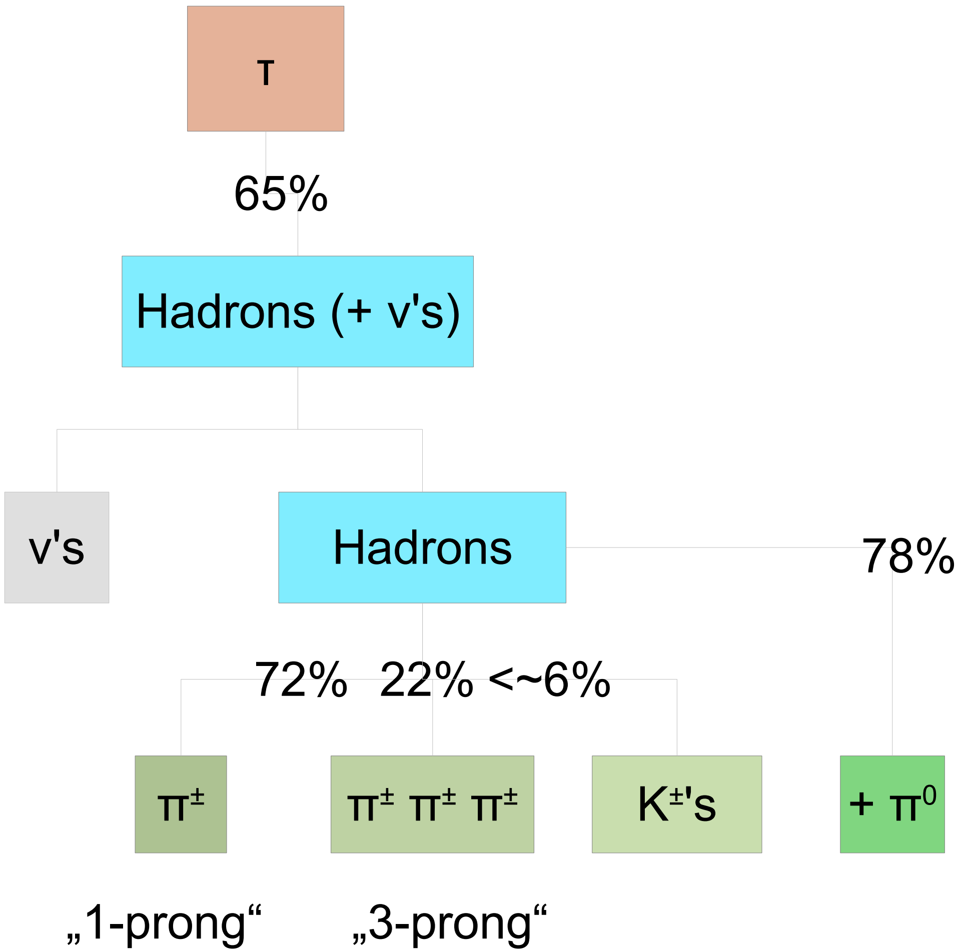
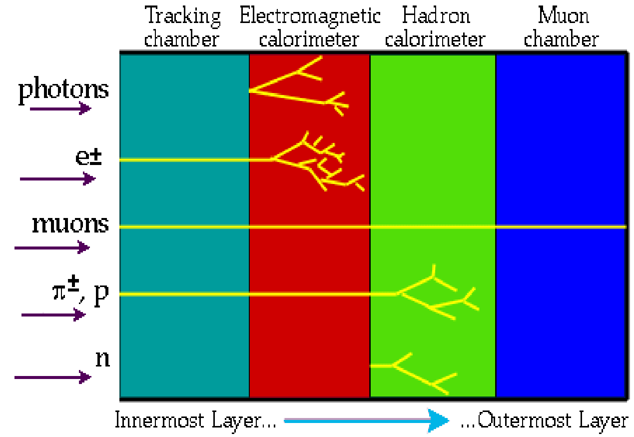
Tau Identification





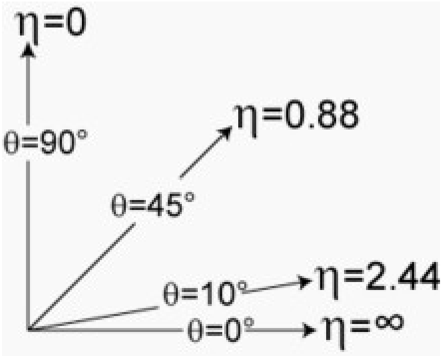
Seems straight forward, but:

- Efficiencies and acceptance finite
- Other particles might mimic signatures:
  - Jets
  - Electrons
  - Muons

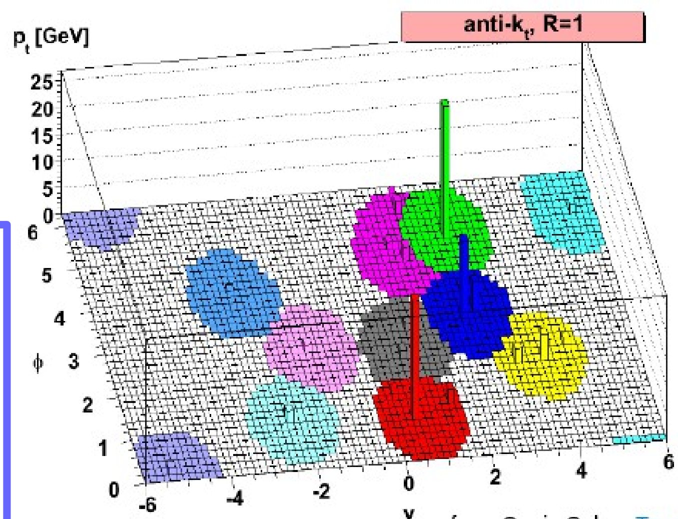
→ 2-step process:

- Reconstruct tau lepton candidates
- Discriminate them from other particles

Reconstruction



- Charged particles → tracking → $|\eta| < 2.5$
- Hadronic showers → clustering algorithm
  - Narrow: R = 0.4
  - p_T comes from $\Delta R = 0.2$



from Gavin Salam Towards Jetographie

- Tau candidate:
  - Hadronic jet with R = 0.4
  - Within $|\eta| < 2.5$*
  - With $p_T > 20$ GeV in $\Delta R = 0.2$

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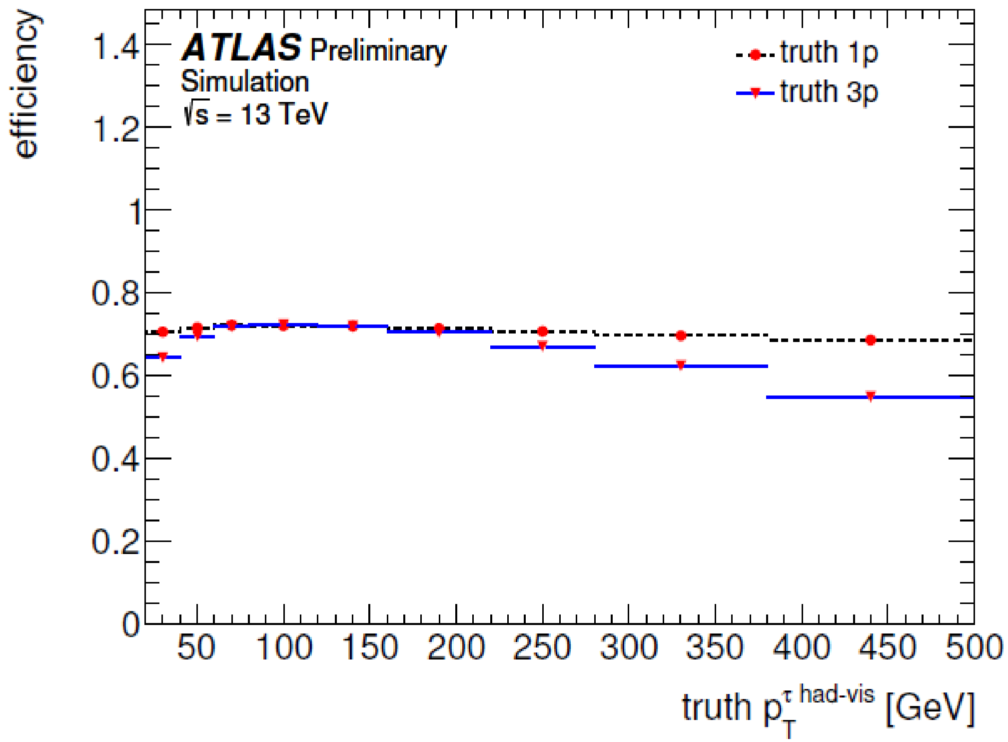
* crack region excluded

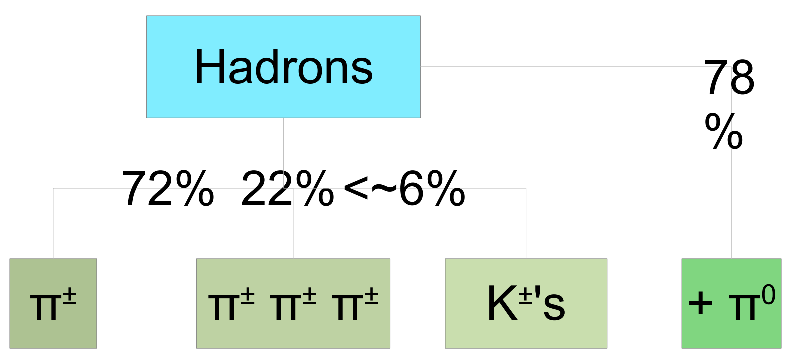
Reconstruction

- Reconstruction efficiency
  - # of 1-prong hadronic taus that are reconstructed as tau candidates with exactly one track
  - # of 3-prong hadronic taus that are reconstructed as tau candidates with exactly three tracks



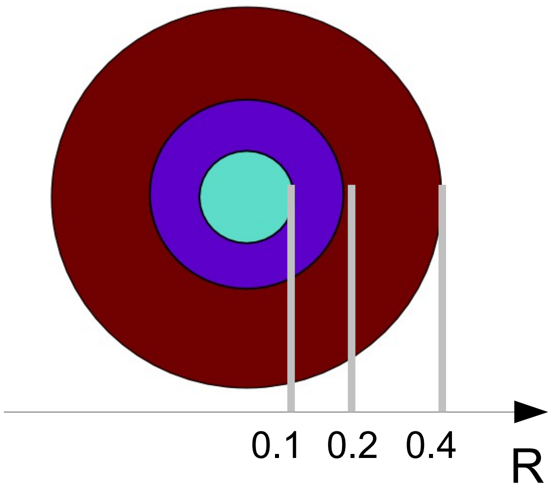
Discrimination Against q/g Jets

- Tau jets have distinct number of tracks
- Tau jets decay generally more in more collimated and democratic way
- (Vertexing)
- Discrimination performed by BDT
- Will introduce some input variables (4/12)
- This is why tau candidate definition is R = 0.4 and not R = 0.2



Discrimination Against q/g Jets

$$f_{cent} = E_T(R=0.1)/E_T(R=0.2)$$



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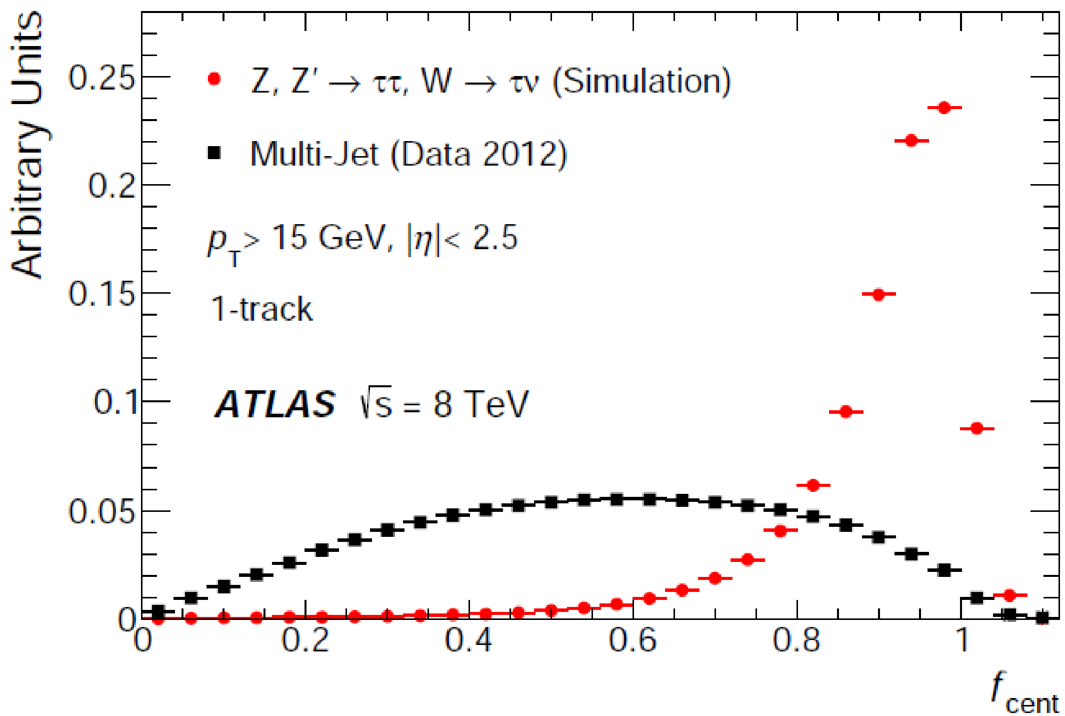

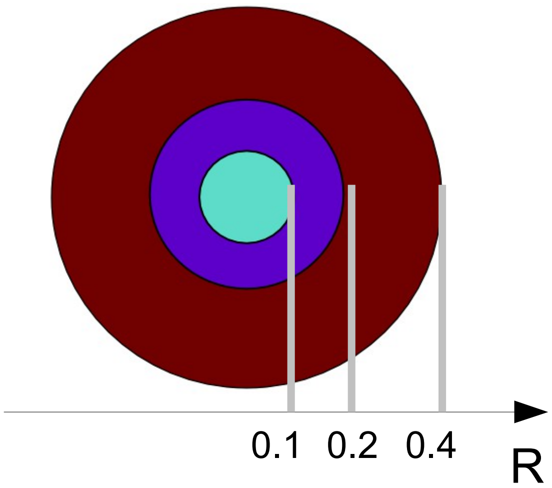

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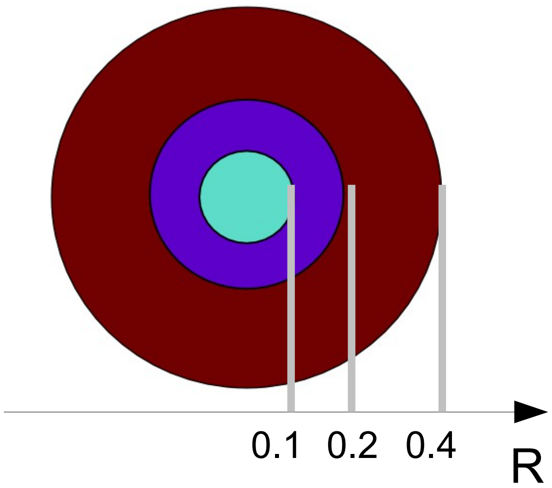
Discrimination Against q/g Jets

$$N_{track}^{iso} = no.trks\left(0.2 < R < 0.4\right)$$



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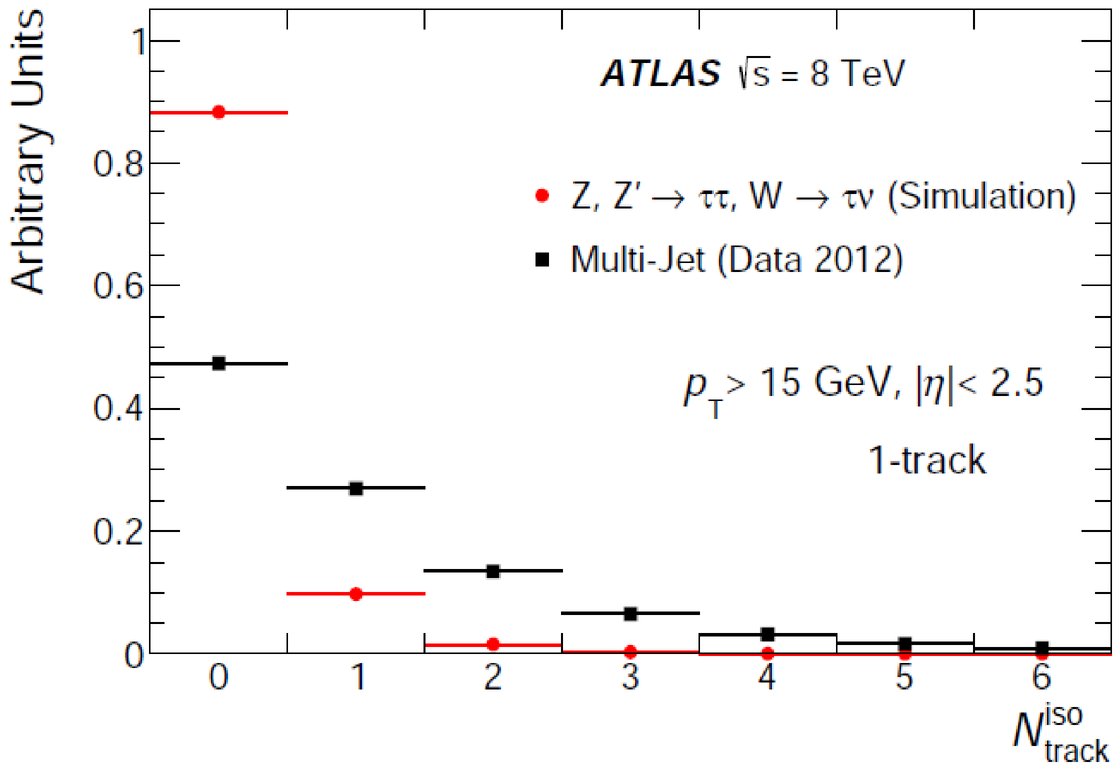
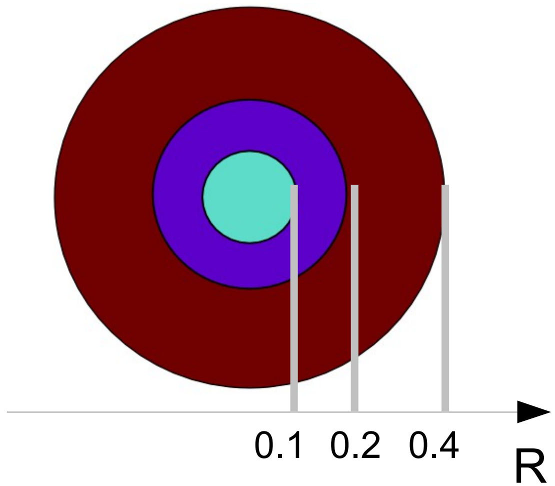
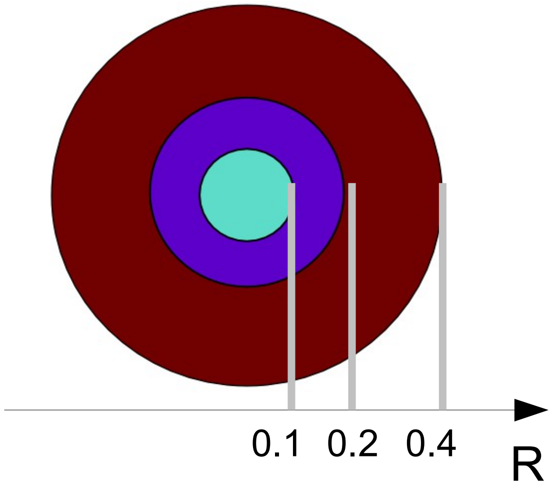




Discrimination Against q/g Jets

- R_{track}: p_T weighted distance of tracks from centre of tau jet ($0.0 < R < 0.4$)



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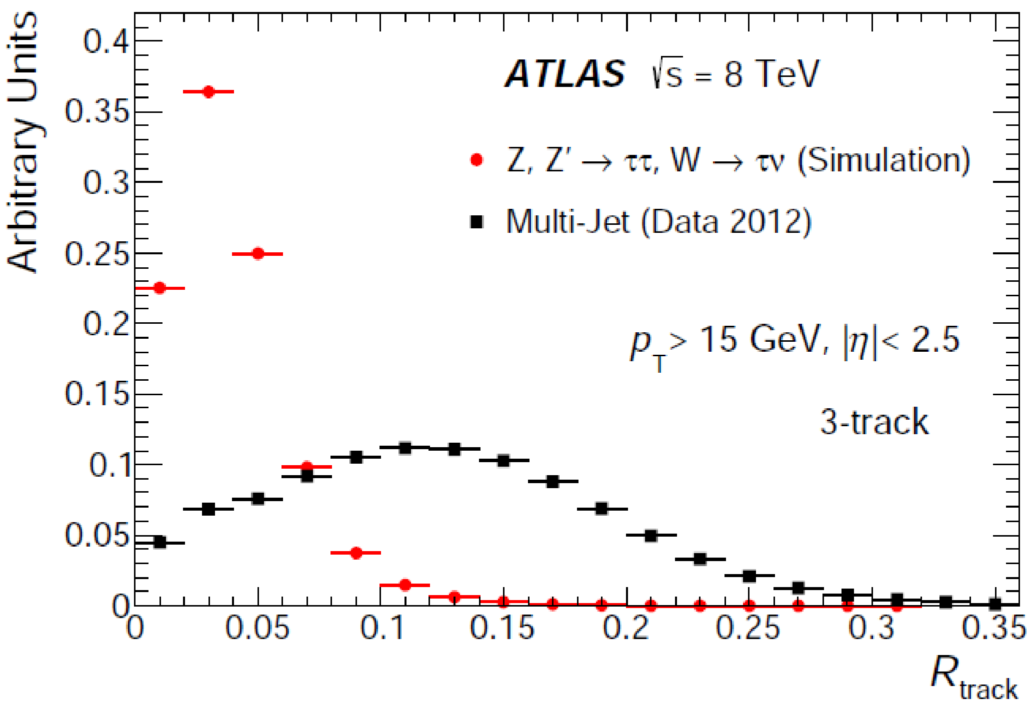
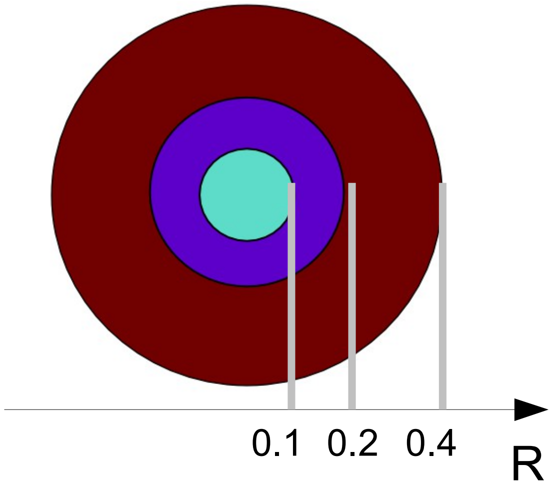
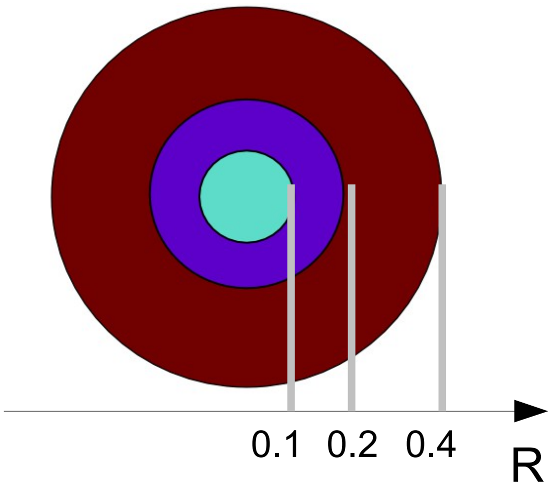




Discrimination Against q/g Jets

$$f_{track}^{iso} = \frac{\sum p_T(0.2 < R < 0.4)}{\sum p_T(0.0 < R < 0.4)}$$



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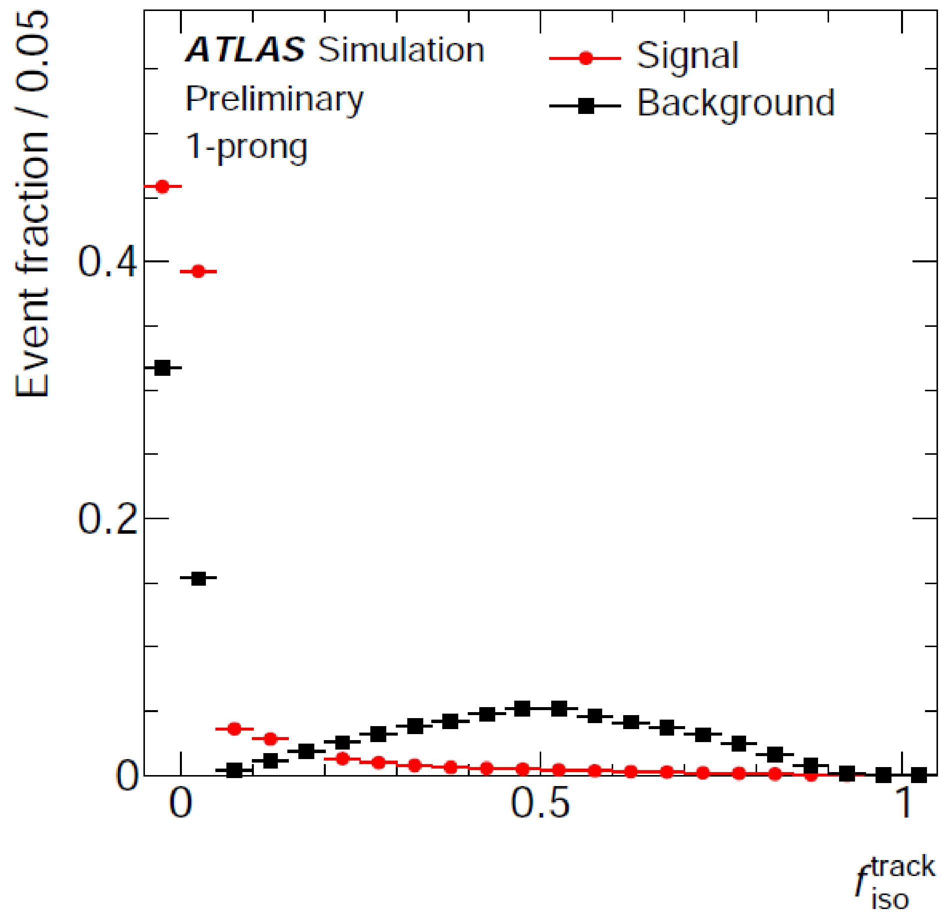
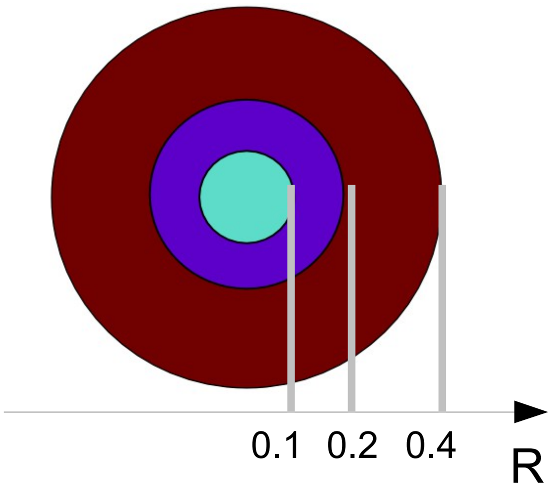
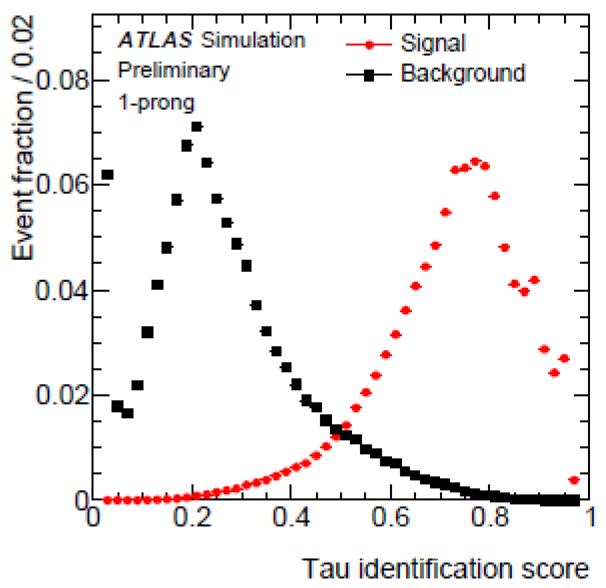
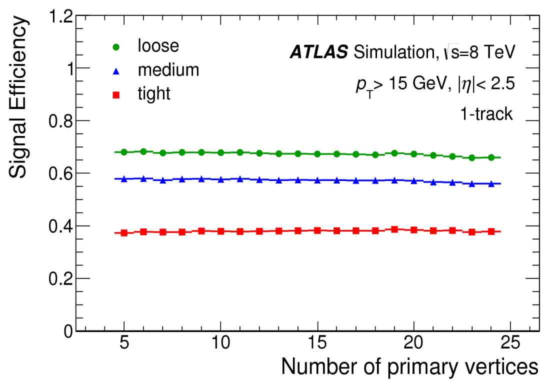


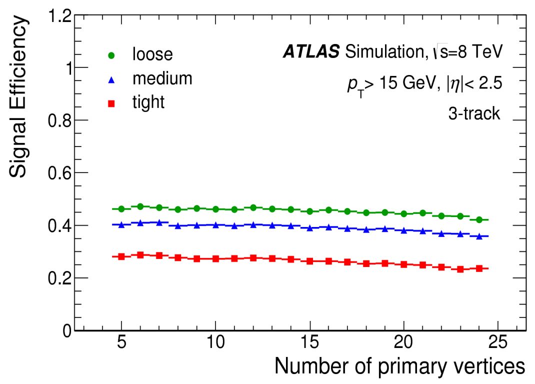


Performance

- BDT gets 12 input variables
- Define three working points

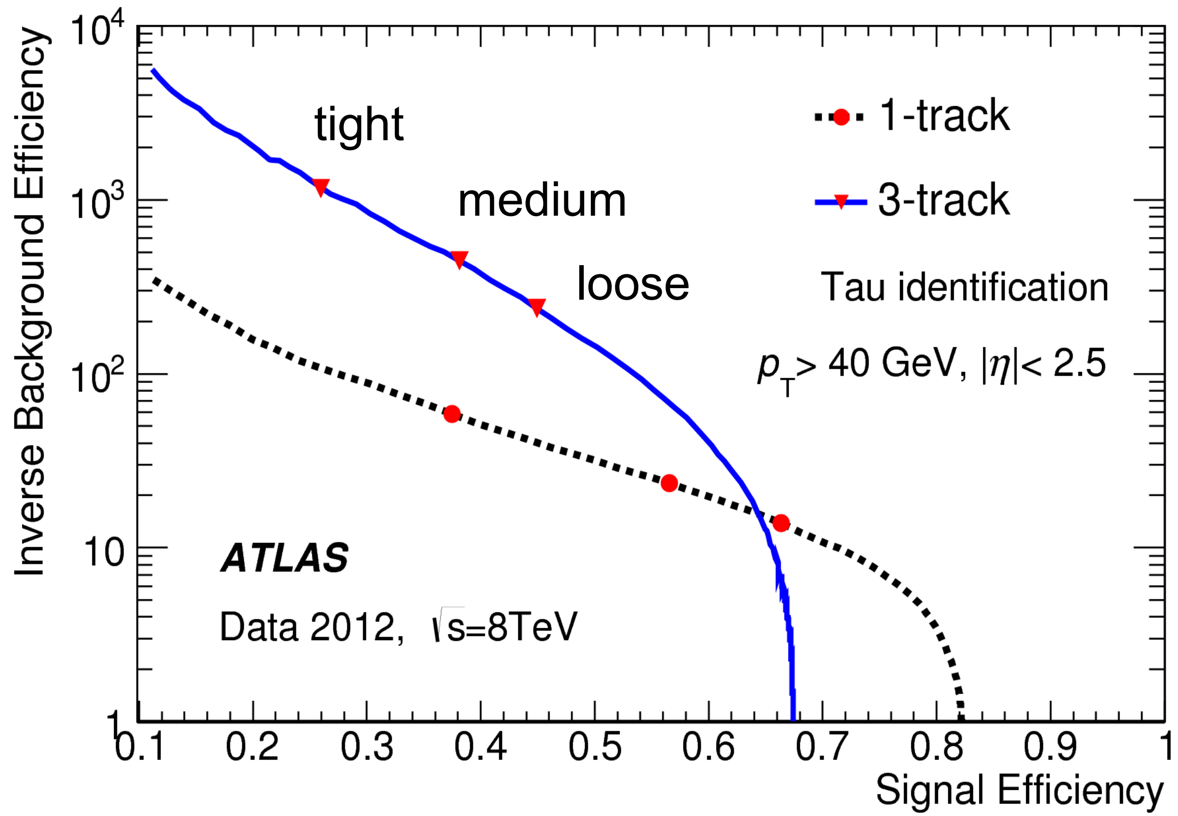






Performance

Misidentify less jets as taus



Identify more taus

The Conclusion

- Tau leptons are „messy“
- 35% decay leptonically
- 65% decay hadronically
- Identification challenging
- BDT with well-chosen input parameters
- Overall ID effidiency ~60%

Thanks for your attention!

The Conclusion

What This Is About

1. Experimental Physics is Dirty!

Or „Limitations of Experiments and the Universe"

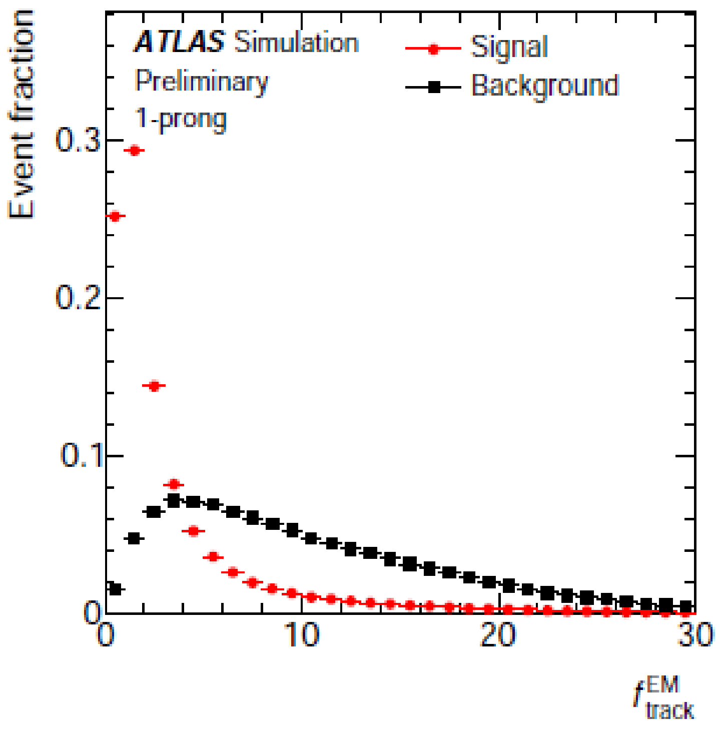
Or „Why We Cannot Do Everything You Theoriticians Want Us To"

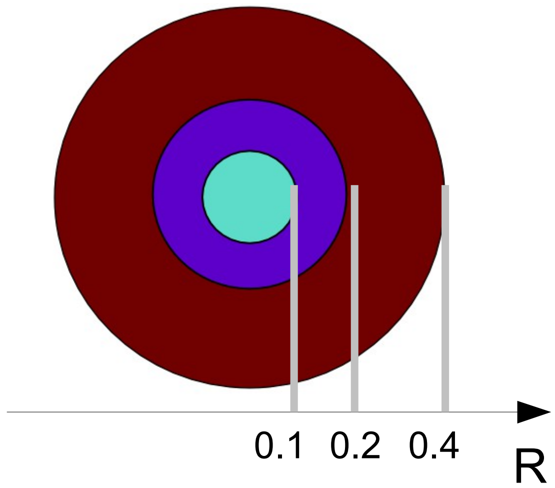
2. Unfolding for a Better Life

3. Searching for Nothing and Burning Billions of Euros for Fun and Recreation

Discrimination Against q/g Jets

$$\frac{E^{EM}}{\sum p^{track}(0.0 < R\ 0.2)}$$





Lecture 1 (Taus)

- Explain why taus are important to analyses in general and to my search in particular. Also: why is identification efficiency a problem in the first place? (3-4)
- What are tau leptons and how do they behave? → hadronic/leptonic taus (2-3)
- ATLAS detector reminder (1-2)
- Signatures of hadronically decaying taus (2)
- ATLAS strategy of identifying them
  - Reconstruction & identification (2-3)
  - Explain various discriminating variabes (5)
  - Performance (2-3)
- How I use the tau veto in my analysis and how I benefit from it (2)

Introduction

- Focus on two things that are affected by this
  - Particle identification and „fakes“
    - τ leptons (← messiest common particle)
  - Advanced methods for background estimations
    - Data-driven approaces