Cosmic Ray Composition Studies with IceTop

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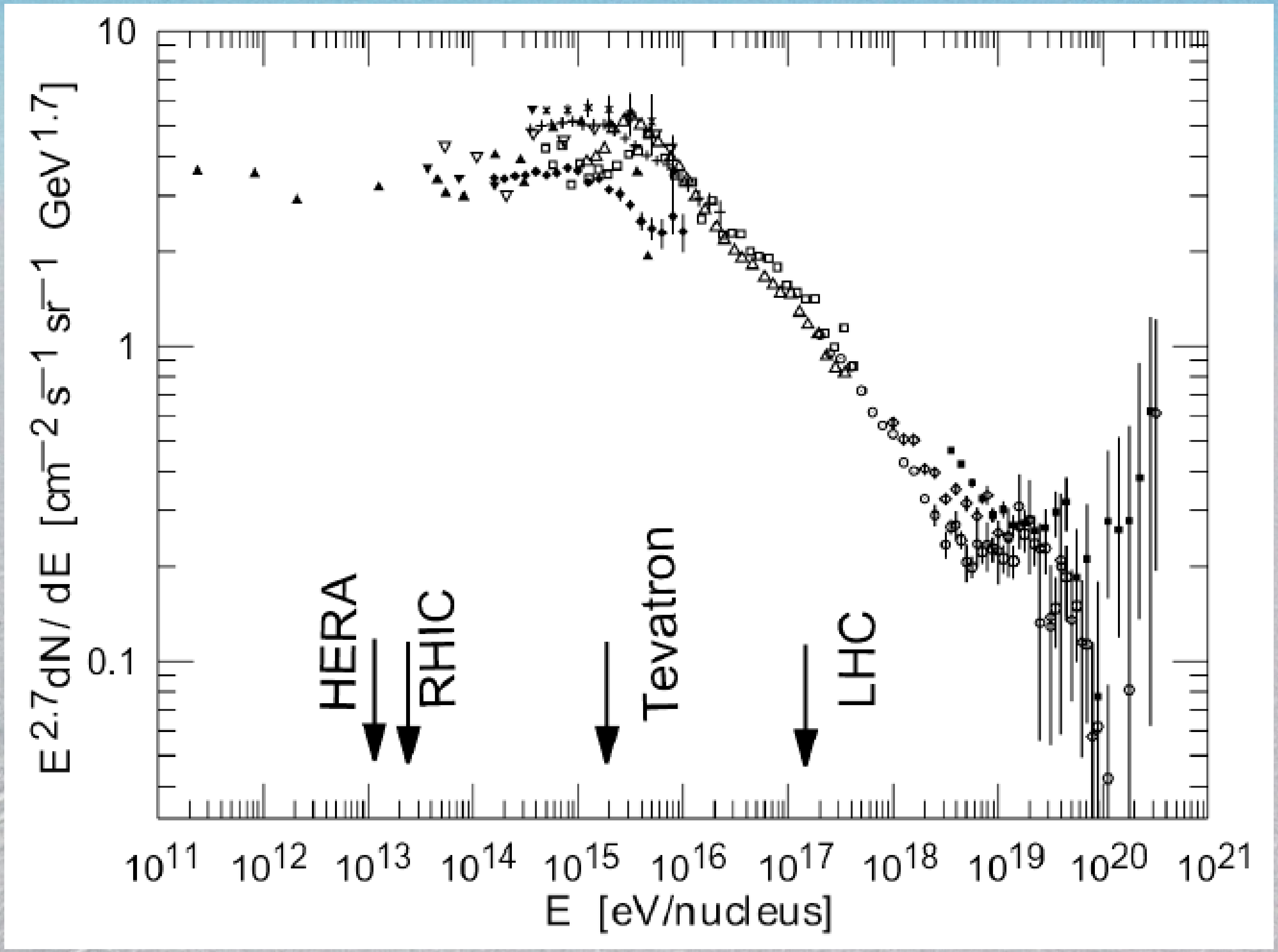
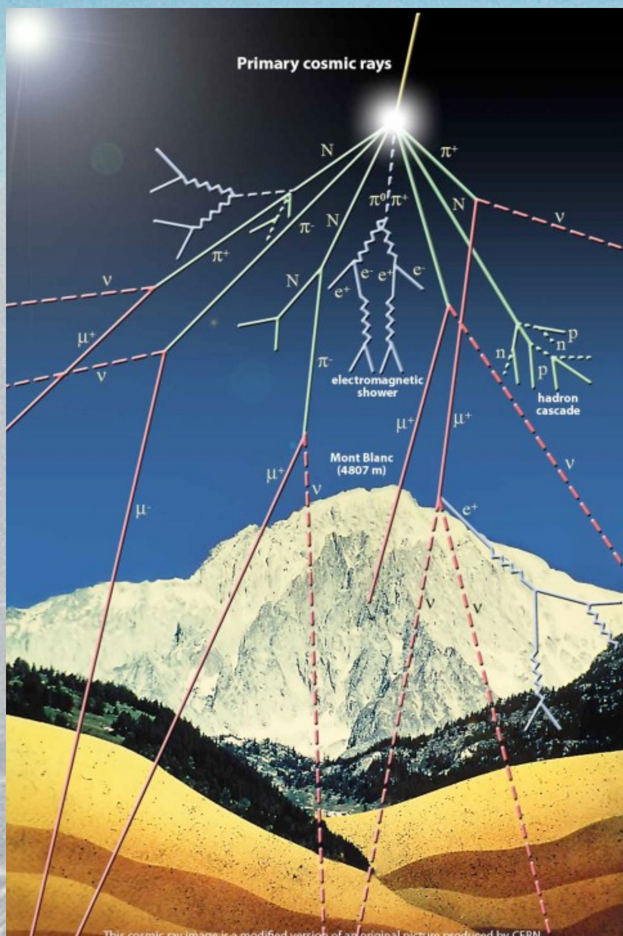
Outline

- Cosmic rays and air showers
- Measuring CR composition
- IceCube and IceTop
- IceTop charge calibration
- Charge distributions and muon excess
- Preliminary results

Cosmic rays: spectrum



Cosmic rays: air showers



- Cosmic ray interacts in atmosphere
- Produces air shower
- Secondary particles created until energy is too low
- Shower reaches maximum, then peters out
- At ground level: mainly muons, EM and neutrinos

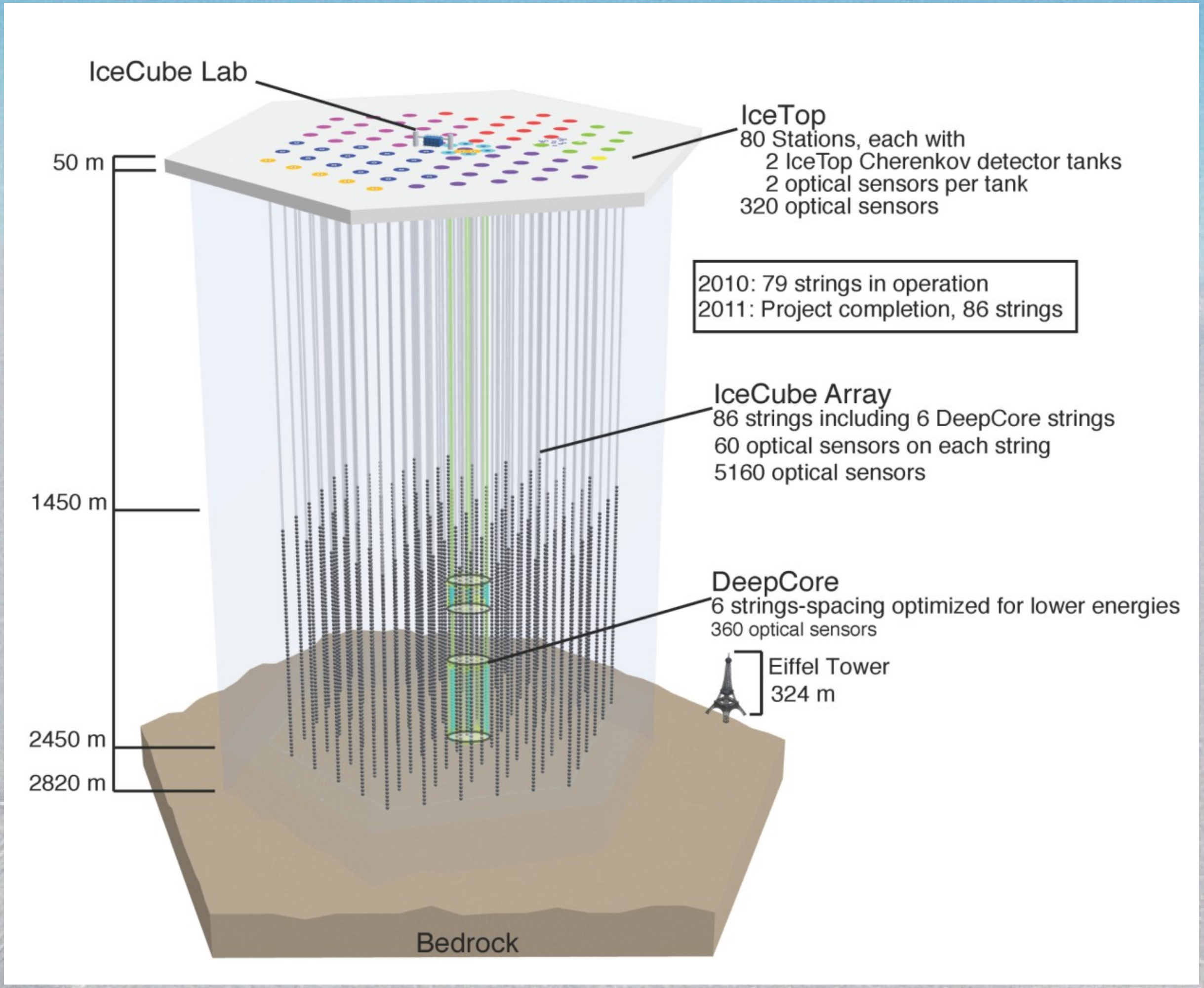
Air shower: probing the primary

- Primary energy E_0
  - Shower size at maximum increases with E_0
    - Shower lasts longer before secondaries have insufficient energy for further cascades
  - Maximum lies deeper for higher E_0
  - Other observables, e.g. curvature of shower front

Air shower: probing the primary

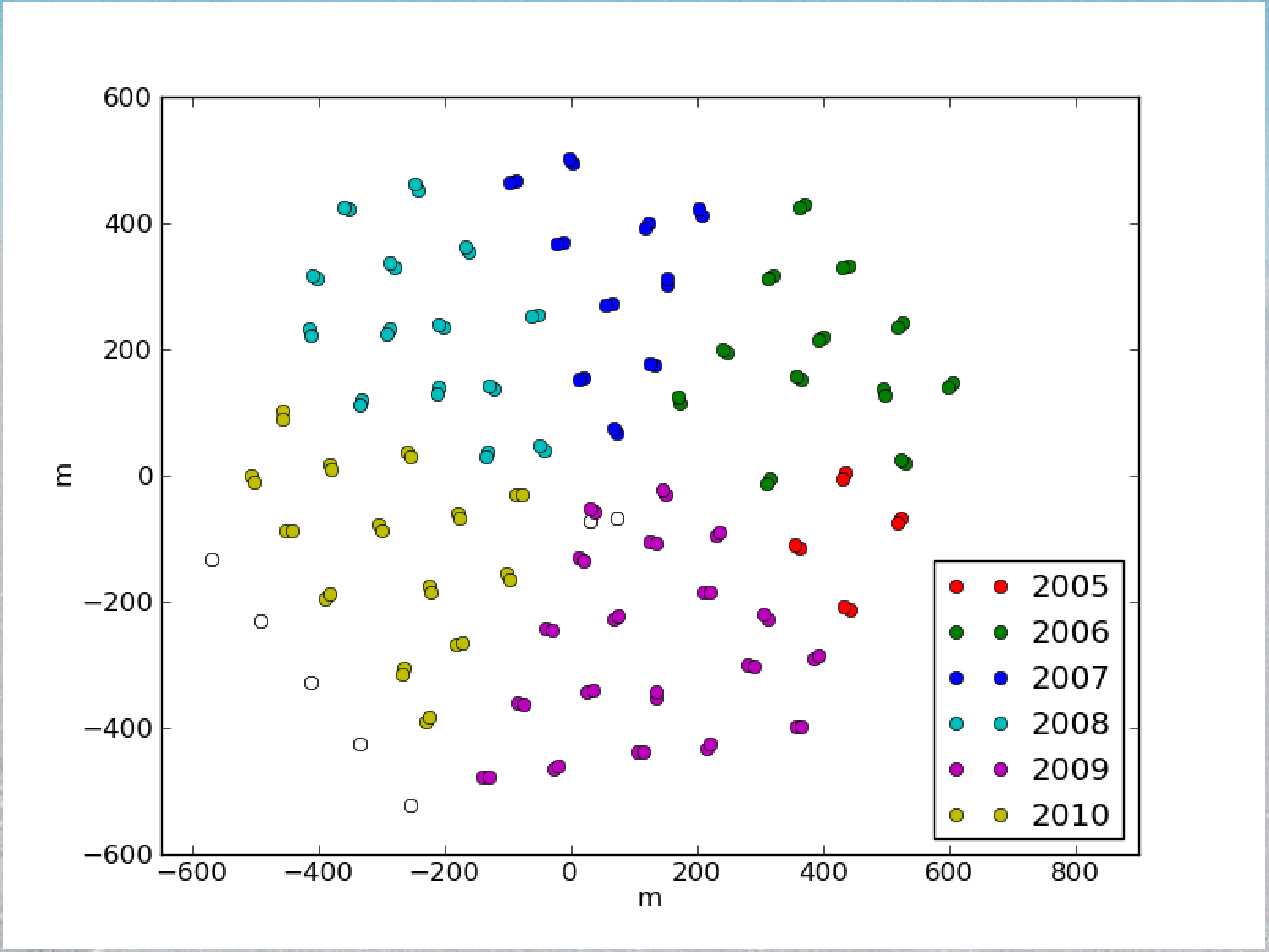
- Primary mass A
  - Location of maximum compared to size
    - One nucleus with E_0 counts as A individual nucleons with E_0/A: “superposition” of showers
  - Strength of muon component
    - High A: many primary nucleon interactions high in atmosphere
    - Produced pions decay before interacting
    - More HE muons than for low A

IceCube



IceCube Lab
IceTop
80 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
320 optical sensors
2010: 79 strings in operation
2011: Project completion, 86 strings
IceCube Array
86 strings including 6 DeepCore strings
60 optical sensors on each string
5160 optical sensors
DeepCore
6 strings-spacing optimized for lower energies
360 optical sensors
Eiffel Tower
324 m
50 m
1450 m
2450 m
2820 m
Bedrock

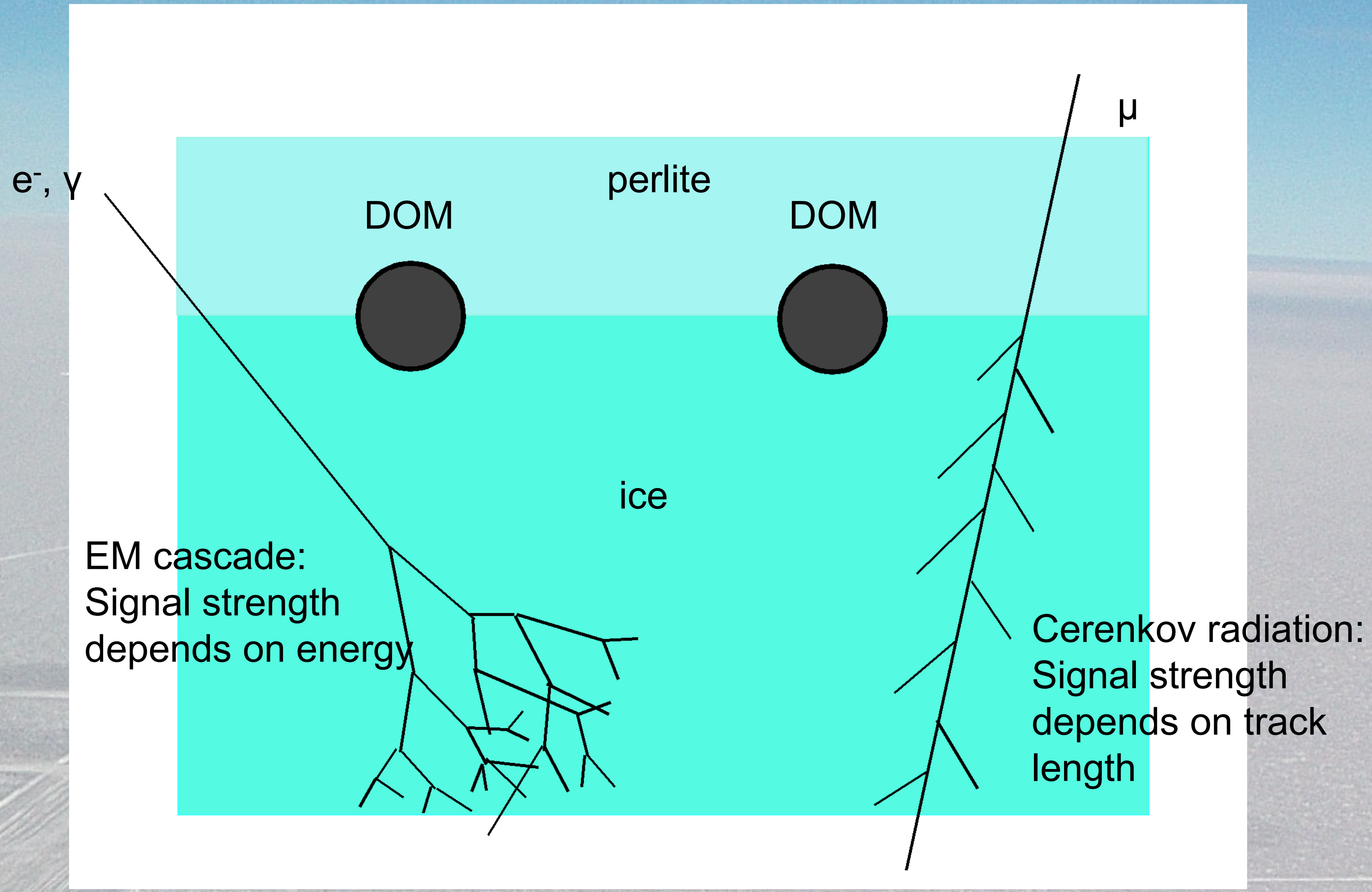
IceTop geometry



IceTop tanks

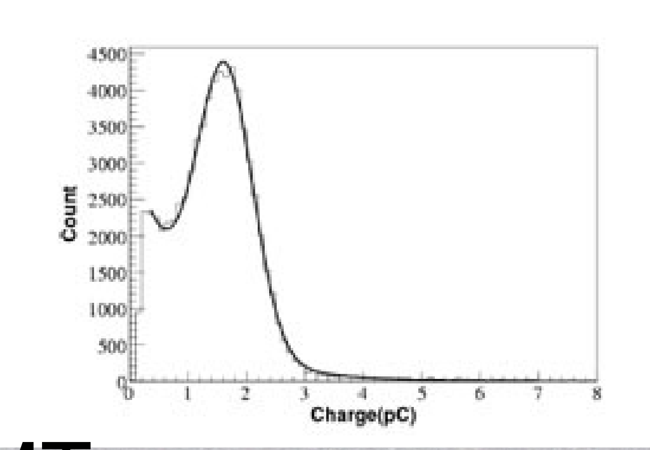
IceTop DOMs

Signals in IceTop tanks



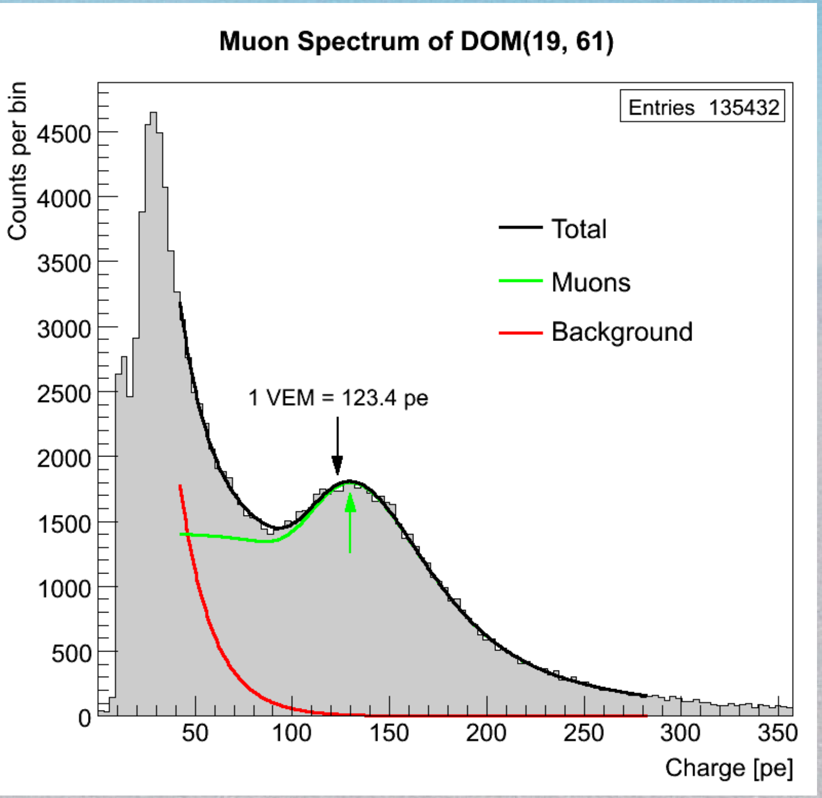
Charge calibration: Q to NPE

- Measured: integrated charge in PMT (Q)
- Needed: number of photoelectrons (NPE)
- For each PMT, determine charge q_0 corresponding to 1 pe (using dark noise)
- NPE = Q/q_0
- Common for all IceCube PMTs



Charge calibration: pe to VEM

- All IceTop tanks have different properties
- Need one measure to compare signals in different tanks
- Vertical Equivalent Muon
- Only used in IceTop



SLC and HLC

- Signal observed in two tanks within station: “Hard Local Coincidence” (HLC)
- Signal observed in only one tank in station: “Soft Local Coincidence” (SLC)
- SLC hits more likely to be noise
- Before 2009, only HLC hits were used in IceTop analyses

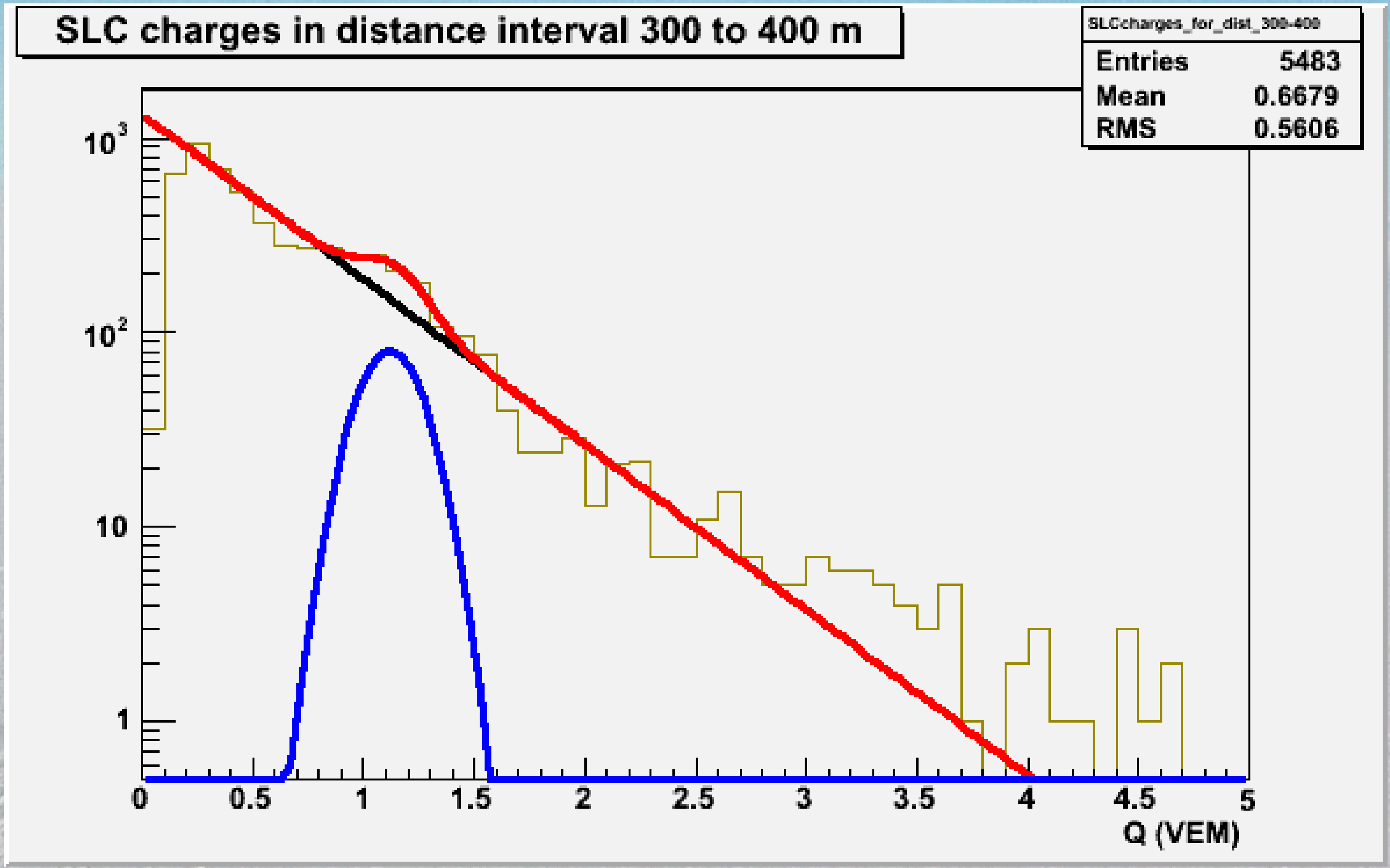
Strategy

- One single muon will not produce HLC hit
  - EM signal in one tank and muon only in the other tank is quite unlikely
  - Look for muons in SLC hits!
- Close to shower axis: signal dominated by EM component
  - Muon signal should be clearer farther away from core
  - With IceTop near completion, we can go there

Simulations

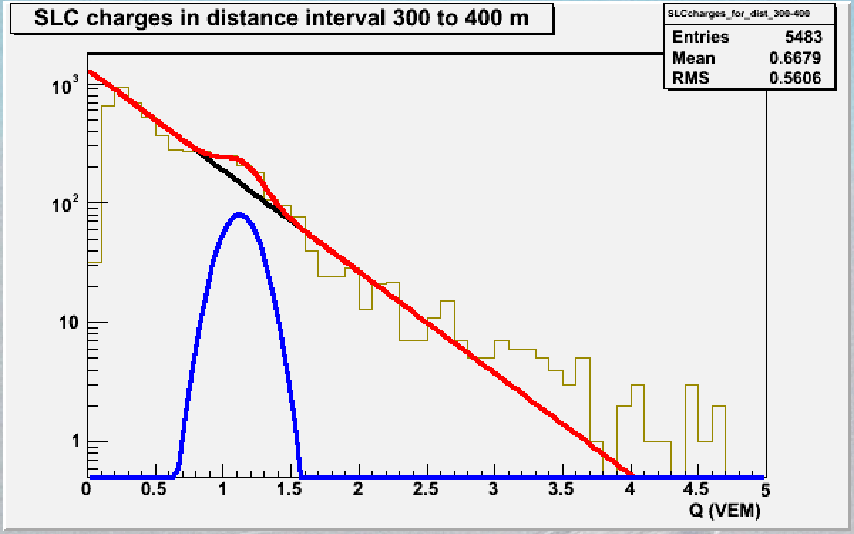
- Simulations for IT59 are being performed
- Some p and Fe data available
- As yet, low statistics…

Muon excess



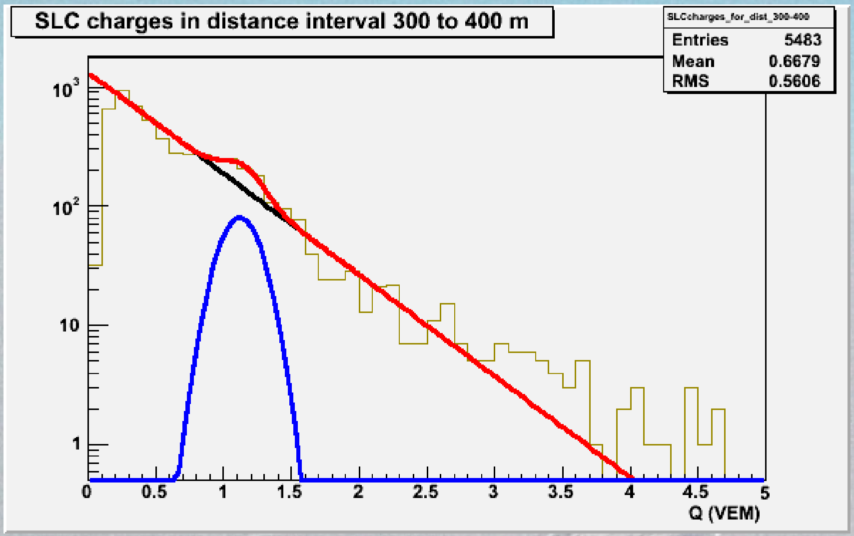
SLC charges in distance interval 300 to 400 m
SLCcharges_for_dist_300-400
Entries 5483
Mean 0.6679
RMS 0.5606
10^3
10^2
10
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Q (VEM)

Muon excess



- Fe, 300-400 m from core
- Assume:
  - exponential decay due to EM component
  - Gaussian peak due to muons
- Fit exponential first, fix parameters
- Fit Gaussian excess

Muon excess

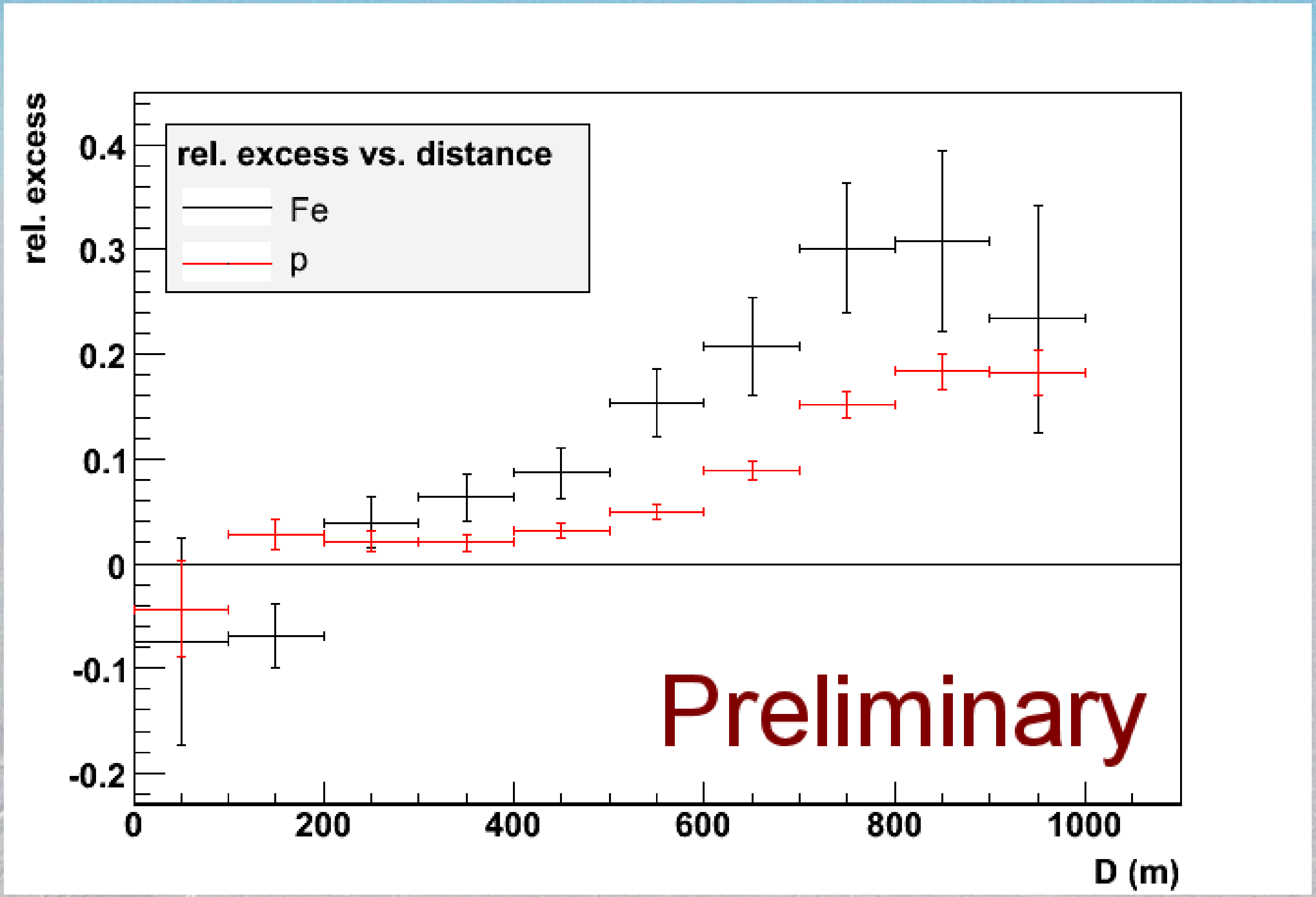


- Quantify excess:

$$x = \frac{\int Gaussian}{\int Exponential}$$

- Determine excess as function of distance to shower axis

p vs Fe

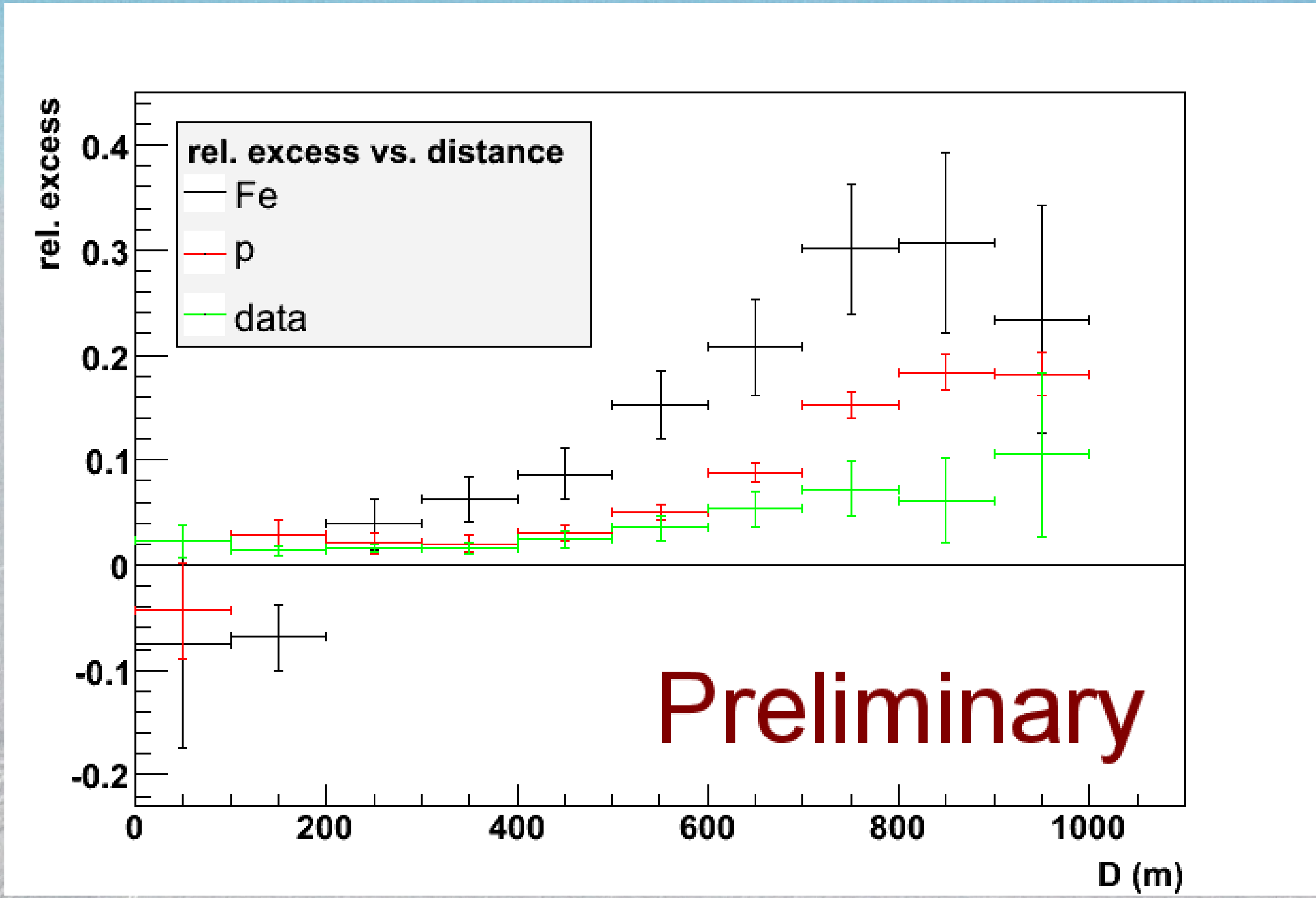


rel. excess
0.4
0.3
0.2
0.1
0
-0.1
-0.2
rel. excess vs. distance
Fe
p
Preliminary
0
200
400
600
800
1000
D (m)

And now… the data

- First look: ~ 100,000 IT59 events
- Event selection: independent IceTop trigger
  - More advanced selections possible: nr. of active DOMs, reconstructed energy, …
- SLC hit cleaning to remove noise
- Shower axis reconstructed from tank signals
  - At the moment, only HLC
  - Resolution:
    - ~ 1° for shower direction
    - ~ 15 m for position of shower core
    - Can be improved for coincident events (IC/IT)

Observed muon excess



Necessary improvements

- Use much more data (both real and MC)
- Optimise event selection
- Use more advanced reconstruction methods
- Take energy into account
- Use IT73 (and larger)

Conclusions and outlook

- Search for muon signal in SLC hits looks promising
- Technicalities to be finetuned
- Large amount of data available, ready to be analysed!
- Method to be used alongside other methods following different strategies
- Combine different methods in one analysis?