Calorimeter Calibration with DIO electrons

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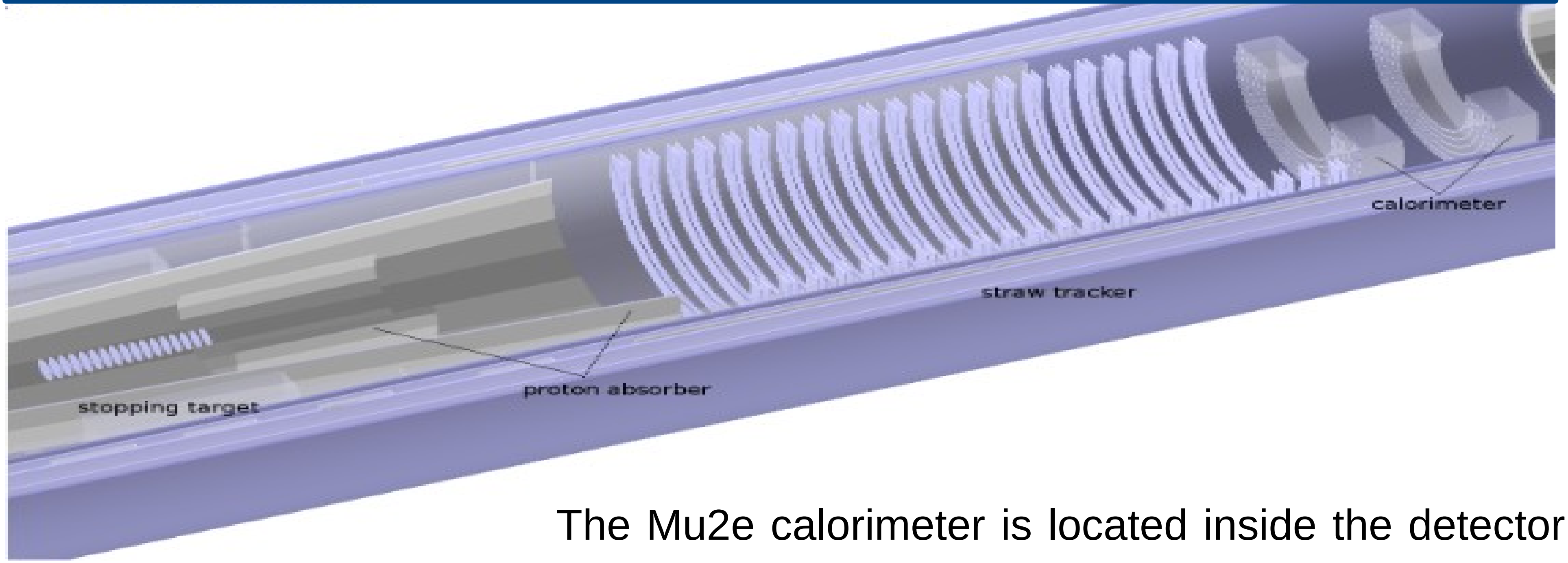
Topics

- Channel to channel calibration
- Absolute scale calibration
- Using calorimeter to extrapolate tracker momentum calibration from 0.5 T to 1 T

Outline

- Mu2e Calorimeter
- Calorimeter calibration strategy
  - DIO electrons
- Channel to channel calibration
- Absolute scale at 0.5 T
- Extrapolating Calibration from 0.5 T to 1 T
  - E/P distribution
  - E/P vs P behaviour
  - Results
  - Extrapolation
- Preliminary Conclusion

Mu2e Calorimeter (1)

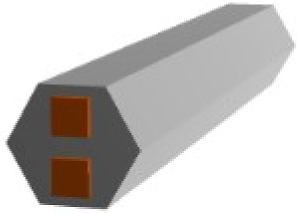


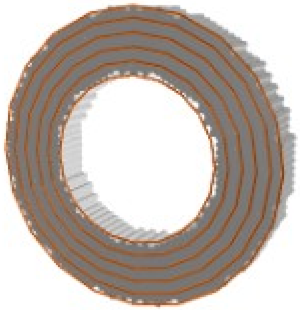
The Mu2e calorimeter is located inside the detector solenoid in a nearly uniform magnetic field of 1 T. Its acceptance is optimized for ~105 MeV electrons.

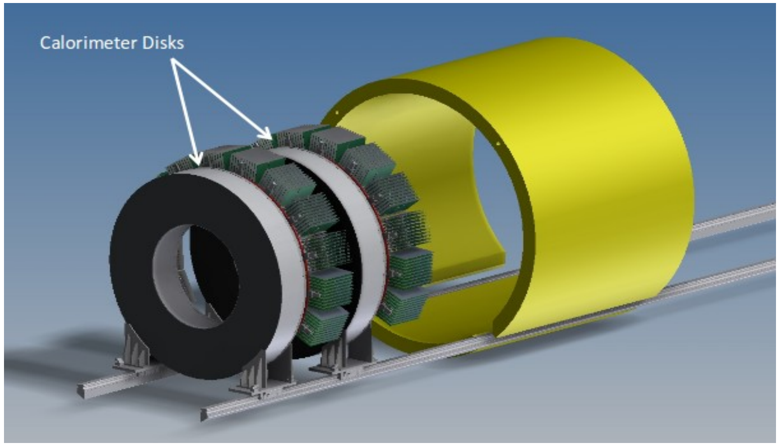
Mu2e Calorimeter (1)

- Two disks: Rin= 35.1 cm, Rout= 66 cm, disk separation = 70 cm
- 930 Barium Fluoride hexagonal crystals/disk. 1860 crystals in total
- Redout: 2 APD's per crystal

Requirements: energy resolution of about 5%, systematic uncertainty of 1%
0.1% or better is needed for the tracker calibration







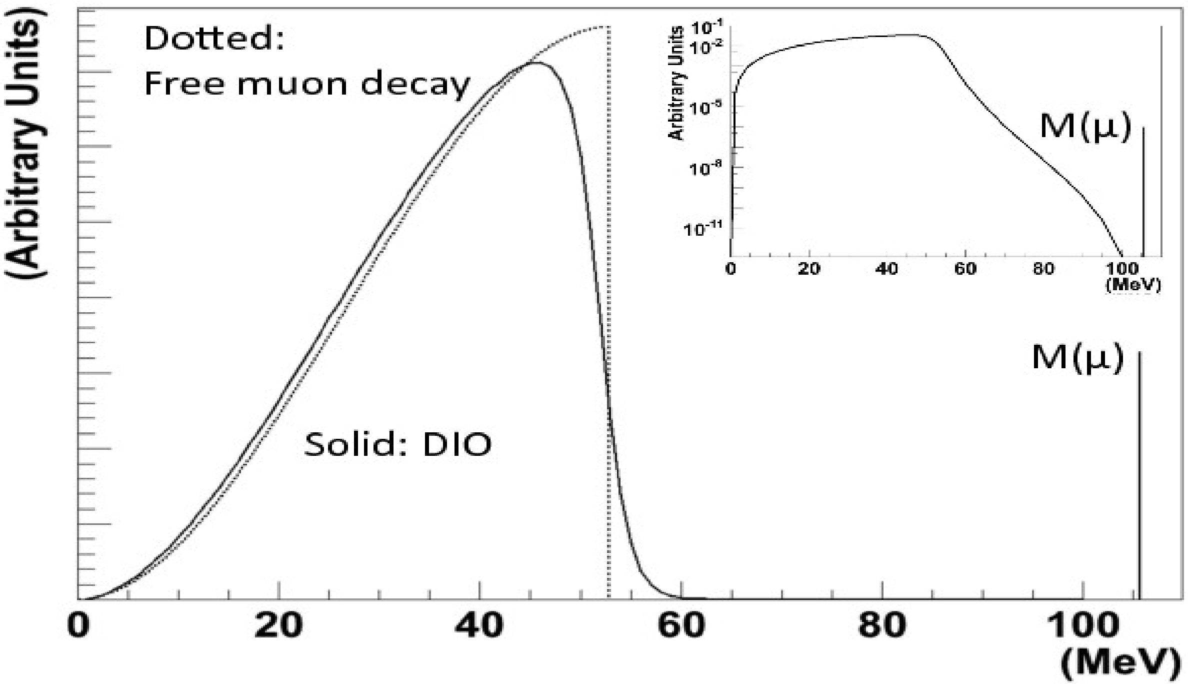
Calorimeter Calibration Strategy

- **Equalize the response of each channel** (then it is possible to calibrate the total response assuming the response of each channel is the same)

- **Source Calibration**
  - radioactive liquid activated by a neutron source
  - Absolute calibration of each crystal with 6 MeV photons

- **Calibration with DIO** electrons
  - Start from 0.5 T – have absolute momentum calibration at this field
  - Use source calibration to extrapolate the calorimeter calibration to 1 T
  - Use E/P to “extrapolate” the momentum calibration to nominal field (1 T);

DIO electrons



- Peak probability at maximum energy at about half the muon rest energy (52.8 MeV)
- Tail extends to very near the predicted CE energy

The only difference between a DIO electron and CE is its energy (which is reduced by the energy carried off by the 2 neutrinos).

Crystal calibration (1)

Using the DIO's full spectrum

- At 1 T, an electron deposits in the seed crystal ~40 MeV
- At 0.5 T, an electron deposits in the seed crystal ~20 MeV...
- Assuming channel/crystal linear response:

$$E_{Calorimeter}(electron) \approx a\,E_{True}(electron) + b$$

$$E_{kinetic}(electron) \approx E_{True}(electron) \equiv p_{Tracker}$$

Crystal calibration (2)

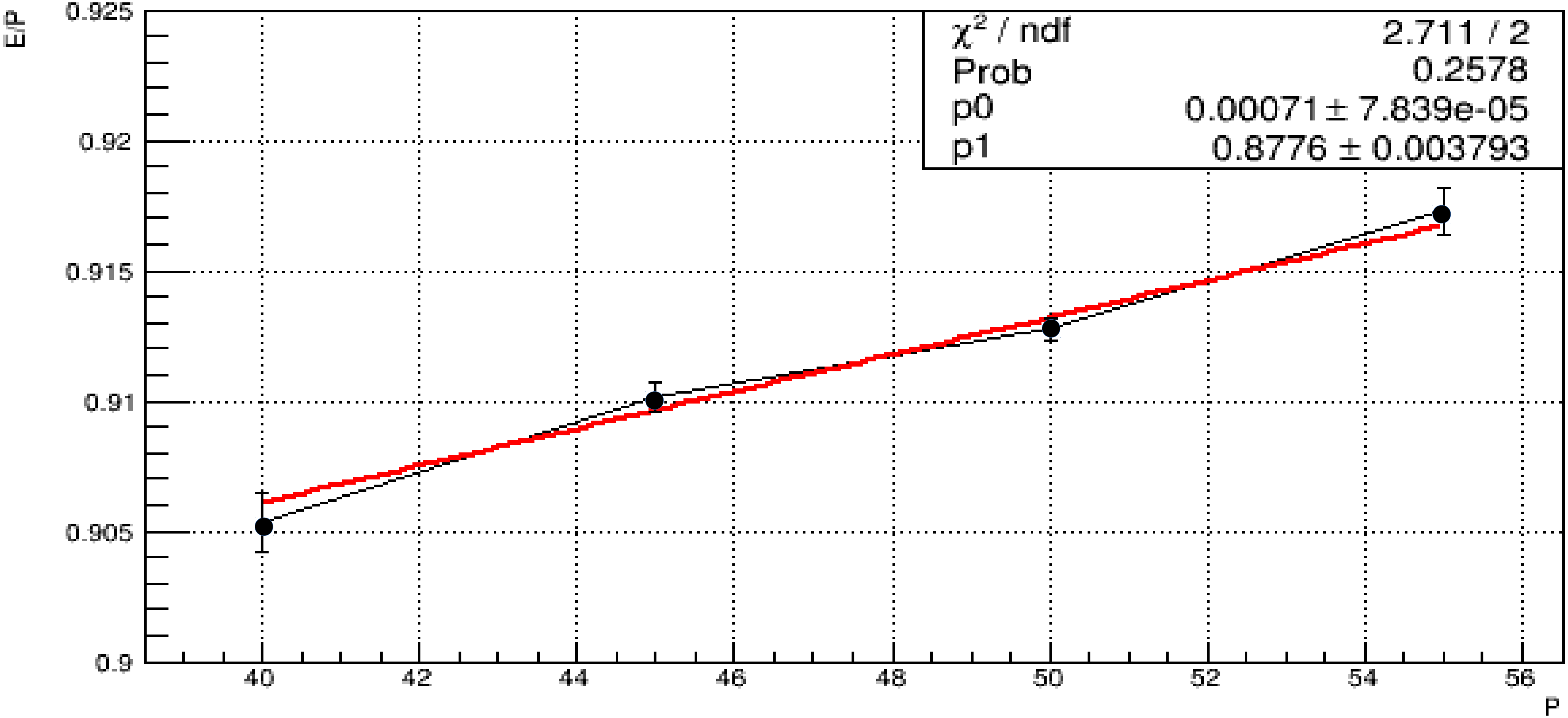
- For each crystal at each magnetic field, 2 points in the graph of $E_{measured}$ vs E_{true}: the first is at 6Mev and the second depends on the calorimeter's acceptance
- repeat the calibration with the radioactive source for each magnetic field

Absolute Scale at 0.5 T (1)

- Assuming a) channel-to-channel calibration is done and

  b)the tracker is calibrated
- Compare E/P distributions for data and MC
- The measured shift gives the absolute scale of the calorimeter
- Several handles to cross-check the results: for example, using different ranges of the dip angle

Absolute Scale at 0.5 T (2)



- 1,000,000 DIO electrons per momentum value
- Plot the M.P. value of the E/P distribution returned by the fit

Extrapolating Calibration from 0.5T to 1T

- As of today, 4 different DS maps are available (0.5 T, 0.7 T, 0.85 T and 1 T) → 4 different calorimeter acceptance ranges

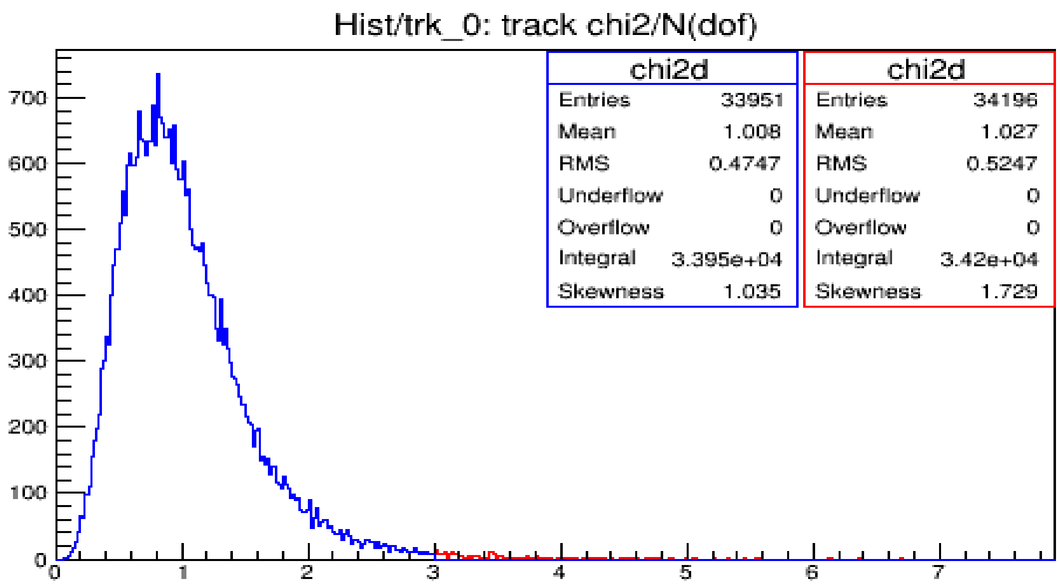
- For simplicity, only monochromatic DIOs were produced
  - 50%: (40, 45, 50, 55)MeV
  - 70%: (55, 60, 65, 70, 75, 80, 85)MeV
  - 85%: (70, 75, 80, 85, 90, 95)MeV
  - 100%: (85, 90, 95, 100)MeV

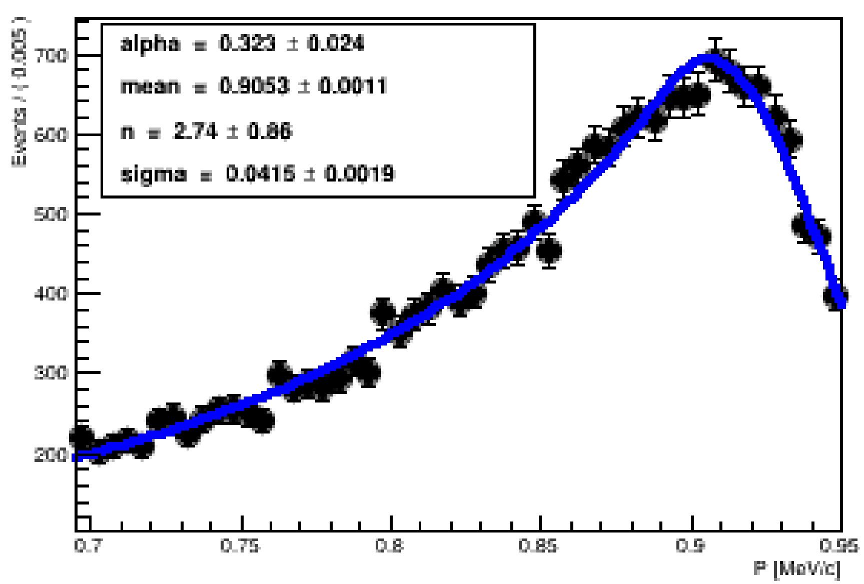
- 1,000,000 DIOs for each momentum value

- Clustering threshold : 1 MeV

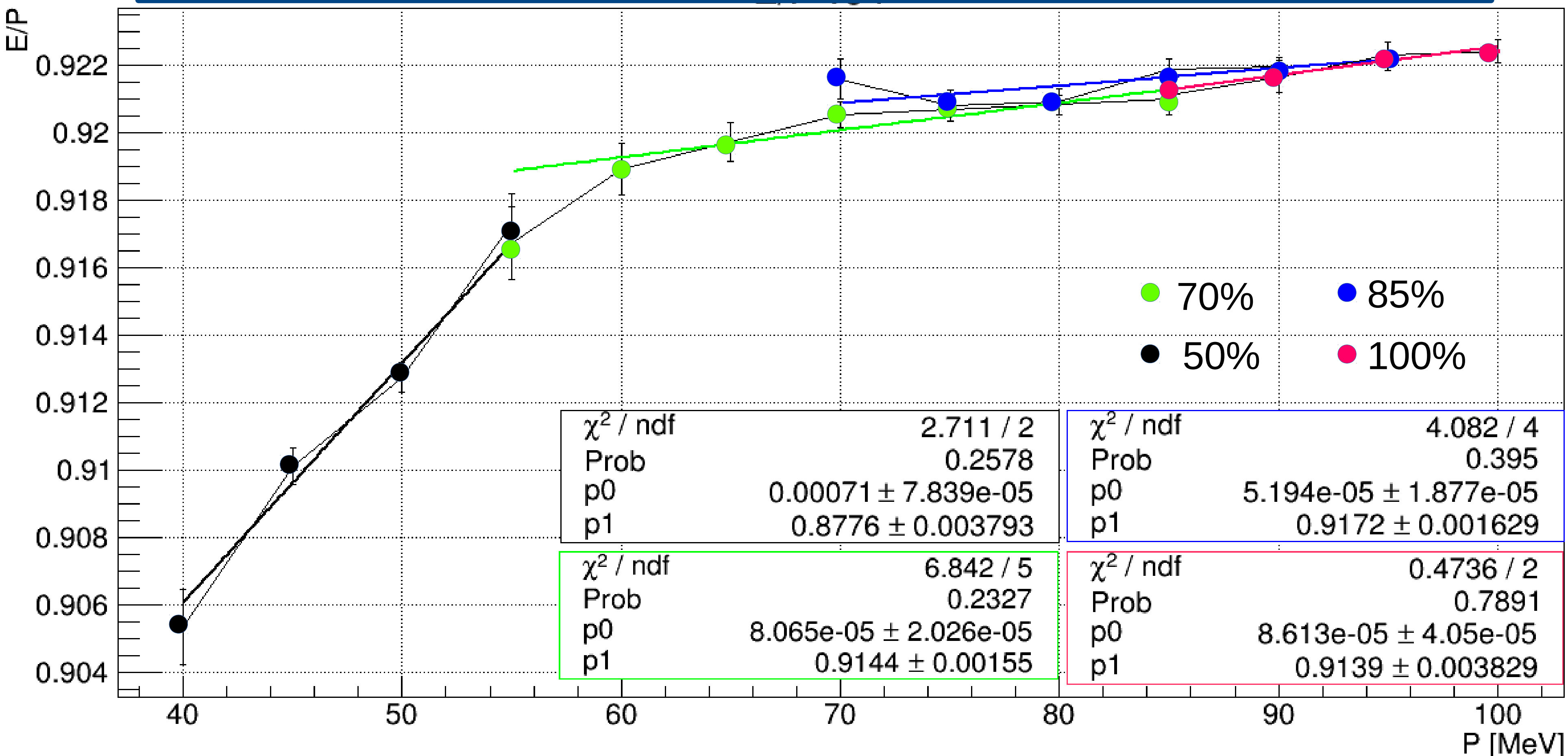
E/P distributions

- To analize the E/P vs P behaviour:
  - Plot E/P distribution of the reconstructed tracks with $\chi^2/_{dof} < 3$ for each momentum value
  - Fit each distribution with a Crystal Ball function
  - Get the most probable value (maximum)
  - plot $(E/P)_{MP}$ vs P



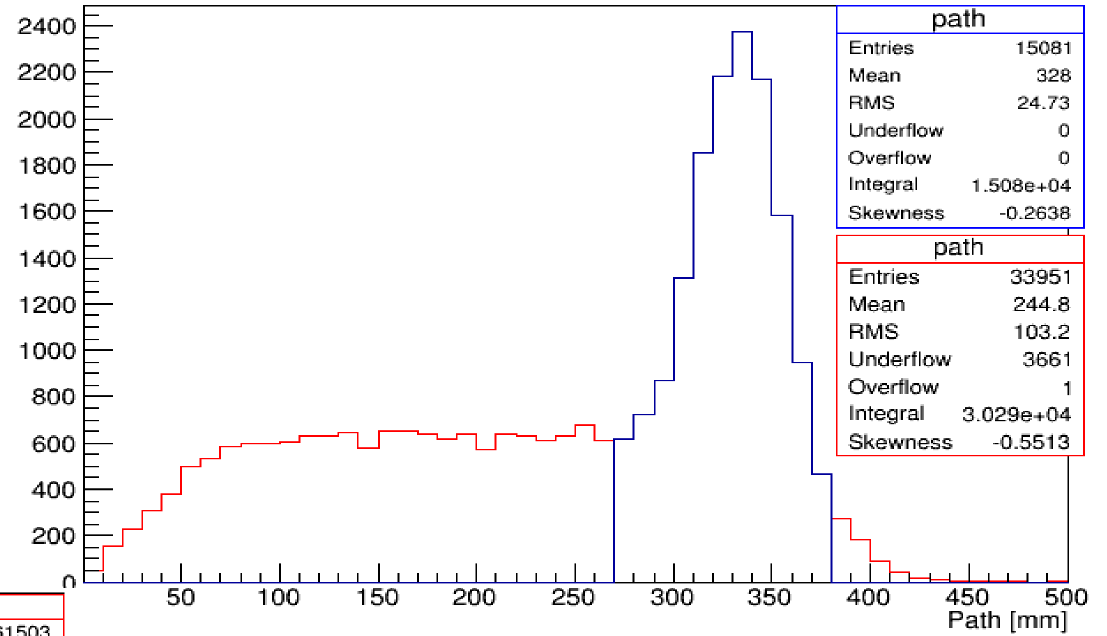


E/P vs P



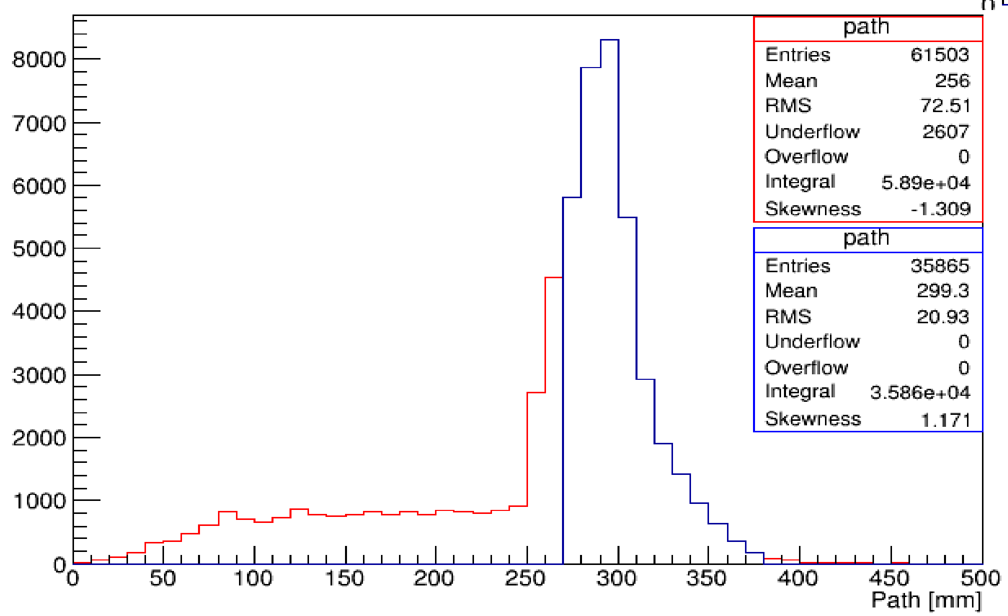
- Different colors correspond to different magnetic field values
- E/P increases with P, however the total change < 2%
- agreement better 0.1% in the overlap regions

Results (1)



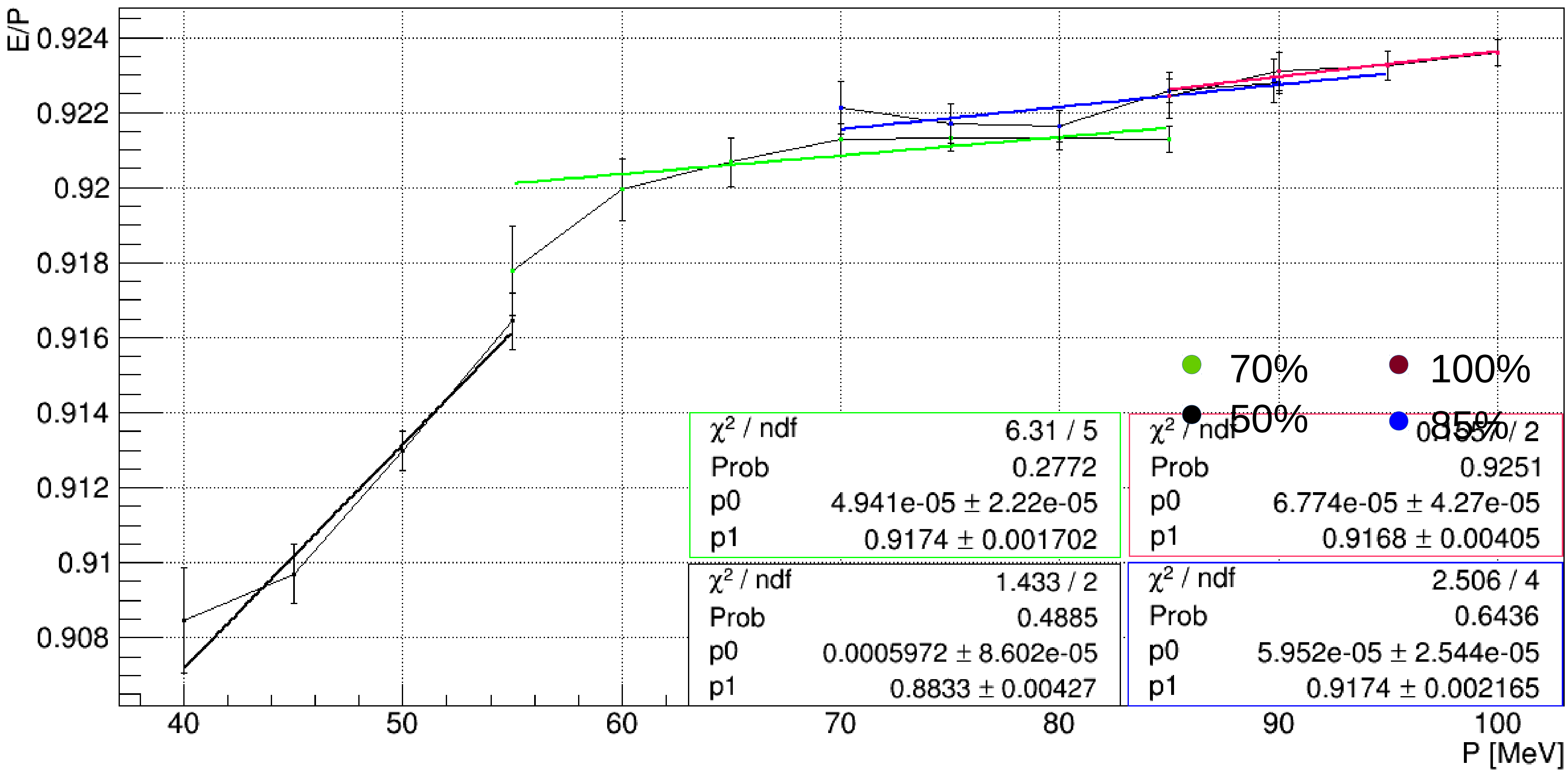
Not a flat distribution!

It is necessary to understand the contributing effects...



1) Cutting on the track path: only reconstructed tracks with path in the calorimeter of more than 270 mm and less than 380mm (cut on the tail of path distributions)

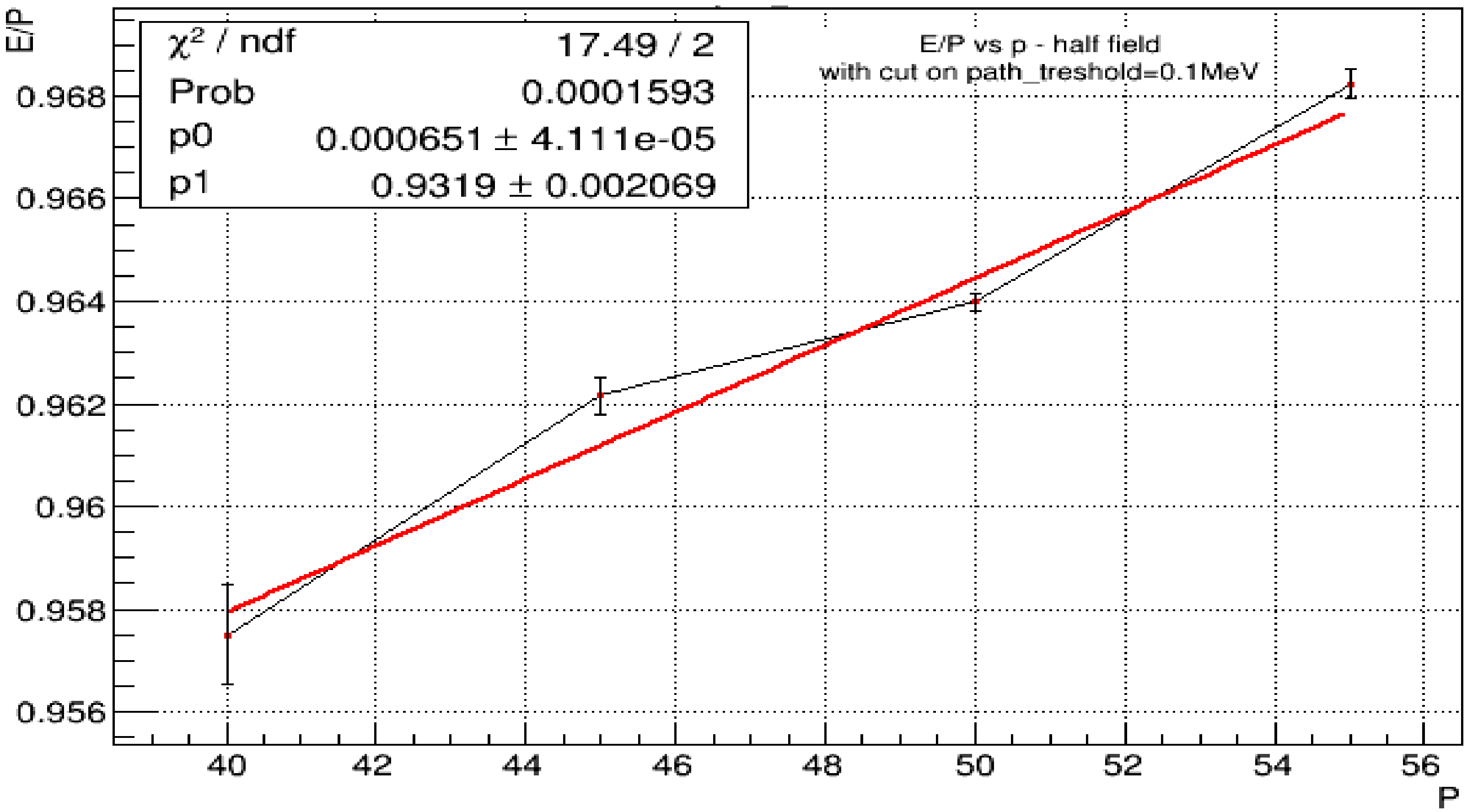
Results (2)



- Cutting on the track path, E/P vs P behaviour is almost the same

Results (3)

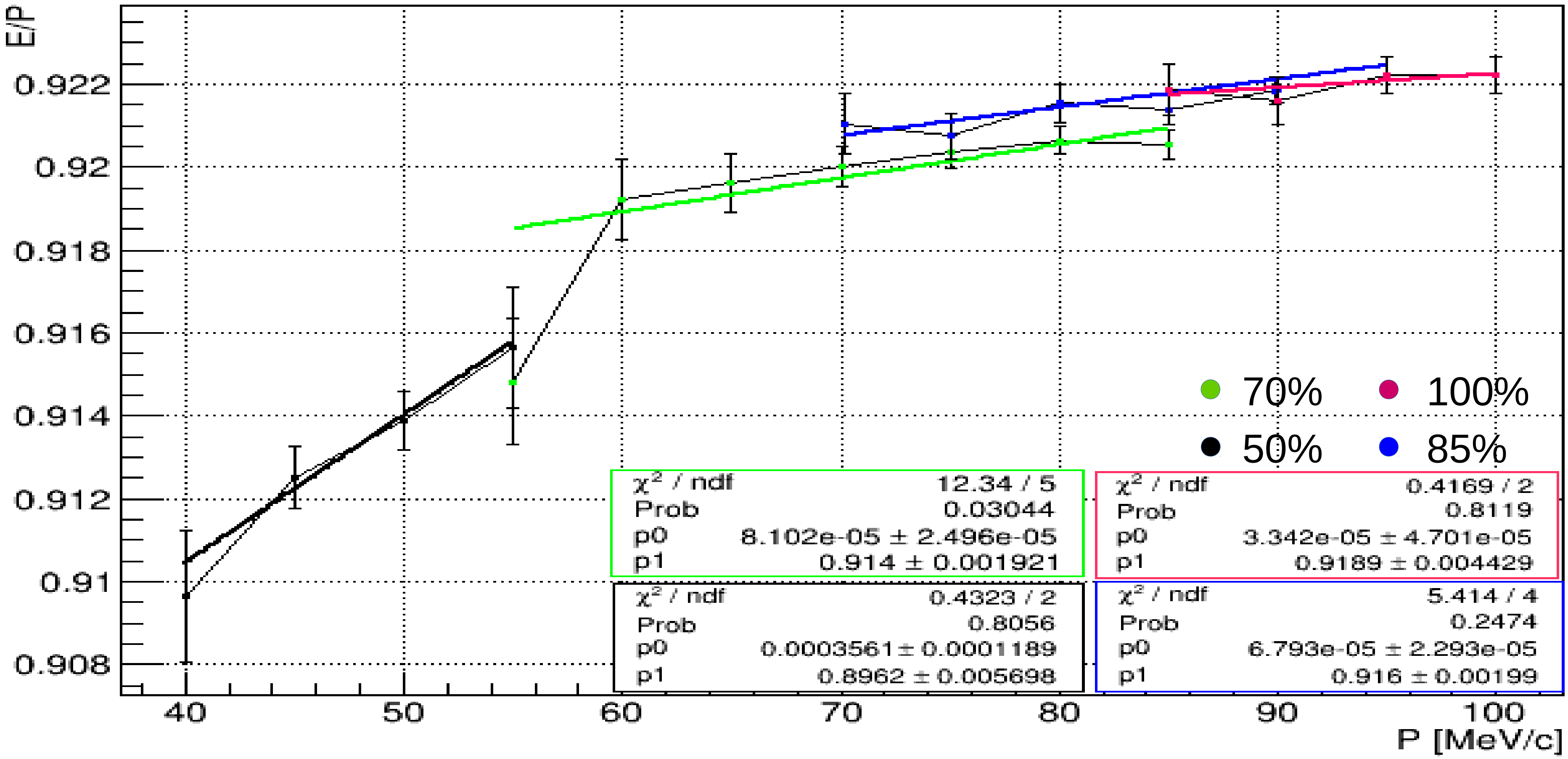
2) Lowering the clustering treshold to 0.1MeV,



- All the points are shifted upwards with the same behaviour

Results (4)

3) Using reconstructed tracks passed cut set C



- the distribution is slightly flatter, but not completely so

Preliminary Conclusion

The Extrapolation of tracker calibration with a precision of 0.1% (as the precision of tracker measurement) from half field (0.5 T) to full field (1 T) using E/P distributions seems to be possible.

Many questions need to be answered. Next steps:

- What is the origin of 2% change in <E/P> ?
- how many measurements at different magnetic field values are needed ?