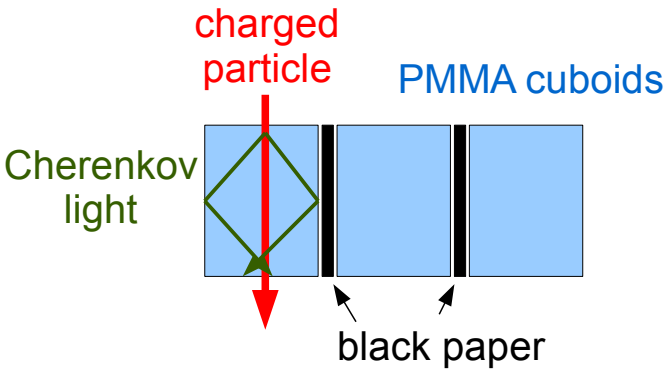
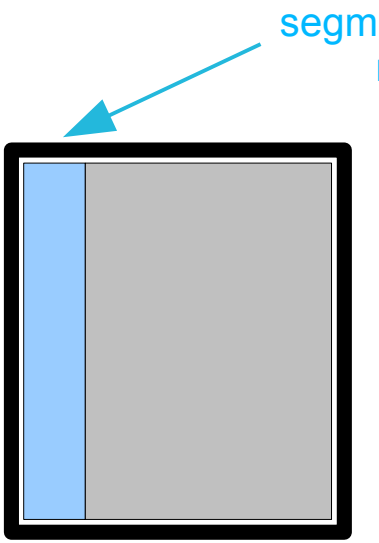
CERN MCP-TOF Results

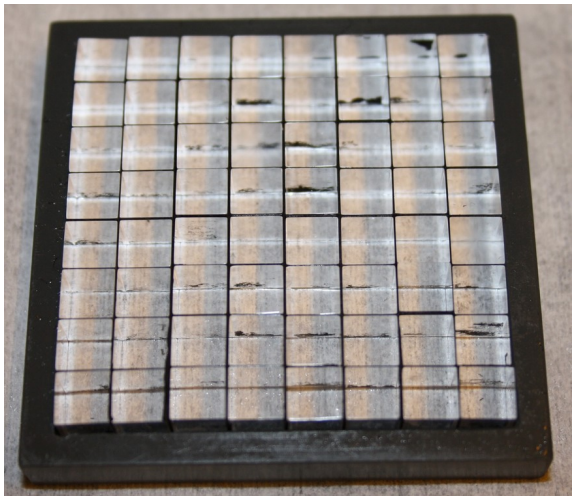
A. Lehmann, M. Böhm, M. Pfaffinger, F. Uhlig

- MCP-TOF setup
- TOF resolutions
- From TOF resolutions to counter resolutions
- Counter resolutions
- Summary

MCP-PMT Setup with Radiator

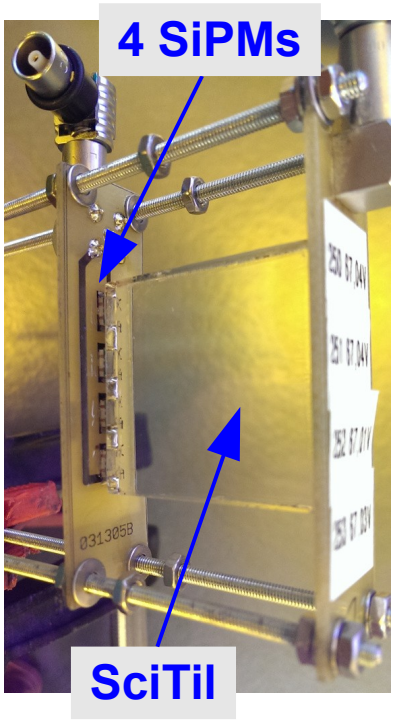


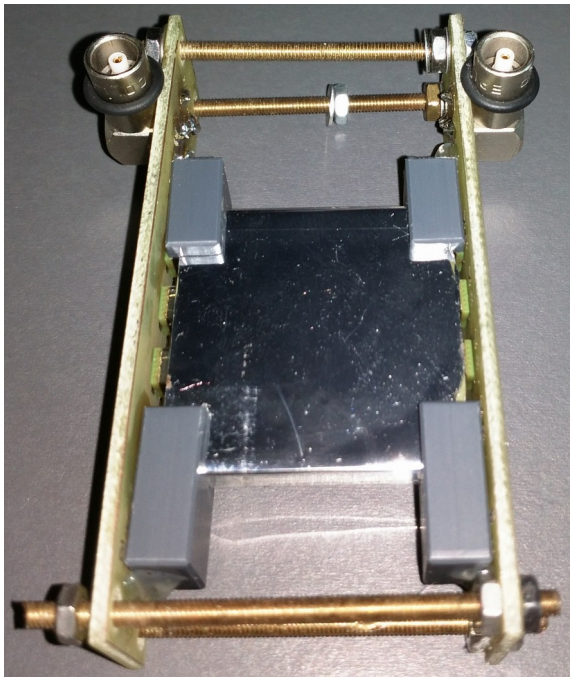


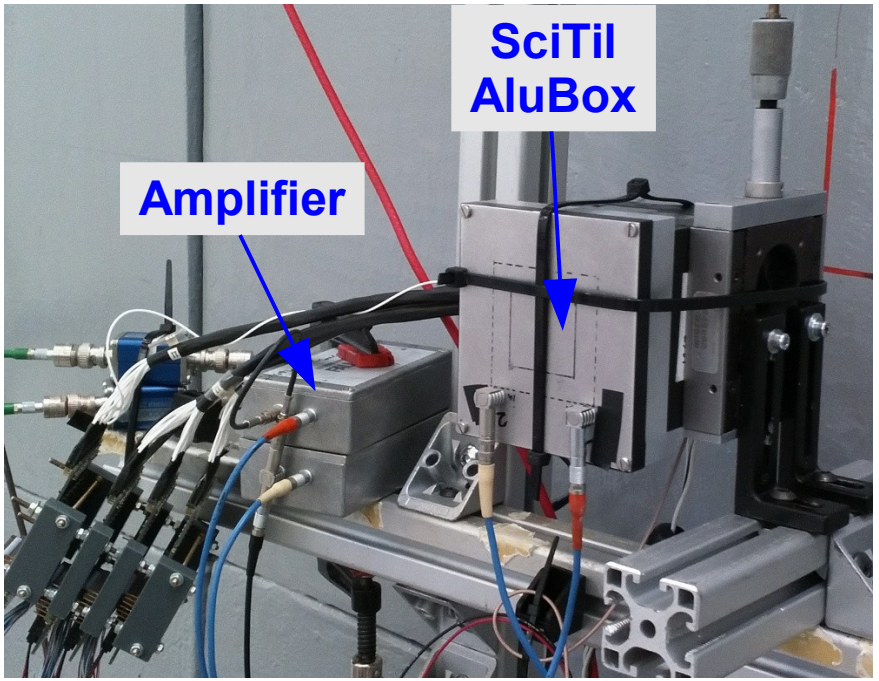


- Segmented PMMA radiator coupled directly to Photonis XP85012/XP85112
  - Each PMMA segment matches MCP anode pixel (8x8 pixel, 6x6 mm^2 each)
  - Particle beam perpendicular to radiator directly through MCP-PMT
- Readout of 64 anode pixels and 1 MCPout (sum of all anodes) with Padiwa frontend boards and TRB DAQ

SciTil Setup

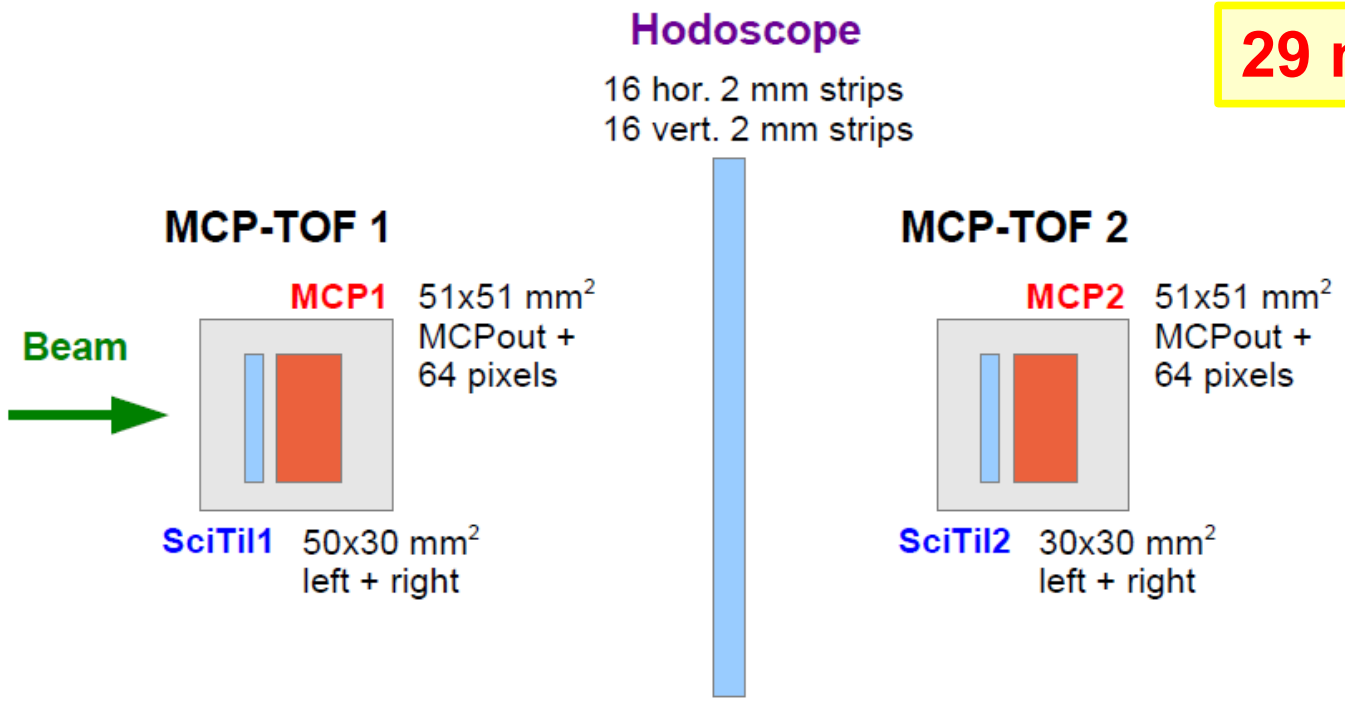






- SciTil (BC418, 30x30x5 mm^3)
  - Wrapped in aluminum foil
  - Read out at 2 sides with 4 SiPMs (Ketek, 3x3 mm^2) connected in series
  - SciTil + SiPM readout boards packed in light tight alubox
- Raw signals fed through amplifiers and given to Padiwa frontend boards

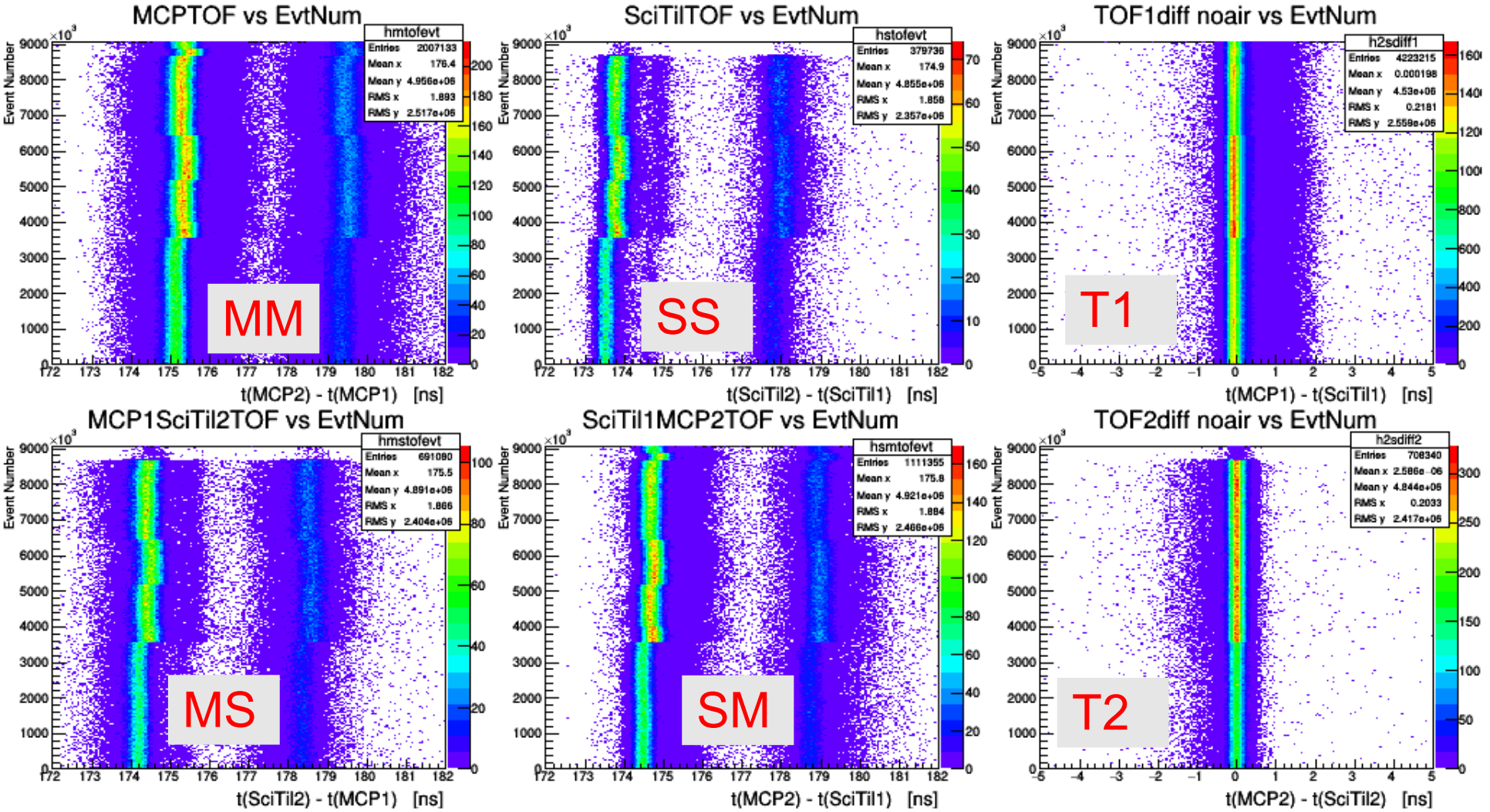
MCP-TOF Setup



29 m flight path

- In both MCP-TOF stations 1 SciTil and 1 MCP counter each
  - MCP-TOF1 (MCP-out, SciTil_l, SciTil_r) at one Padiwa (no reftime needed)
  - MCP-TOF2 (MCP-out, SciTil_l, SciTil_r) at one Padiwa (no reftime needed)
  - Different TRB-boards for MCP-TOF1 and MCP-TOF2 (reftime necessary)
  - Additional setup with all MCP-out and SciTil signals at 1 TRB + aircell cables (no reftime)
- 6 TOF infos → determination of time resolution for each counter possible

TOF vs EventNumber (at 3 GeV/c)



- All 3 GeV/c data used, but different TRB boards for TOF1 and TOF2
- TOF position is not stable over time → correction needed

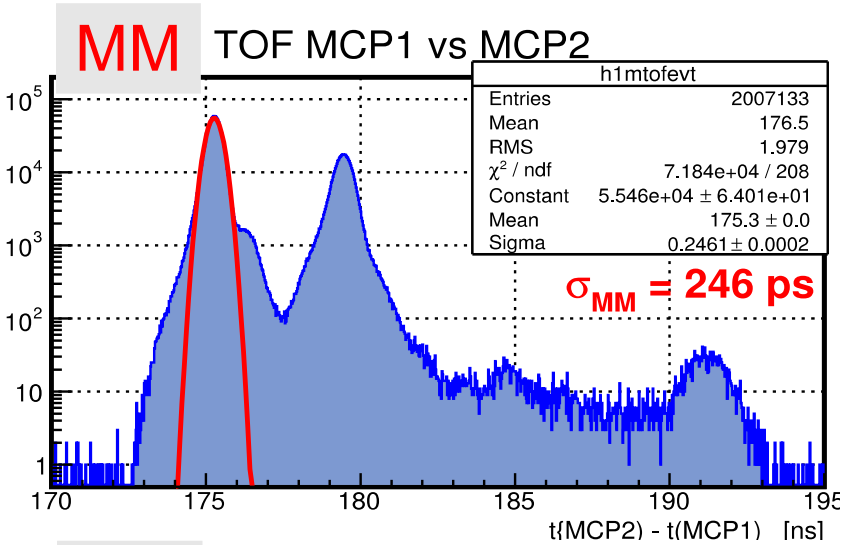
Corrections Applied to TOF Analysis

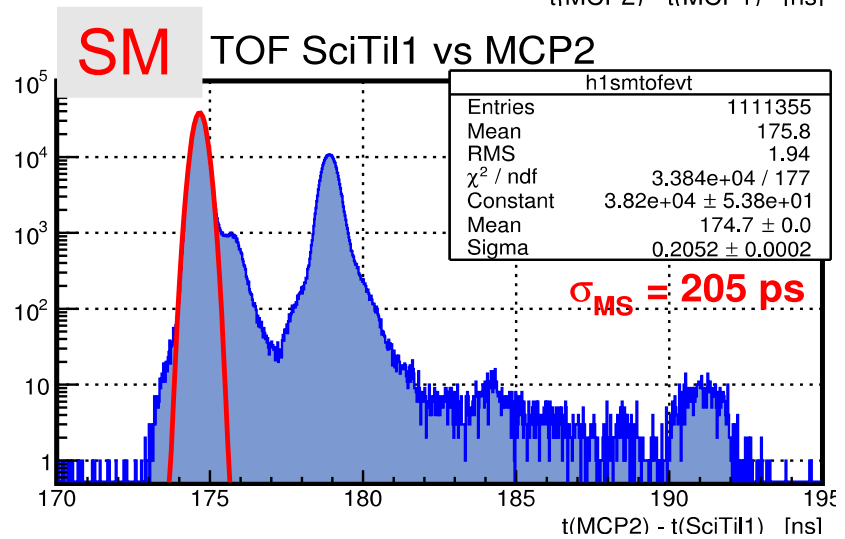
- Time of Flight (TOF)
  - Create 2D histo TOF vs EventNumber
  - Determine TOF positions after ~10k Events using TProfile
  - → event wise correction of TOF (T2 – T1) position
- Time over Threshold (ToT)
  - Create 2D histo ToT vs EventNumber
  - Determine ToT position after ~10k Events using TProfile
  - → event wise correction of ToT1 and ToT2
- Time Walk of corrected TOF and ToT1 and ToT2
  - Create 3D histo from TOF vs ToT1 vs ToT2
  - TProfile2D gives TOF position dependent on ToT1 and ToT2
  - → corrected TOF

Corrected TOF Resolution (3 GeV/c)

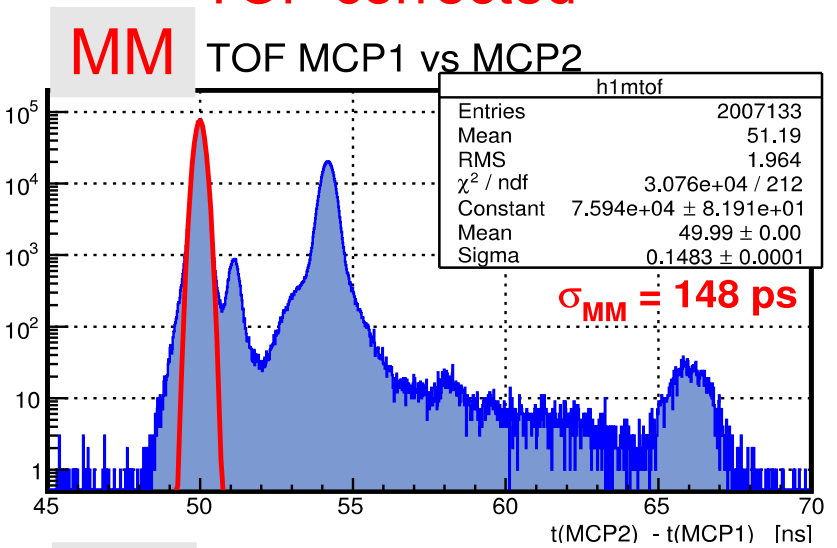
Readout with 2 TRB boards

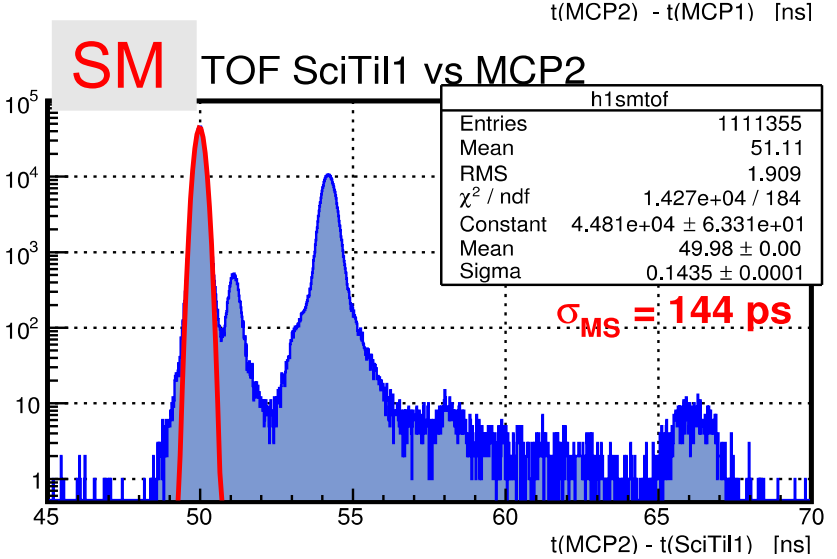
TOF uncorrected





TOF corrected



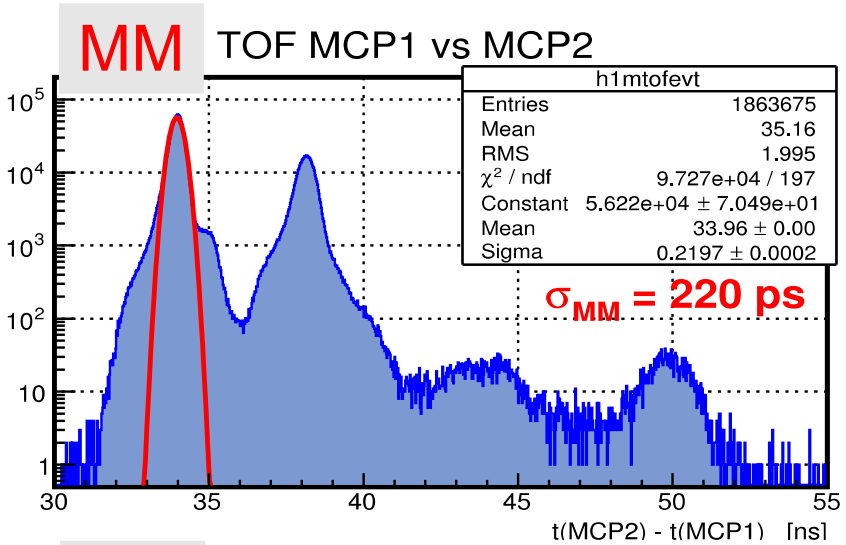


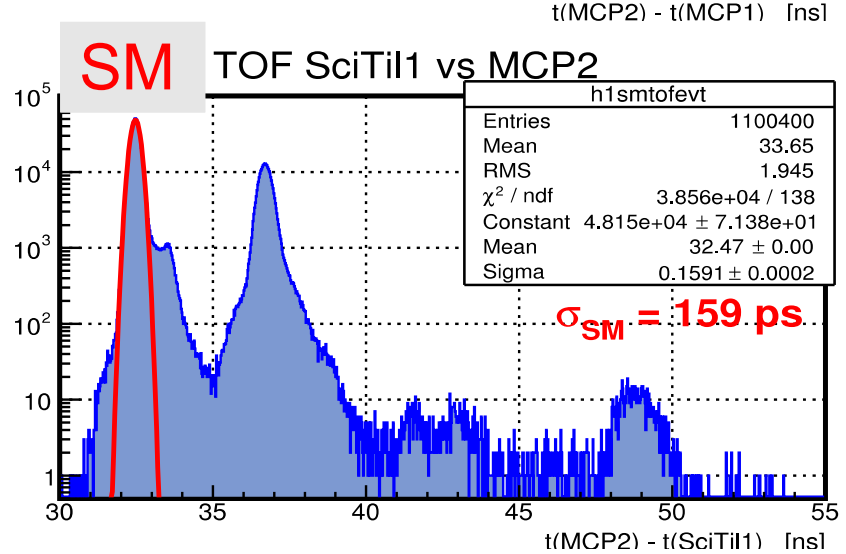
- Significantly improved TOF resolution after corrections

Corrected TOF Resolution (3 GeV/c)

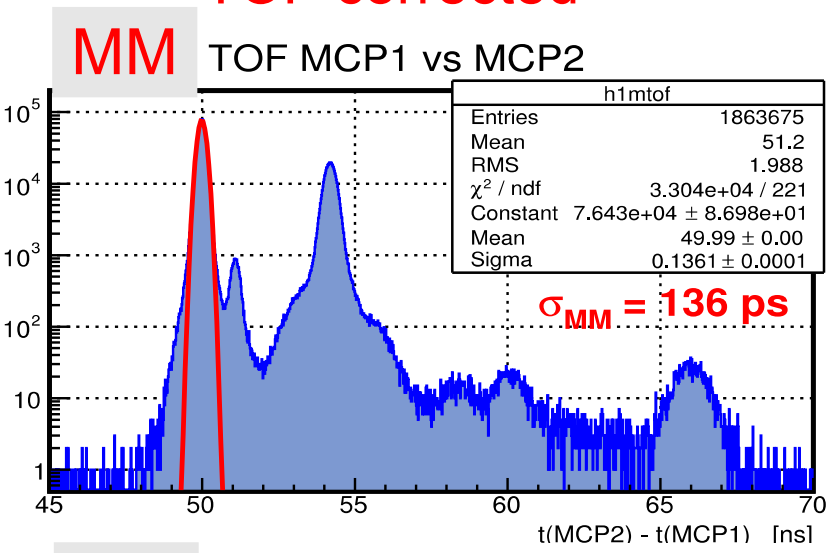
Readout with 1 TRB board
+ long aircell cables

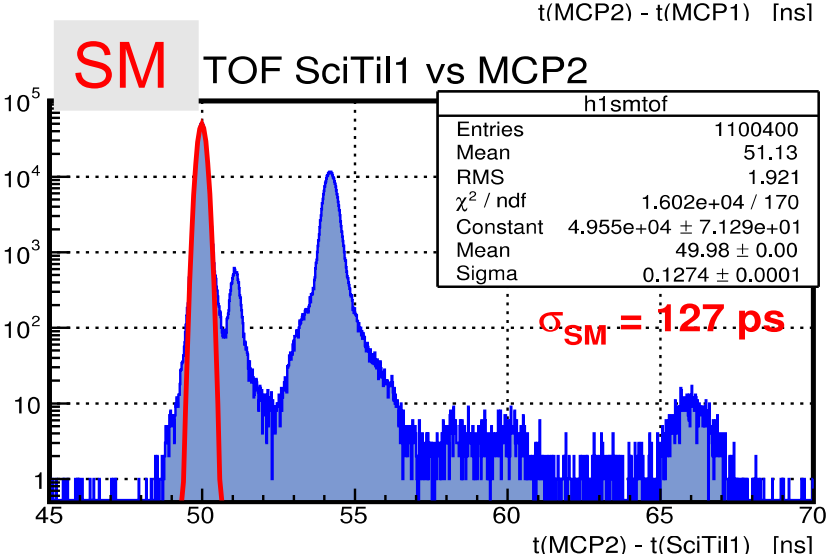
TOF uncorrected





TOF corrected

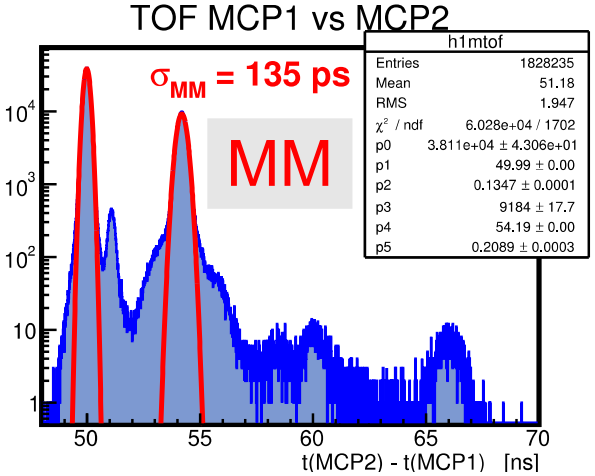


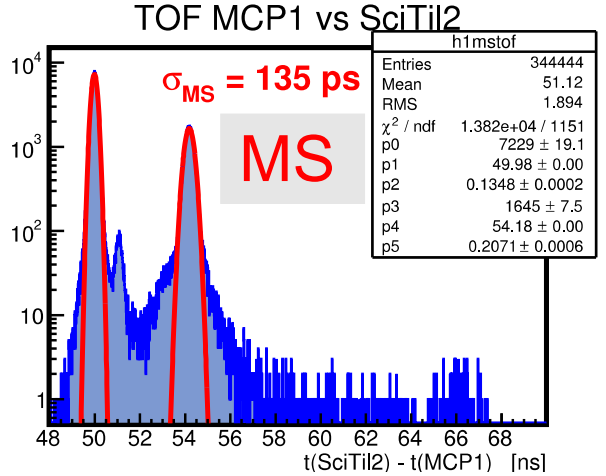


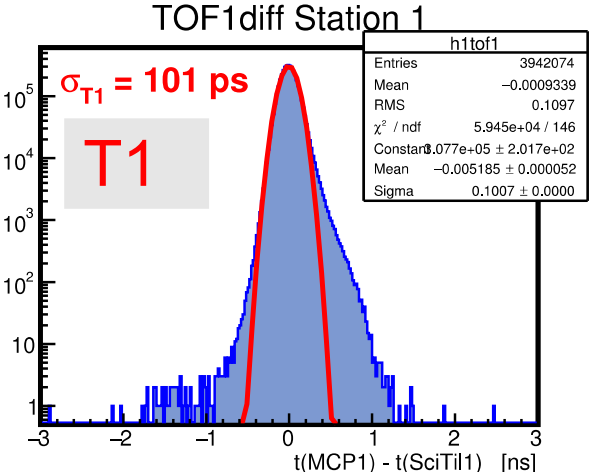
- TOF resolutions with aircell cables and 1 TRB better than with 2 TRBs

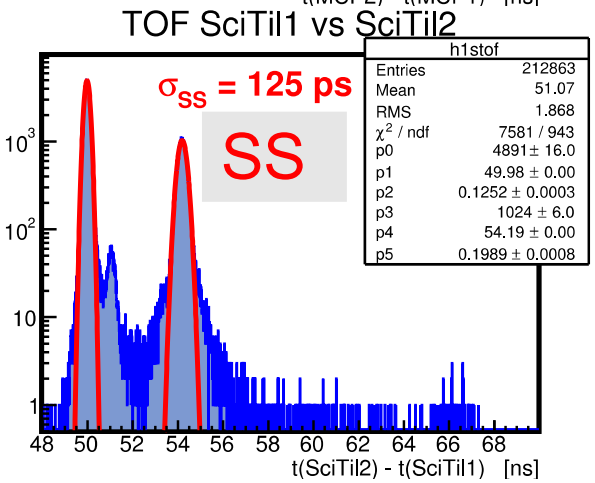
TOF Fits (3 GeV/c, all MCP Pixels)

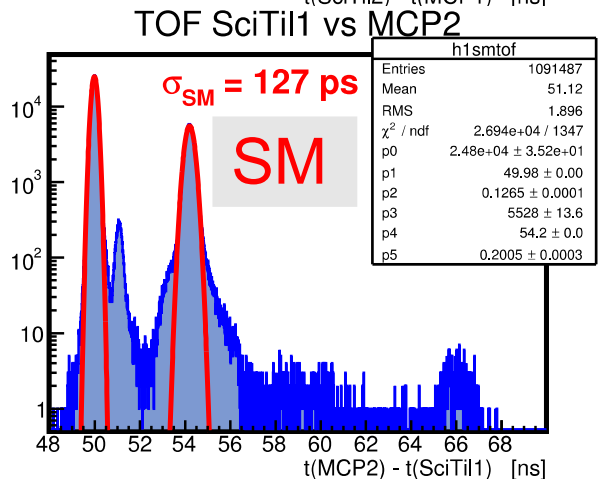
Readout with 1 TRB board
+ long aircell cables

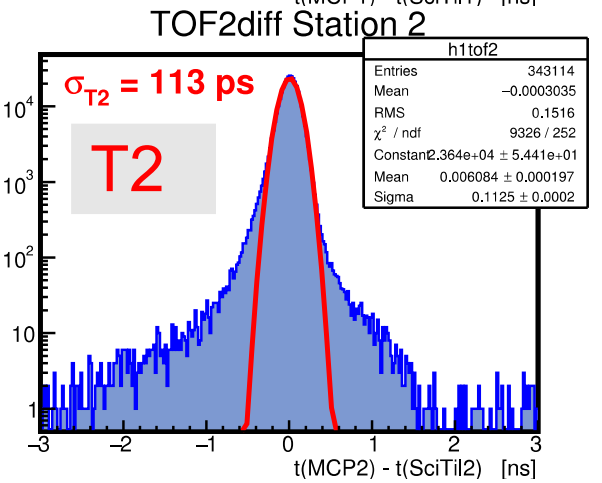








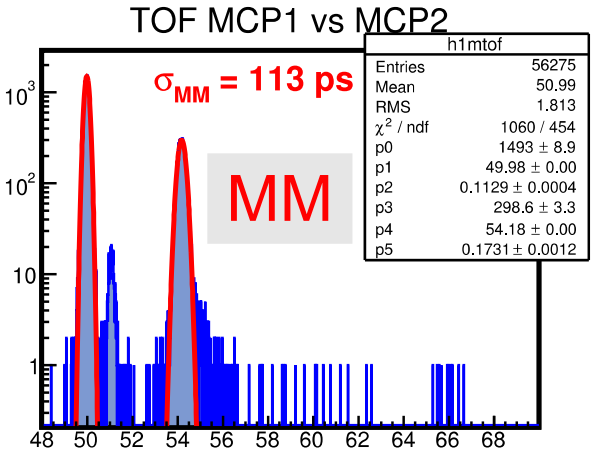


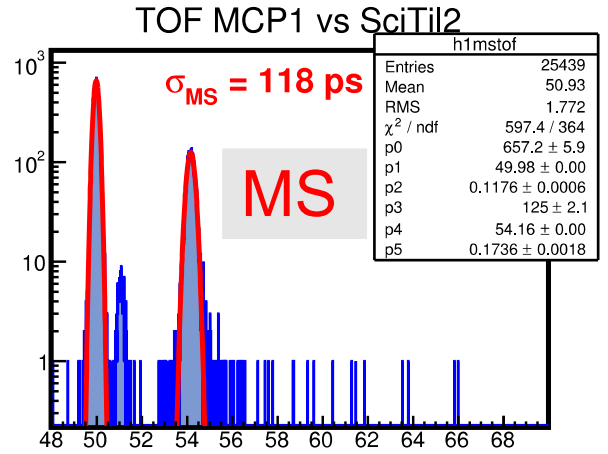


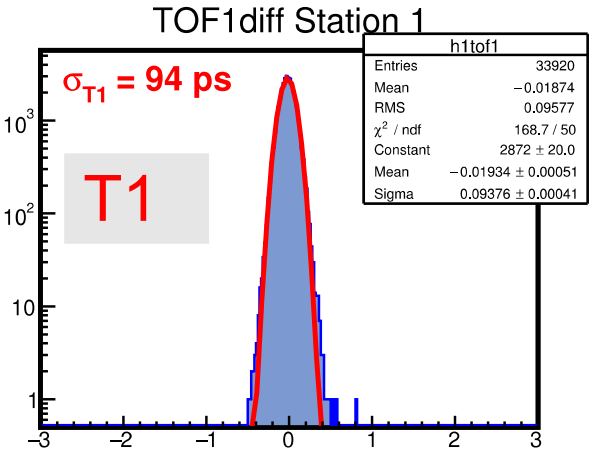
- Corrected TOF distributions of all MCP pixels (MCPout signal)
- Moderate resolutions for all 6 counter combinations

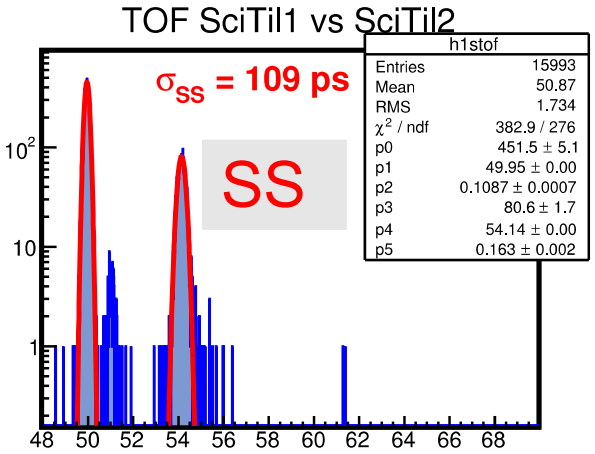
TOF Fits (3 GeV/c, one MCP Pixel)

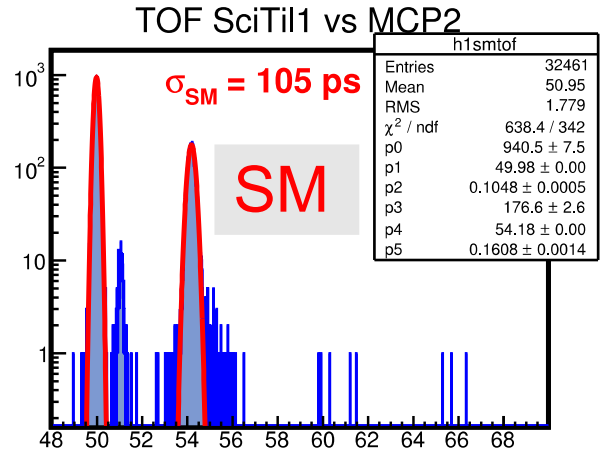
Readout with 1 TRB board
+ long aircell cables

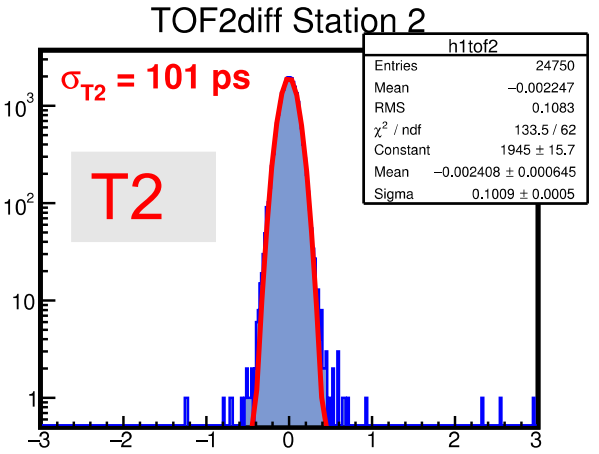












- Corrected TOF distributions (both MCPout signals with trigger on px 4/4)
- better resolutions than with all pixels for the 6 counter combinations
- A lot less statistics but also less background

Determination of Time Resolutions

$$\sigma_{MM} = TOFres(MCP\,2 - MCP\,1)$$
$$\sigma_{SS} = TOFres(SciTil\,2 - SciTil\,1)$$
$$\sigma_{SM} = TOFres(MCP\,2 - SciTil\,1)$$
$$\sigma_{MS} = TOFres(SciTil\,2 - MCP\,1)$$
$$\sigma_{T1} = TOFres(MCP\,1 - SciTil\,1)$$
$$\sigma_{T2} = TOFres(MCP\,2 - SciTil\,2)$$

$$\sigma_{M1} = TimeRes(MCP\,1)$$
$$\sigma_{M2} = TimeRes(MCP\,2)$$
$$\sigma_{S1} = TimeRes(SciTil\,1)$$
$$\sigma_{S2} = TimeRes(SciTil\,2)$$
$$\sigma_{beam} = TimeRes(Beam, Clock, \ldots)$$

$$\sigma^2_{MM} = \sigma^2_{M1} + \sigma^2_{M2} + \sigma^2_{beam}$$
$$\sigma^2_{SS} = \sigma^2_{S1} + \sigma^2_{S2} + \sigma^2_{beam}$$
$$\sigma^2_{MS} = \sigma^2_{M1} + \sigma^2_{S2} + \sigma^2_{beam}$$
$$\sigma^2_{SM} = \sigma^2_{S1} + \sigma^2_{M2} + \sigma^2_{beam}$$
$$\sigma^2_{T1} = \sigma^2_{M1} + \sigma^2_{S1}$$
$$\sigma^2_{T2} = \sigma^2_{M2} + \sigma^2_{S2}$$

- 6 measured TOF resolutions
- 4 counter + 1 “beam” resolutions
- 6 equations, 5 unknowns
  - Create 6 bin histogram with individual TOF resolutions
  - ROOT least square using Minuit
- → **Resolution of each counter**

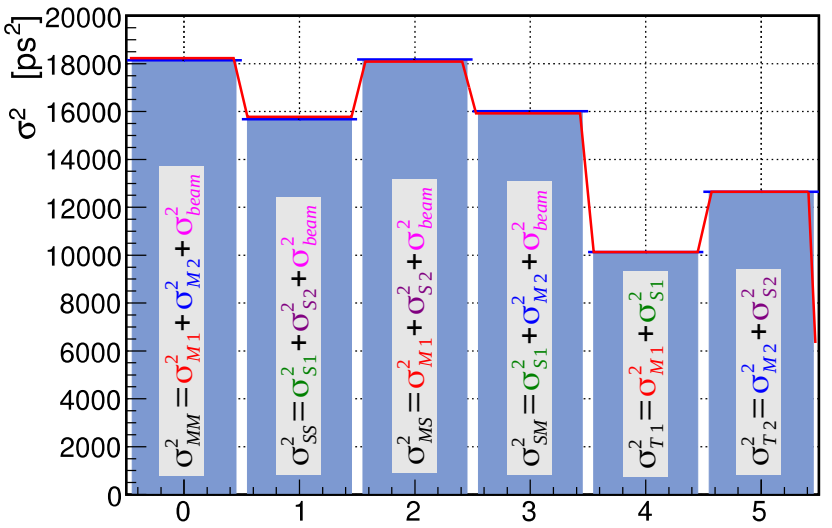
Obtain Counter Time Resolutions

- 6 TOF values and 5 unknown counters
- Solve with ROOT least square fit (Minuit)
- Create 6 bin histogram with TOF values of different combination put to one bin each
- Define a function which contains all counter resolutions as free parameters
- Use ROOT Fit method

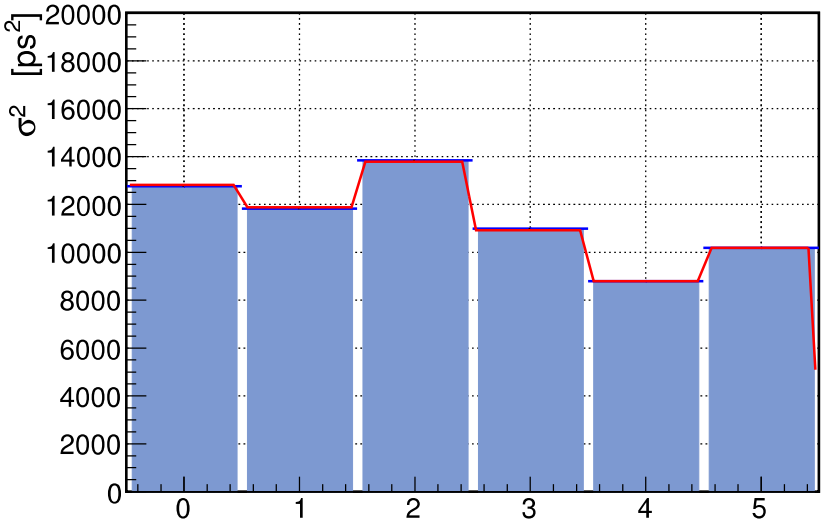
```
Double_t LinEq(Double_t *x, Double_t *par)
{
 Double_t xval = 0.;
 if (x[0] < 0.5)       // MCP2 - MCP1
   xval = par[0] + par[2] + par[4];
 else if (x[0] < 1.5)  // SciTil2 - SciTil1
   xval = par[1] + par[3] + par[4];
 else if (x[0] < 2.5)  // SciTil2 - MCP1
   xval = par[0] + par[3] + par[4];
 else if (x[0] < 3.5)  // MCP2 - SciTil1
   xval = par[1] + par[2] + par[4];
 else if (x[0] < 4.5)  // MCP1 - SciTil1
   xval = par[0] + par[1];
 else if (x[0] < 5.5)  // MCP2 - SciTil2
   xval = par[2] + par[3];

  return xval;
}
```

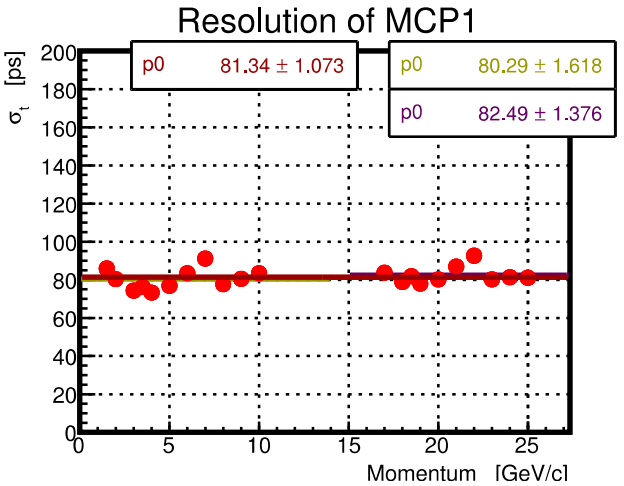
Pions 3 GeV/c all MCP pixels

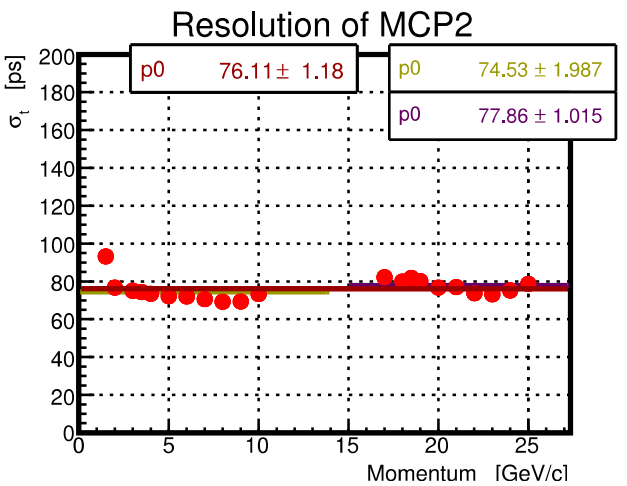


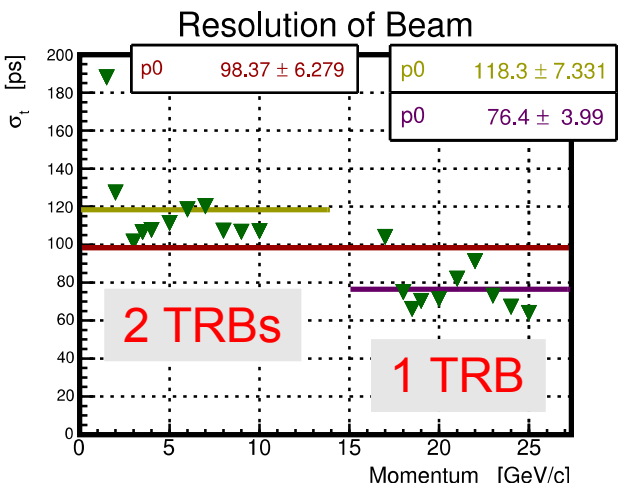
Pions 3 GeV/c one central MCP pixel (4/4)

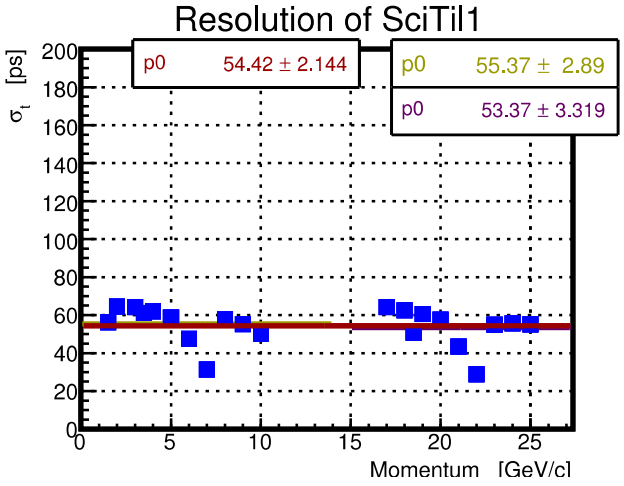


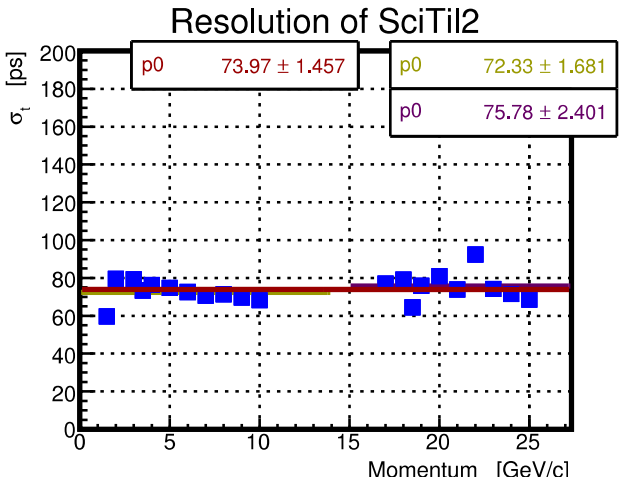
Counter Resolutions (all Momenta)









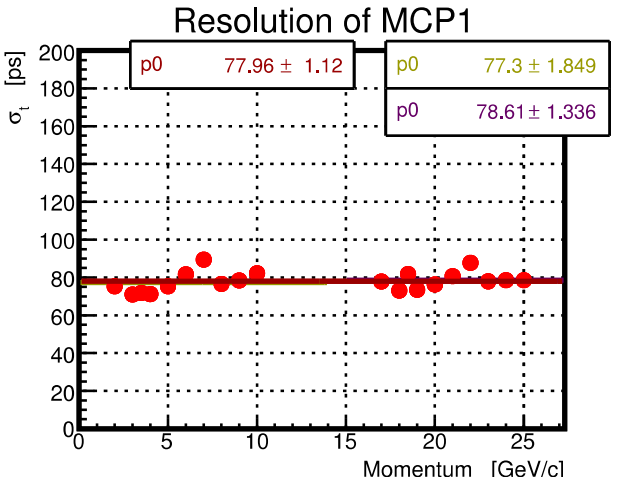


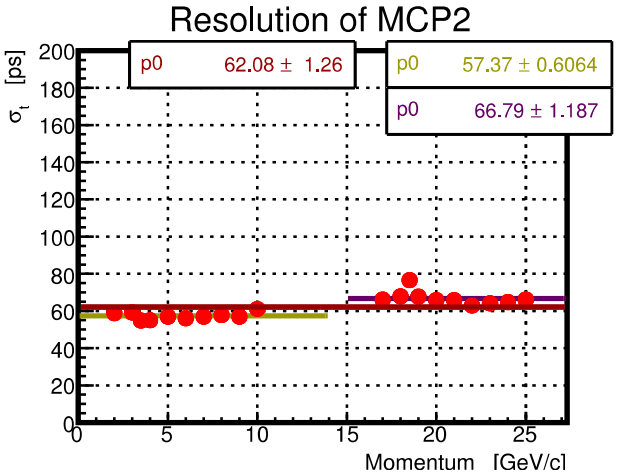
All MCP pixels

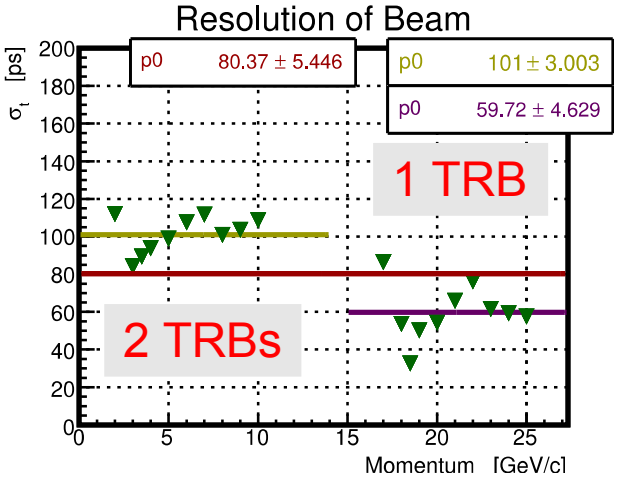
$$\sigma_{M1} = (81 \pm 1)\,ps$$
$$\sigma_{M2} = (76 \pm 1)\,ps$$
$$\sigma_{S1} = (54 \pm 2)\,ps$$
$$\sigma_{S2} = (74 \pm 2)\,ps$$
$$\sigma_{beam,\,2\,TRBs} = (118 \pm 7)\,ps$$
$$\sigma_{beam,\,1\,TRB} = (76 \pm 4)\,ps$$

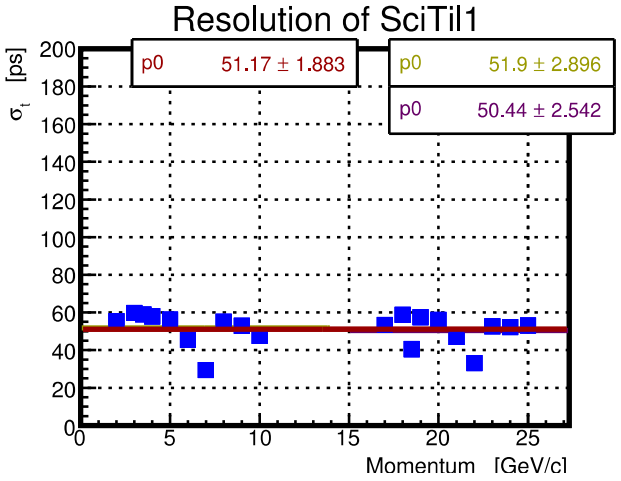
- Different resolutions for σ_{beam} with 2 TRBs and with 1 TRB
- Counter resolutions roughly independent of TRB setup

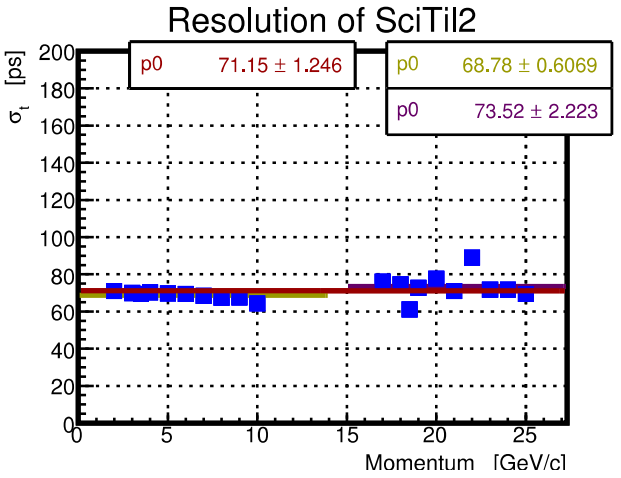
Counter Resolutions (all Momenta)











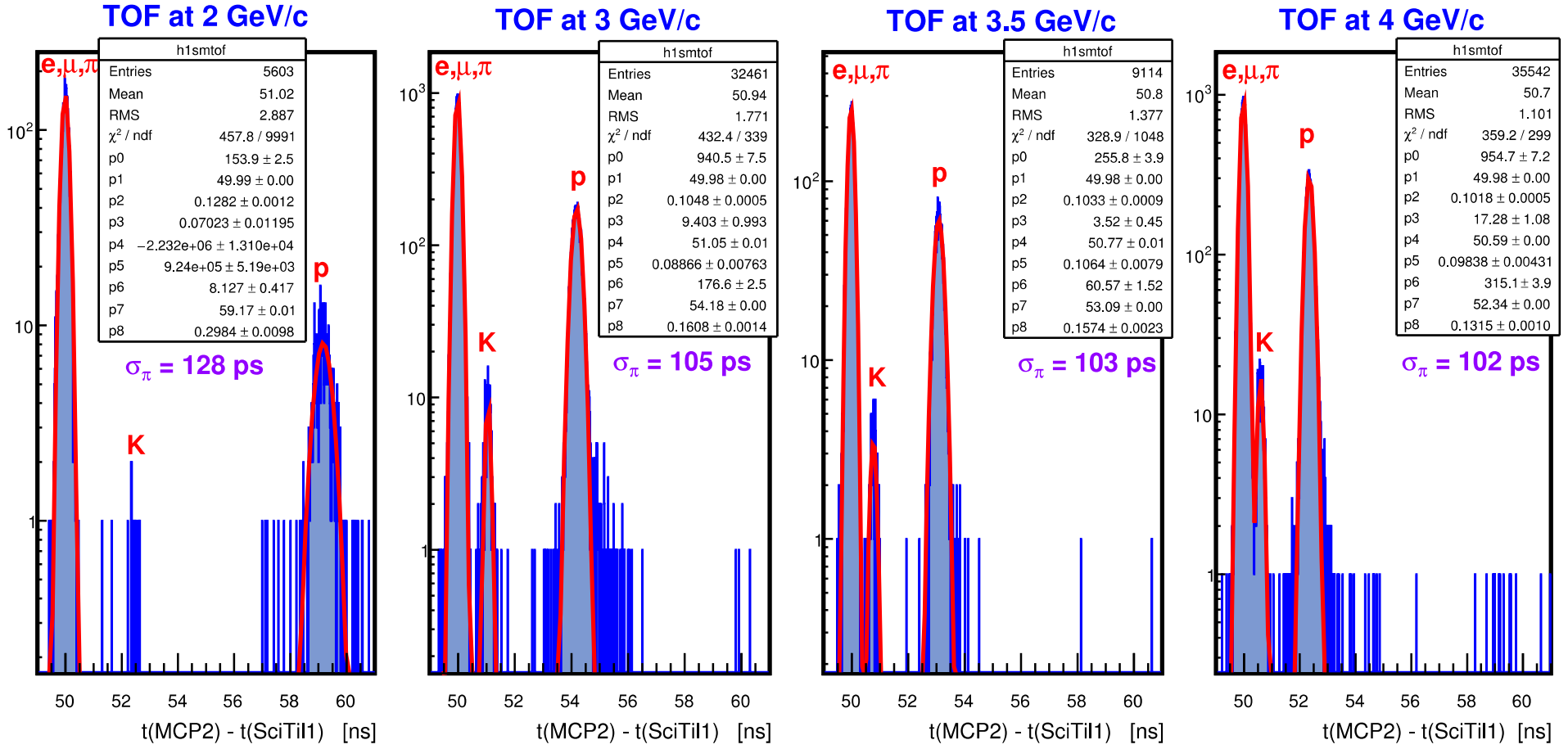
$$\sigma_{M1} = (78 \pm 1)\,ps$$
$$\sigma_{M2} = (62 \pm 1)\,ps$$
$$\sigma_{S1} = (51 \pm 2)\,ps$$
$$\sigma_{S2} = (71 \pm 2)\,ps$$
$$\sigma_{beam,\,2\,TRBs} = (101 \pm 3)\,ps$$
$$\sigma_{beam,\,1\,TRB} = (60 \pm 5)\,ps$$

One MCP pixel (4/4)

- Different resolutions for σ_{beam} with 2 TRBs and with 1 TRB → reftime!
- Counter resolutions slightly better than for readout of all pixels

TOF and PID at 2 – 4 GeV/c

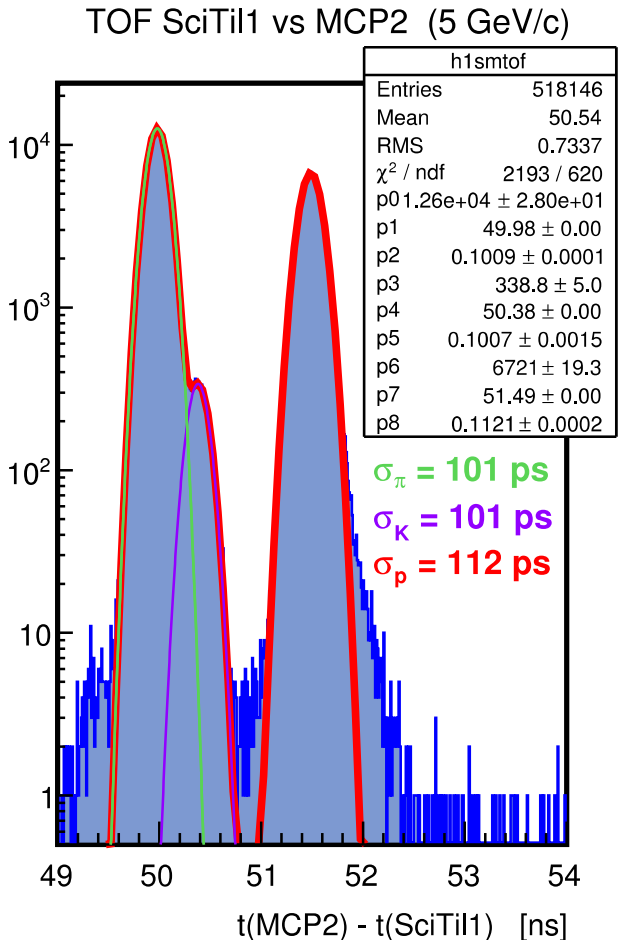
Readout with 1 TRB board
+ long aircell cables

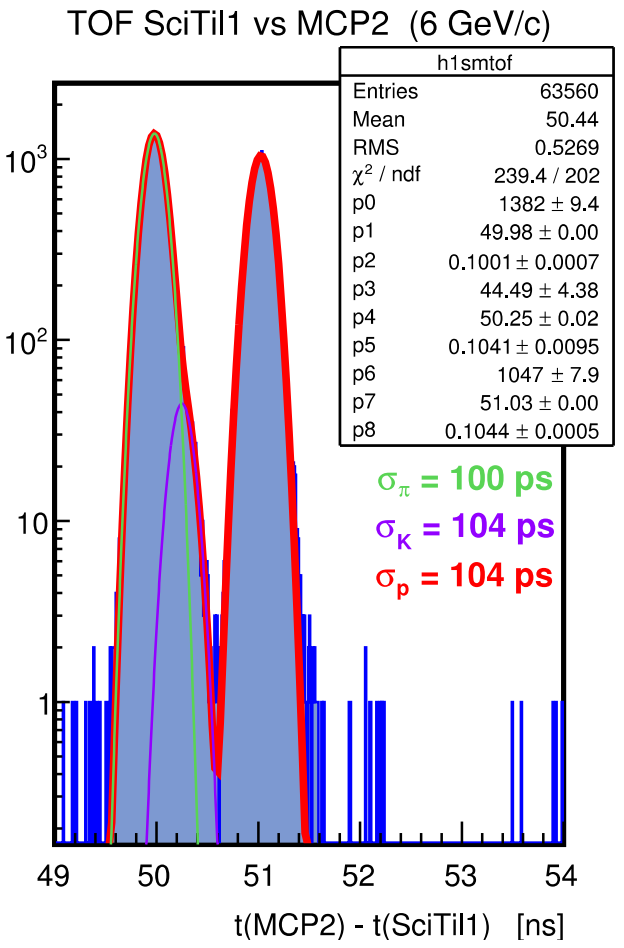


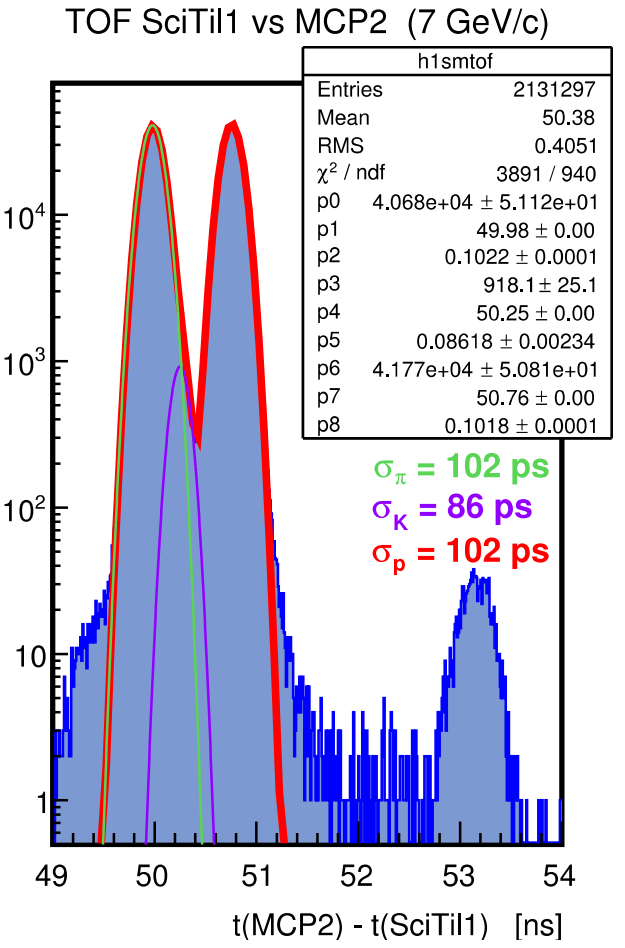
- MCP2out – (SciTil1_l + SciTil1_r)/2 with trigger at pixel 4/4 (MCP1+2)
- Pions, kaons and protons clearly separable up to 4 GeV/c
- TOF Resolution ~105 ps (worse for 2 GeV/c)

TOF and PID at 5 – 7 GeV/c

Readout with 1 TRB board
+ long aircell cables



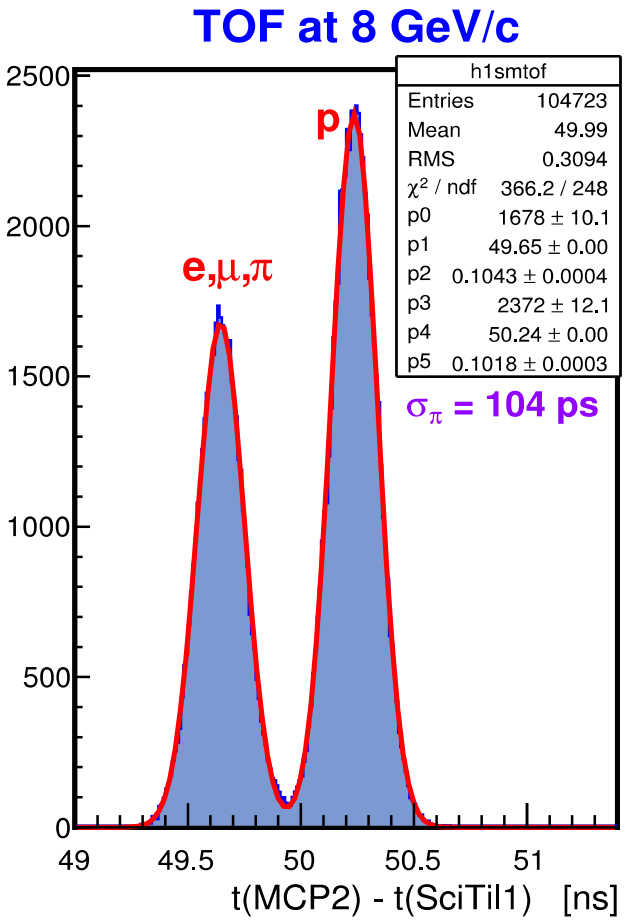


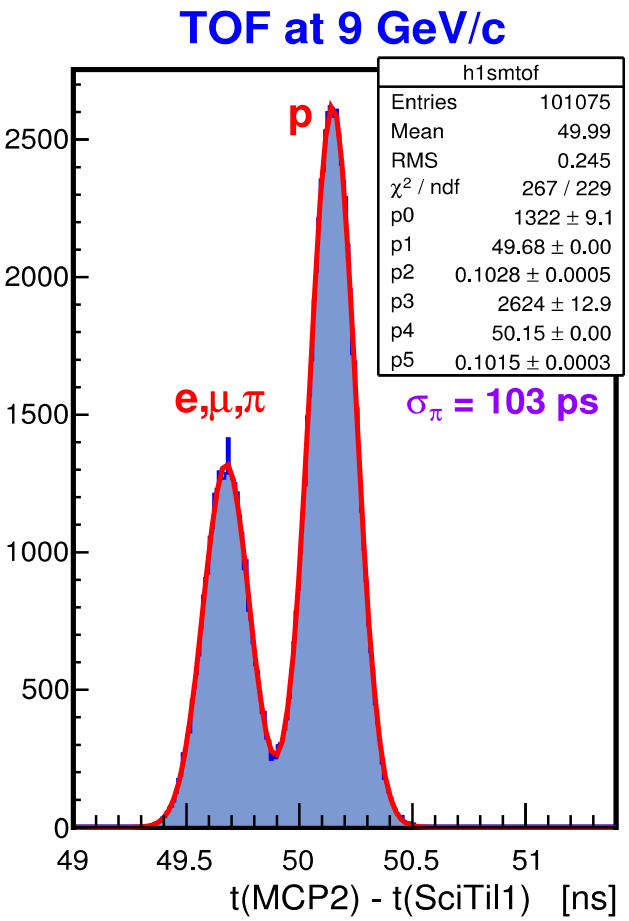


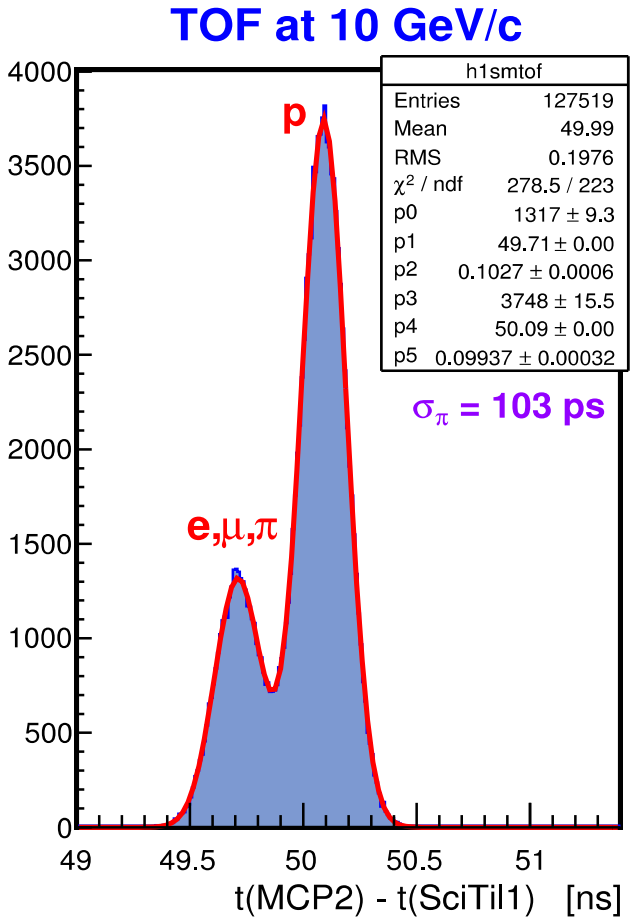
- MCP2out – (SciTil1_l + SciTil1_r)/2 with trigger at pixel 4/4 (MCP1+2)
- TOF resolutions ~100 ps for all particles (π, K, p)
- Kaons also separable at 5 GeV/c, and fitable up to 7 GeV/c

TOF and PID at 8 – 10 GeV/c

Readout with 1 TRB board
+ long aircell cables



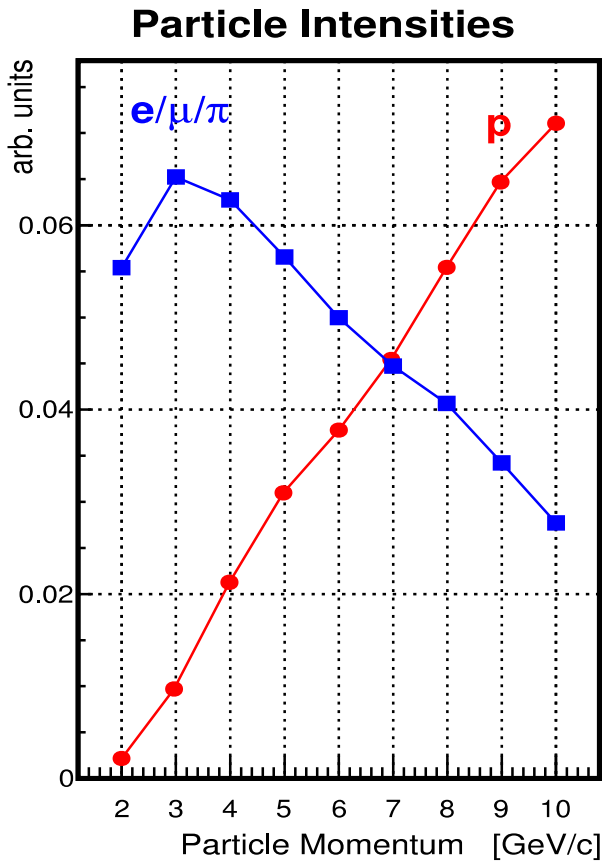


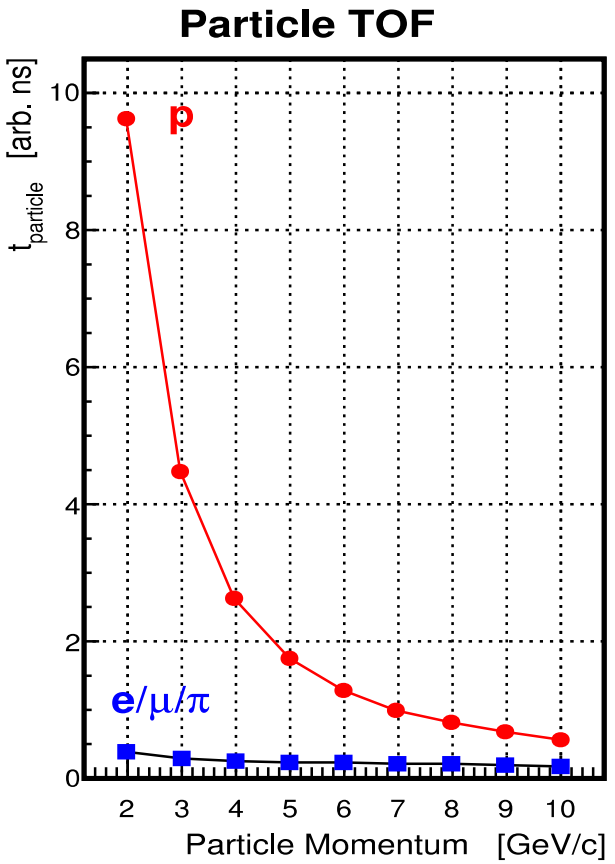


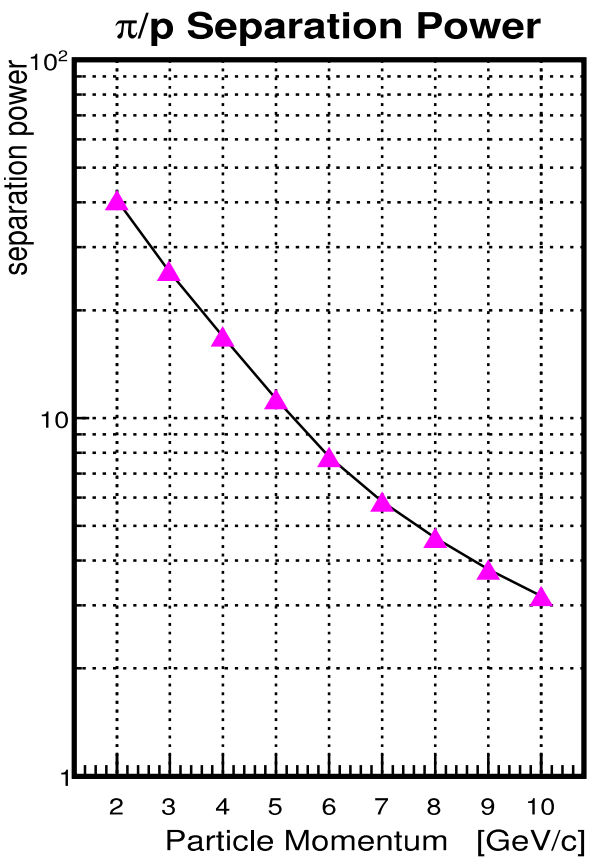
- MCP2out – (SciTil1_l + SciTil1_r)/2 with trigger at pixel 4/4 (MCP1+2)
- Pions and protons clearly separable up to 10 GeV/c
- TOF Resolution ~103 ps (slightly better for protons)

Intensities and Separation Power

!! online data without corrections yet !!



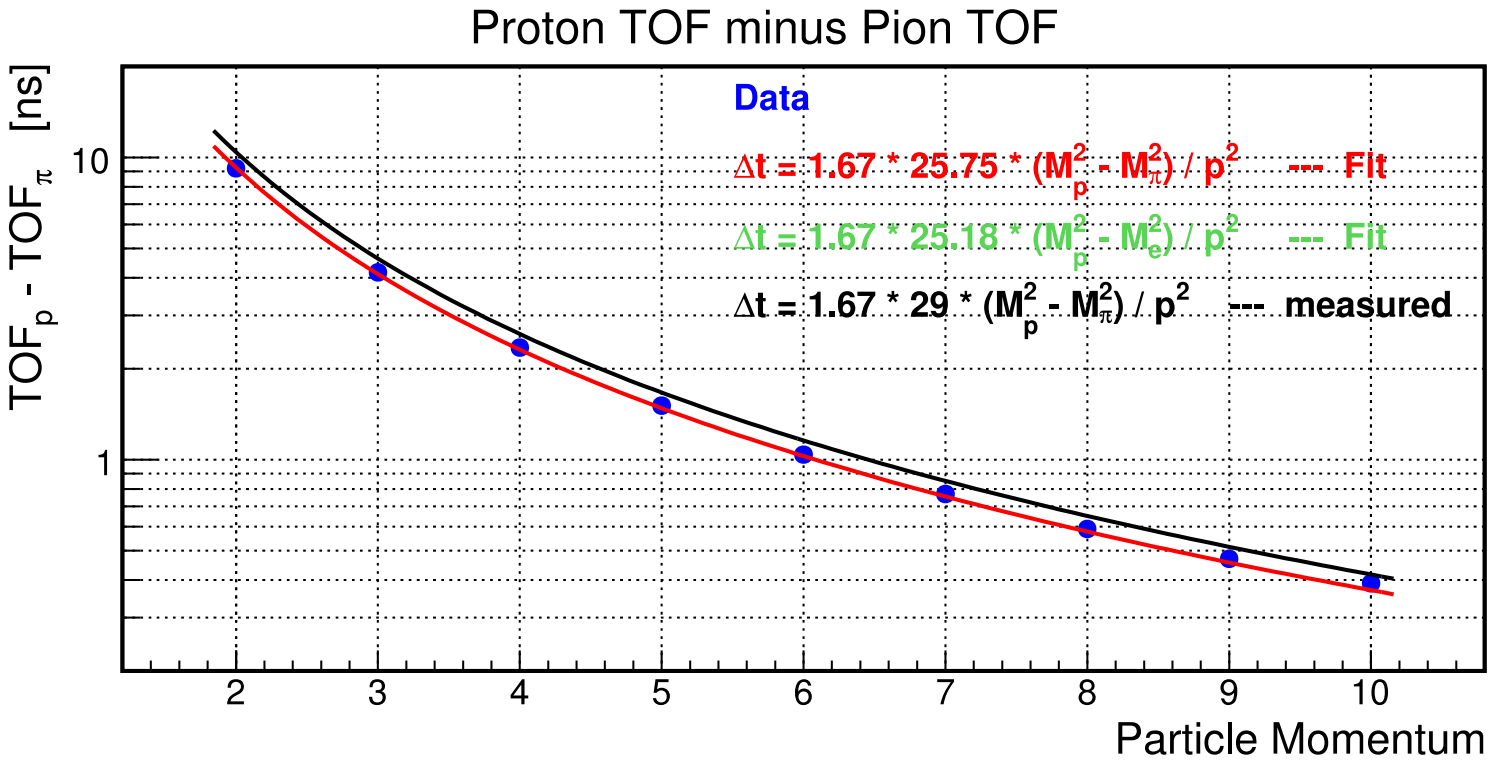




- Parallel focus; 2 TOF and 2 trigger counters in coincidence
- Particle TOFs and intensities behave as expected
- Very good separation power (even at 10 GeV/c) [not final resolution!]

Fit of Flight Path

!! from online data !!



- Fitted flight path is 3-4 m (~10 – 12%) lower than measured
- Other possible interpretations:
  - Beam momentum is wrong by 3 – 4% (seems unlikely)
  - TDC calibration is off by 10 – 12%

Summary

- All MCP-TOF data of June/July 2015 CERN data
- TOF data show slight jumps over time
- The measured TOF combinations of the 4 used counters are a powerful tool to determine the time resolution of each counter
  - MCP time resolutions between 60 and 80 ps
  - SciTil time resolutions between 50 and 70 ps
- Kaons separable from pions up to 5 GeV/c
- Pions and protons separable up to 10 GeV/c
- Fitted flight path does not correspond to measured 29 m
  → TDC calibration off ?