Luminosity Measurement at COMPASS

Christian Höppner - Technische Universität München
for the COMPASS Collaboration

SPIN Praha - July 2010

Outline

- Motivation and Introduction
- Data selection
- Beam flux measurement
- Dead-time corrections: DAQ and μ^+-veto system
- Luminosity results
- Conclusion and Outlook

Motivation

- COMPASS can contribute to global Δg analysis "a la RHIC":
- Double spin asymmetries of high-p_T hadron production cross section at low Q^2 (quasi-real photons)
- To evaluate the applicability of the pQCD framework used for the analysis, the unpolarized cross section has to be evaluated
- Calculations were done for π^0 production so far, but will be updated for charged hadron production soon

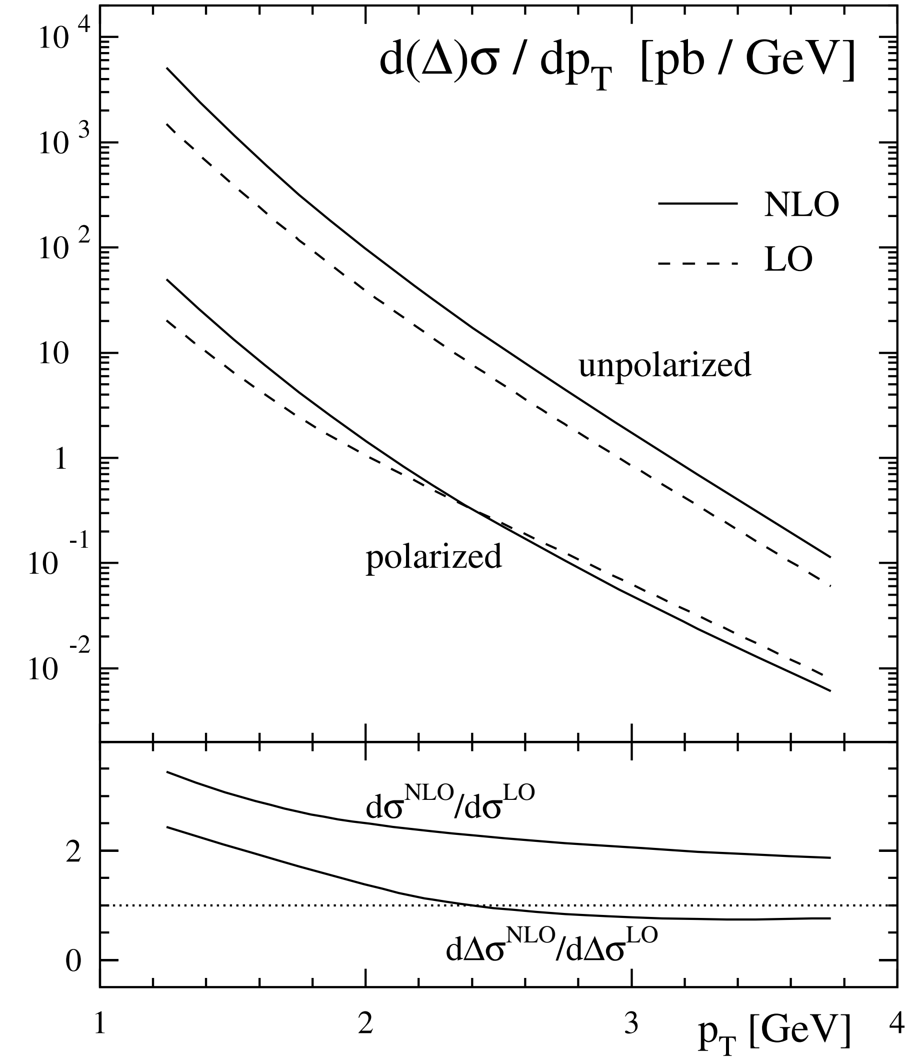


Fig. 2. Unpolarized and polarized p_T-differential single-inclusive cross sections at LO (dashed) and NLO (solid) for the photoproduction of neutral pions, $\mu d \to \mu' \pi^0 X$ at $\sqrt{S} = 18\,\text{GeV}$, integrated over the angular acceptance of Compass. The lower panel shows the ratios of NLO to LO contributions (K-factor)

[Jäger et al., Eur. Phys. J. C44 (2005) 533-543]

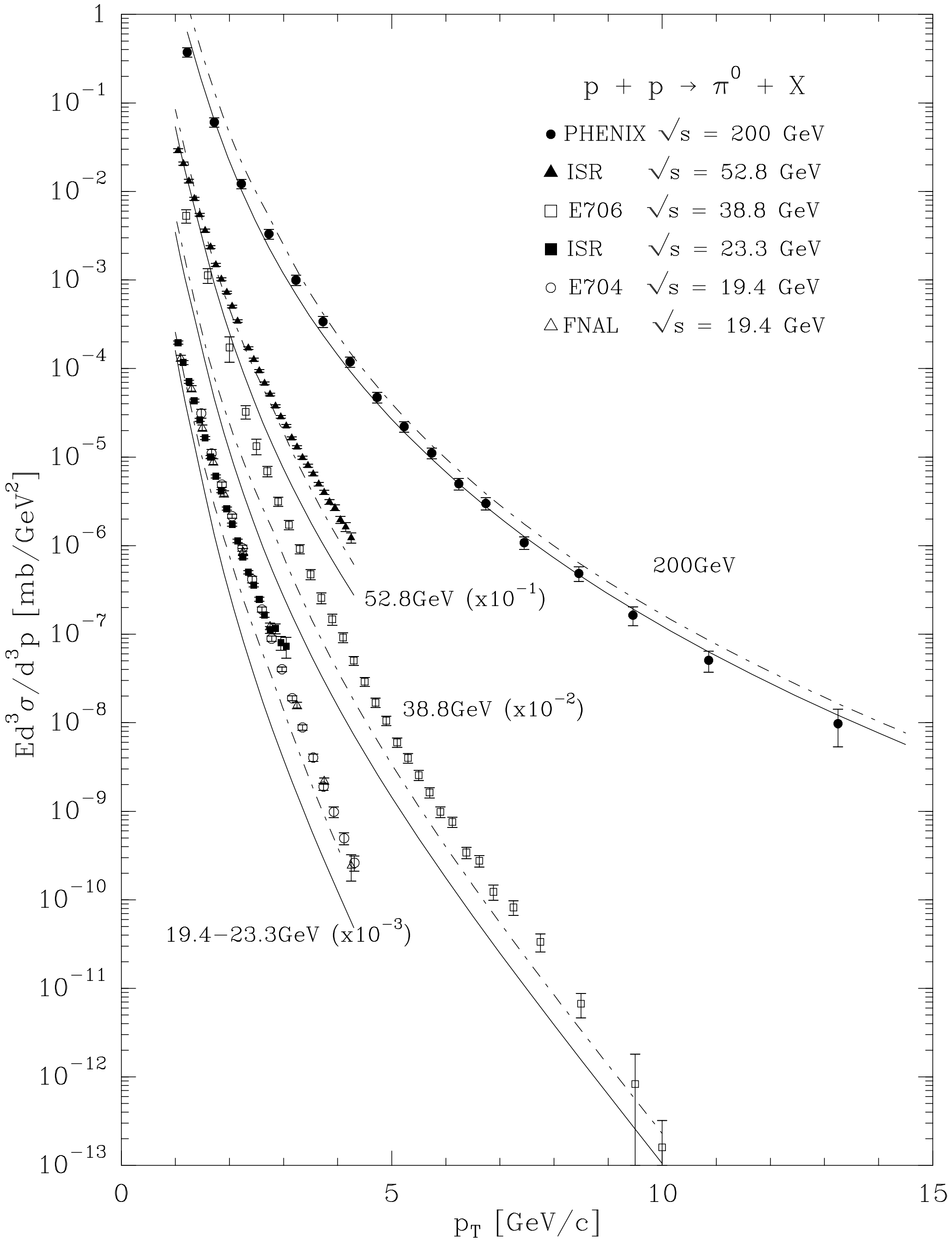
Motivation

- Is the pQCD framework by Stratmann, Vogelsang, et al. applicable at our center of mass energy (18 GeV)?
  Can it be used to extract information on Δg from our high p_T data at low Q^2?

- pQCD does not yet predict cross sections for high-p_T hadron production at lower center of mass energies (experiments systematically larger)

- Relevance of all-order resummations of large logarithms in the perturbative series?
  [de Florian & Vogelsang, Phys. Rev. D 71, 114004 (2005)]

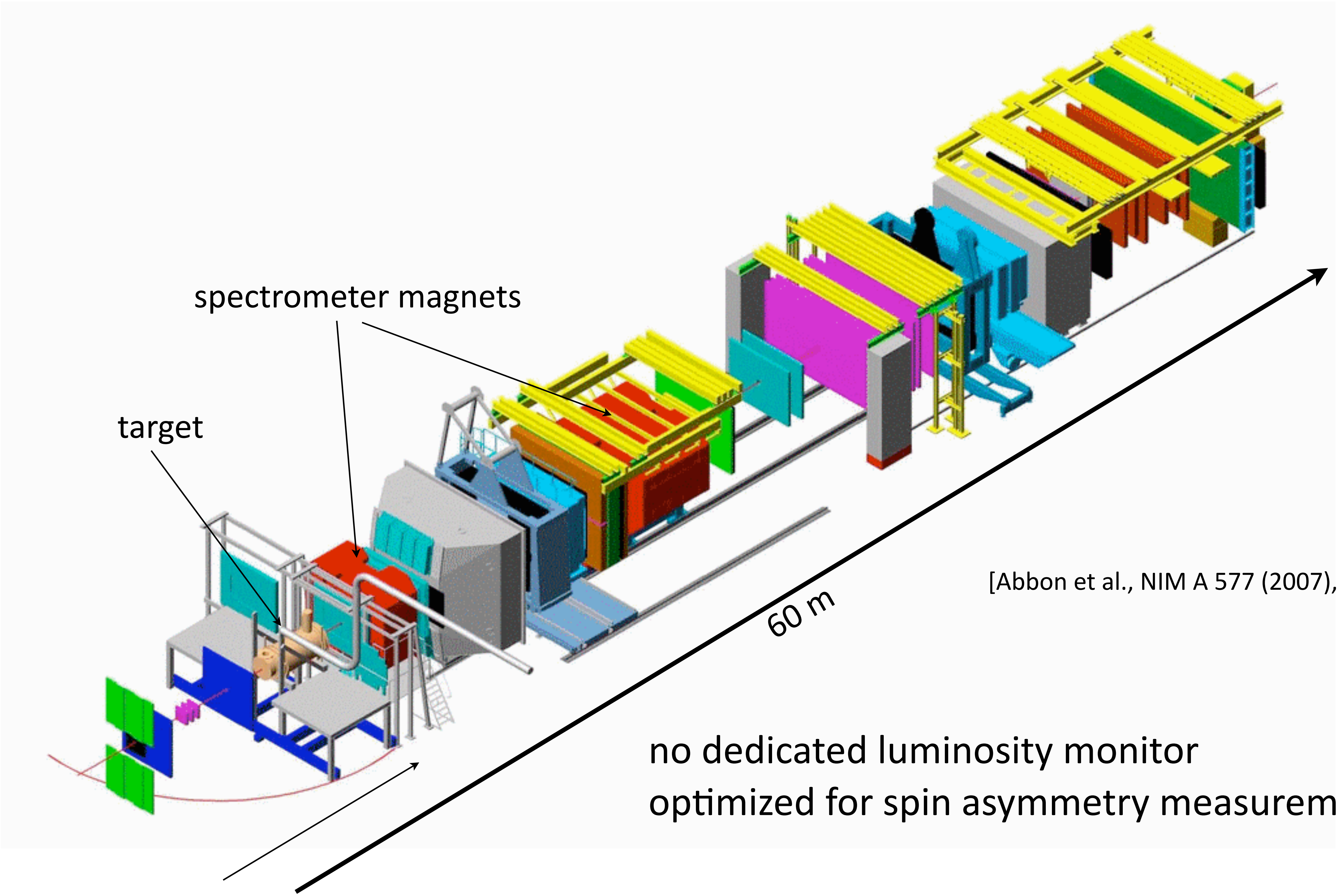
- Impact on other kinds of physics e.g. pQCD calculations for transverse spin physics, ...



[Bourrely & Soffer, Eur. Phys. J. C 36, 371-374]

Figure 2: $Ed^3\sigma/d^3p$ at 90^o and various energies, as a function of p_T. Data are from Refs. [11, 16, 19, 20, 21] and the curves are the corresponding NLO pQCD calculations with $\mu = p_T$ (solid lines) and $\mu = p_T/2$ (dotted- dashed lines).

The COMPASS Experiment at CERN SPS



[Abbon et al., NIM A 577 (2007), 455-518]

no dedicated luminosity monitor
optimized for spin asymmetry measurements

Introduction

- Cross section: $\sigma = \dfrac{\text{number of events / acceptance}}{\text{integrated luminosity}}$

- Luminosity: $$\mathcal{L} = (\text{flux of beam particles through fiducial volume in s}^{-1}) \times (\text{number of nucleons in fiducial volume per area in cm}^{-2})$$

- Effective integrated luminosity corrected for dead time:

$$\tilde{L} = \int_{\text{time in spill}} [\mathcal{L}(1 - \text{DAQ dead time})(1 - \text{veto dead time})]dt$$

Introduction

- Effective integrated luminosity corrected for dead time:

$$\tilde{L} = \int_{\text{time in spill}} [\mathcal{L}(1 - \text{DAQ dead time})(1 - \text{veto dead time})]dt$$

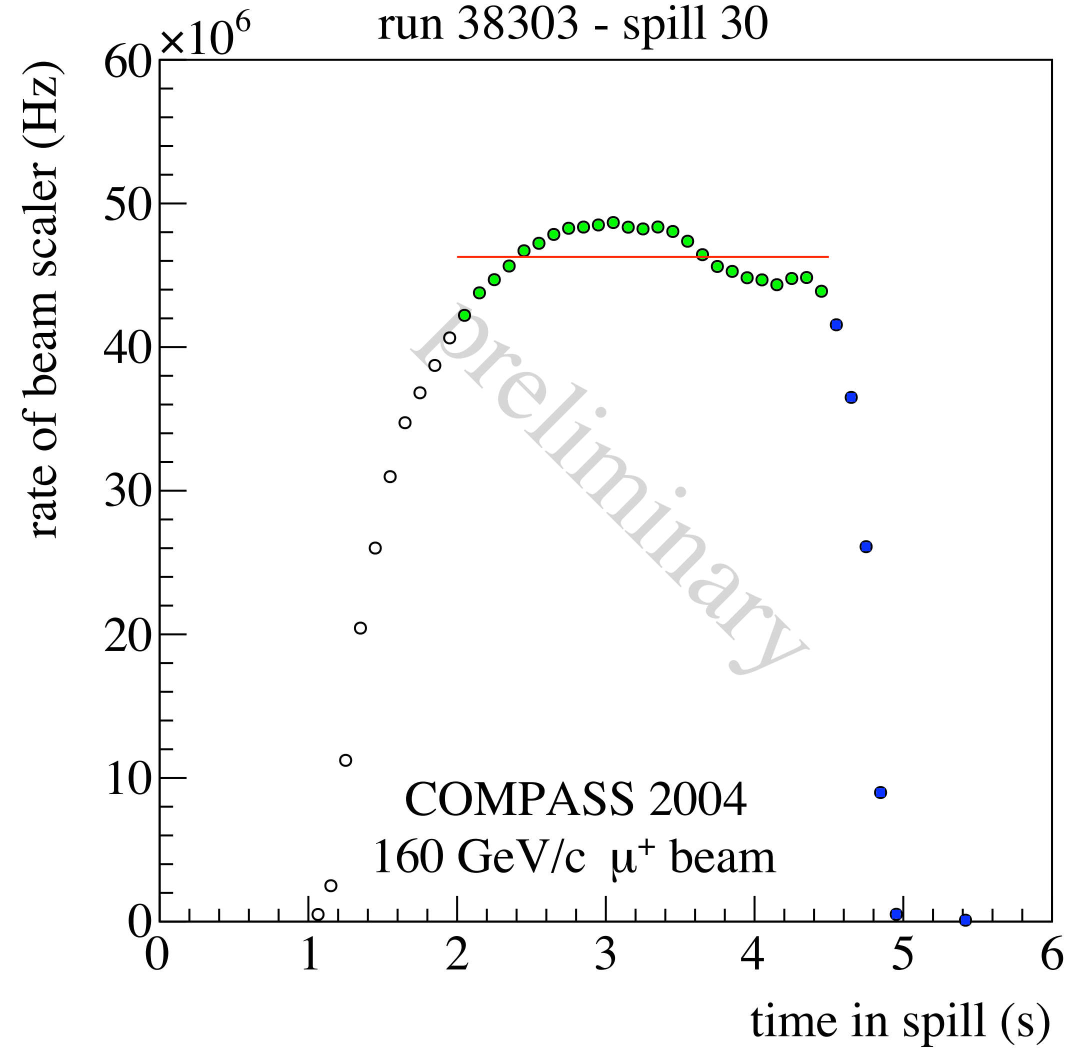
- COMPASS beam is delivered from CERN SPS in so-called spills:
  Beam for 4.8 s, no beam for 12 s (numbers for 2004)
- Intensity is rising at the beginning of spill and then becomes stable
- Intensity of beam varies between different spills
- Dead times are rate dependent:
  Determine integrated luminosity spill-by-spill

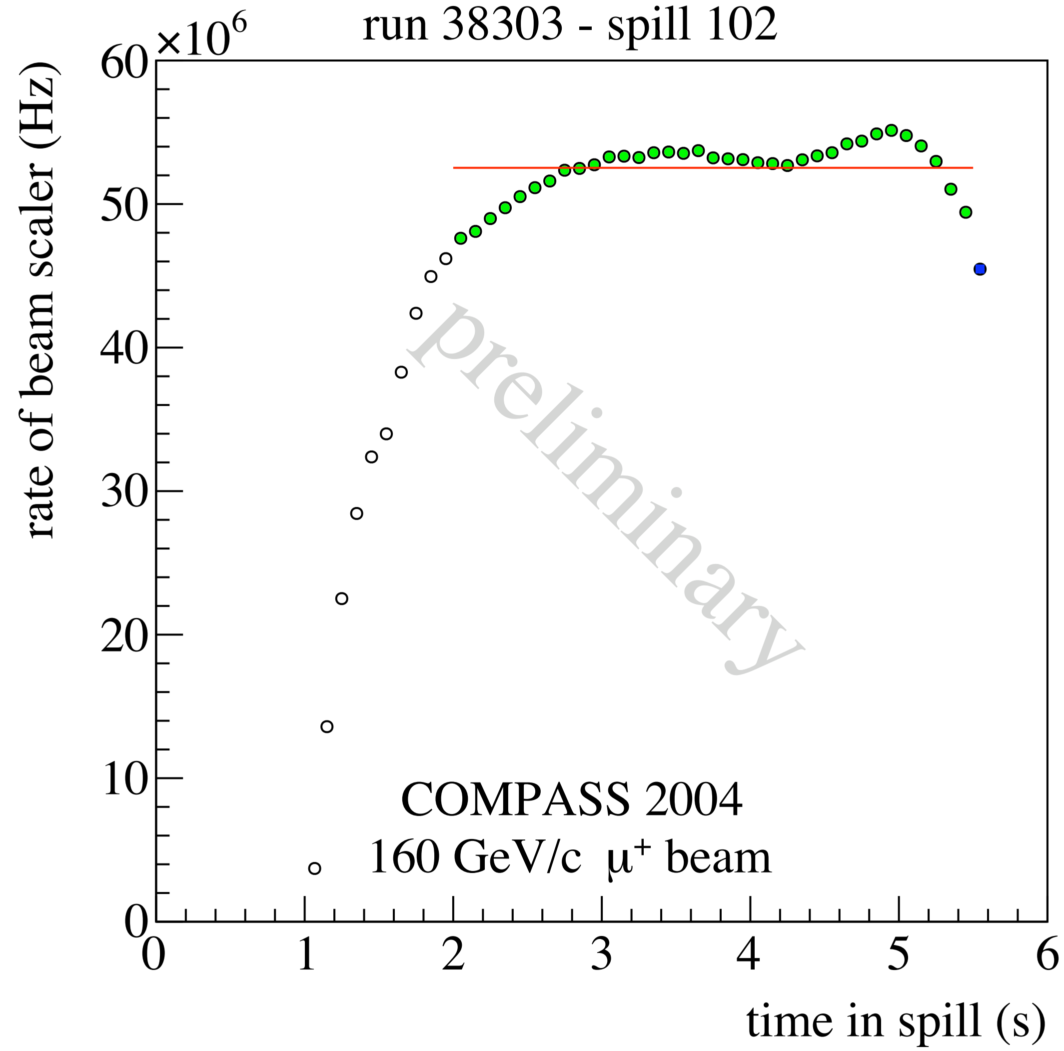
Data Set

- 2004 data is chosen for the high-p_T cross section analysis
- Low Q^2 data comes from triggers which include hodoscope signals of the scattered μ^+, and signals in the hadronic calorimeters
- After installation of an additional EM calorimeter in 2006, the threshold behavior of the hadronic calorimeter trigger has changed: Acceptance description for unpolarized measurements has become more difficult.
- Around 30% of 2004 data have been reproduced with a newer version of the reconstruction software which is used here.

Selection of Stable Beam - Flat Top

- Start evaluating events and luminosity only after $\mathbf{t_1=2\ s}$ in spill
- Evaluate events and luminosity only until beam falls below 90% of average intensity -> dynamic cut $\mathbf{t_2}$



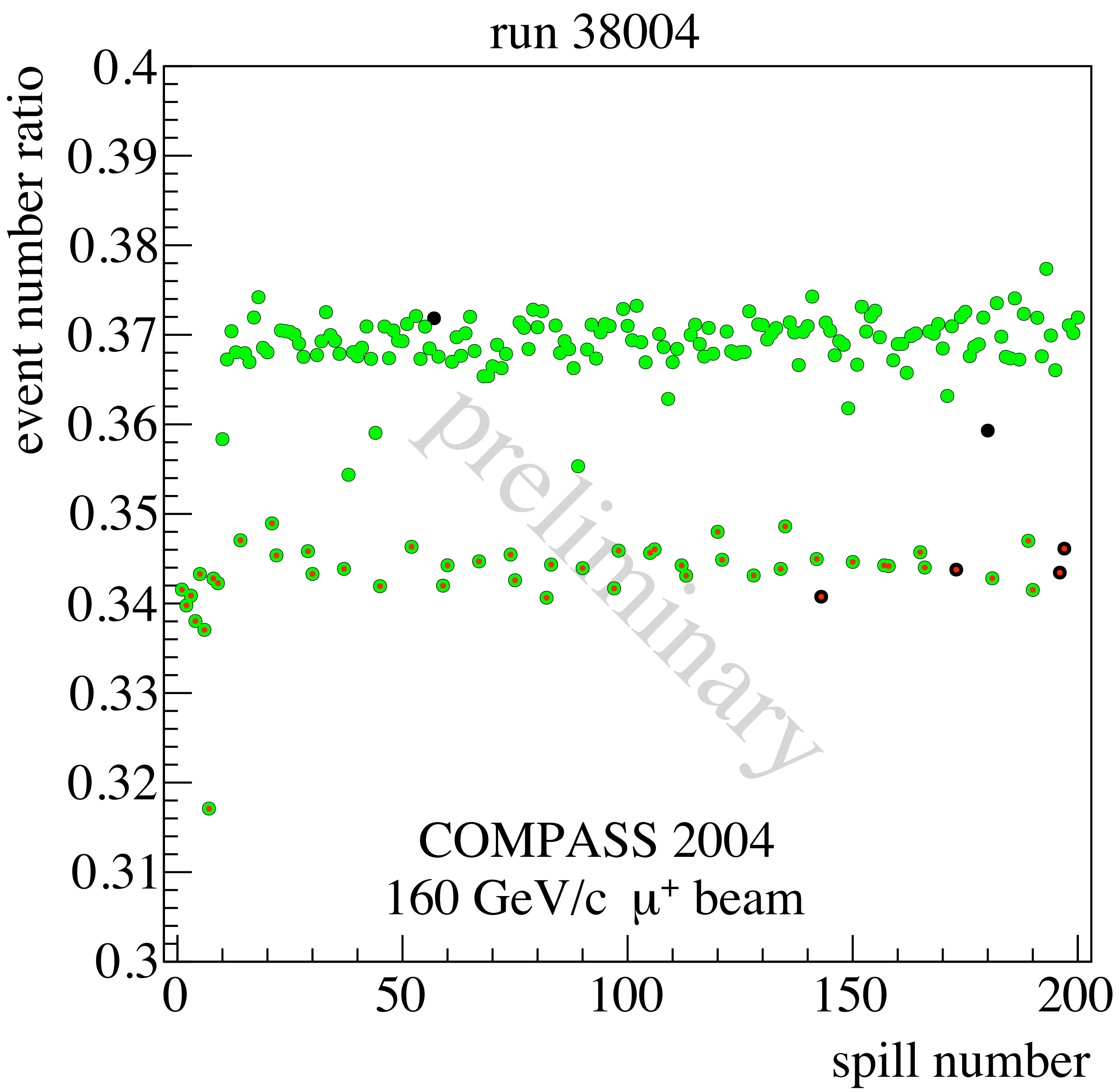


Good Spill Selection

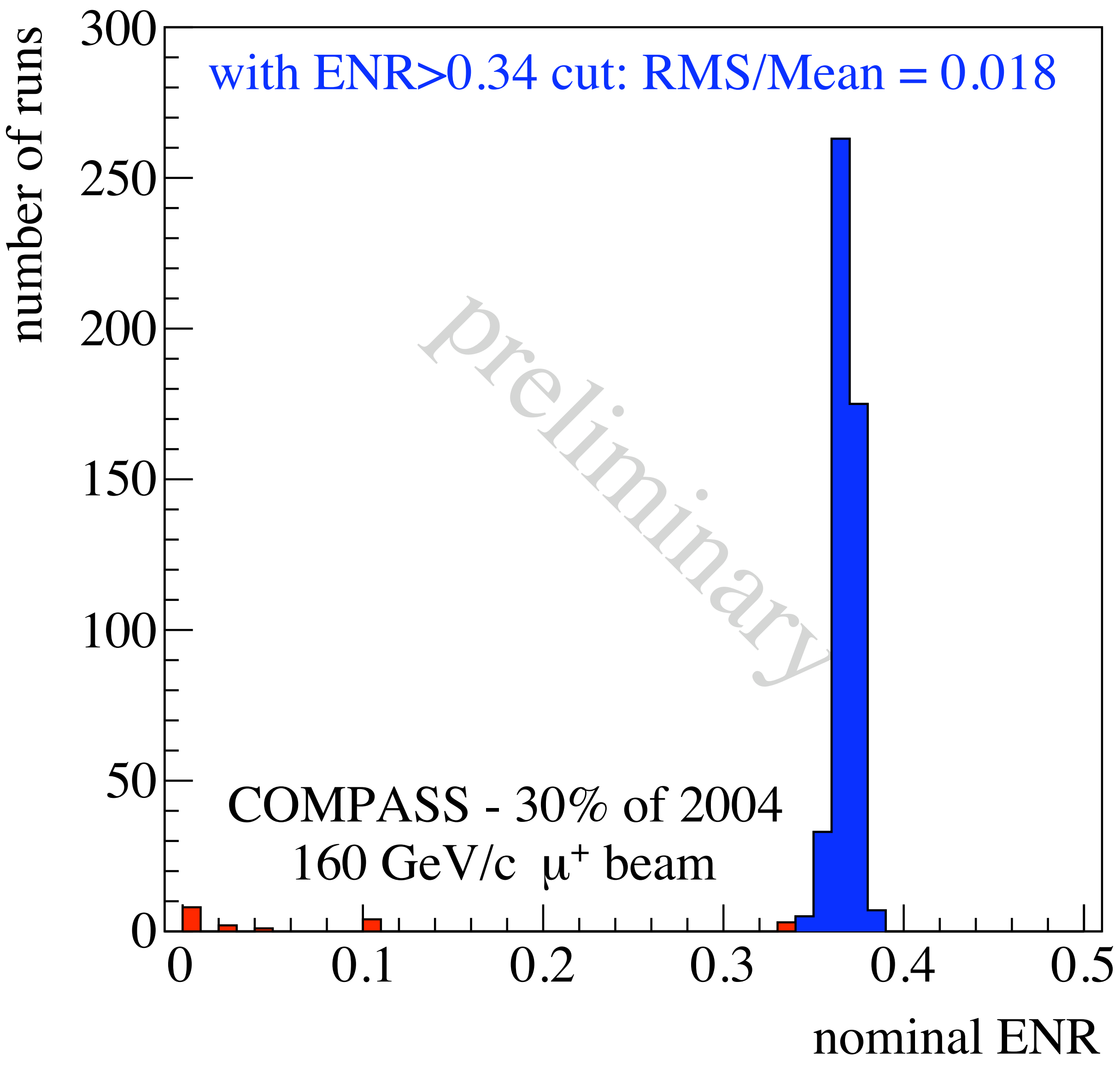
- "Event number ratio" ENR:

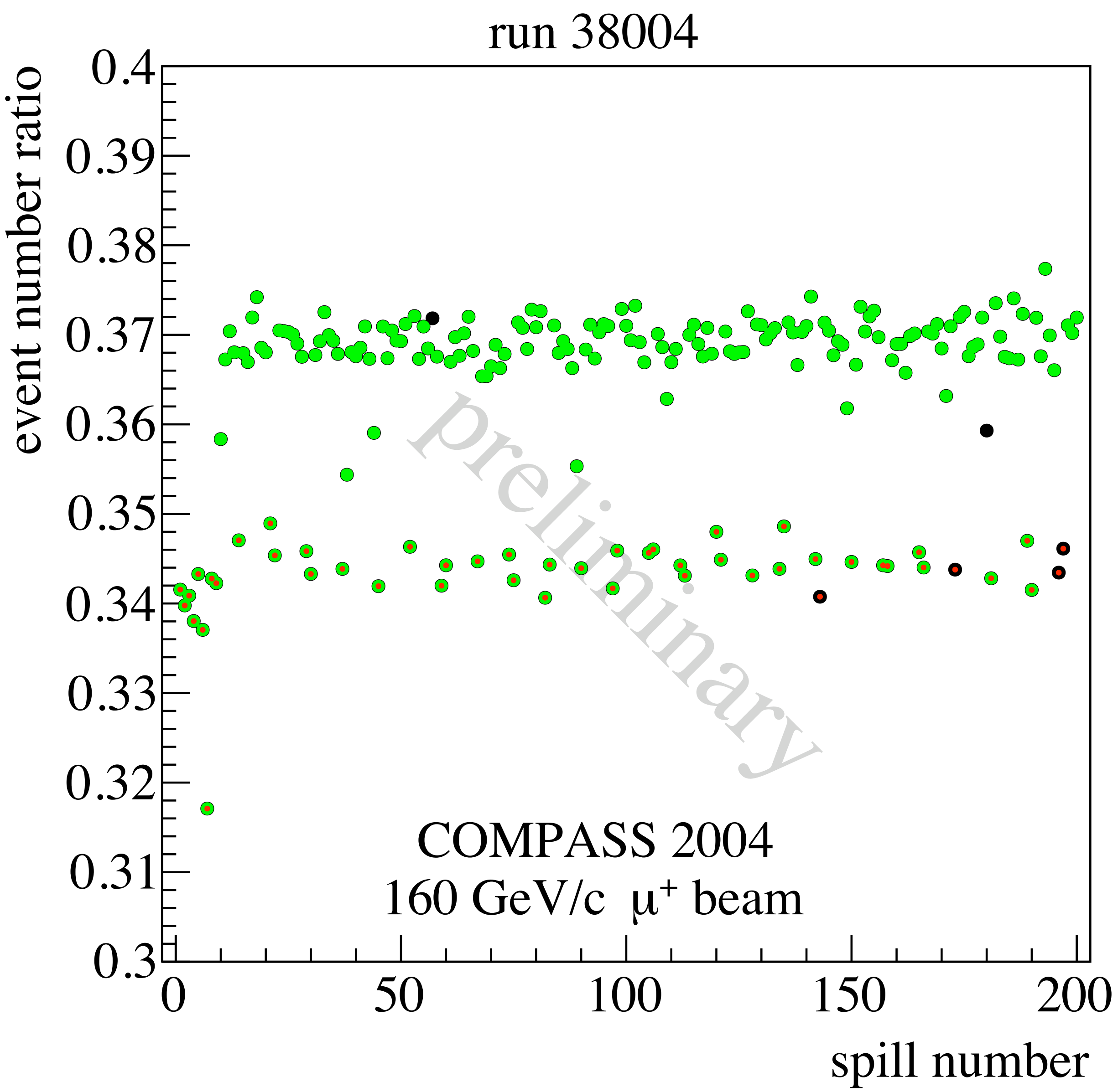
$$ENR = \frac{\text{number of reconstructed events}}{\text{number of triggered events}}$$

- green markers: spills retained by standard bad spill lists for polarized analyses
- red markers: rejected by ENR cut for unpolarized analyses
- spills with low ENR: low voltage problems on one plane of scintillating fibre detector



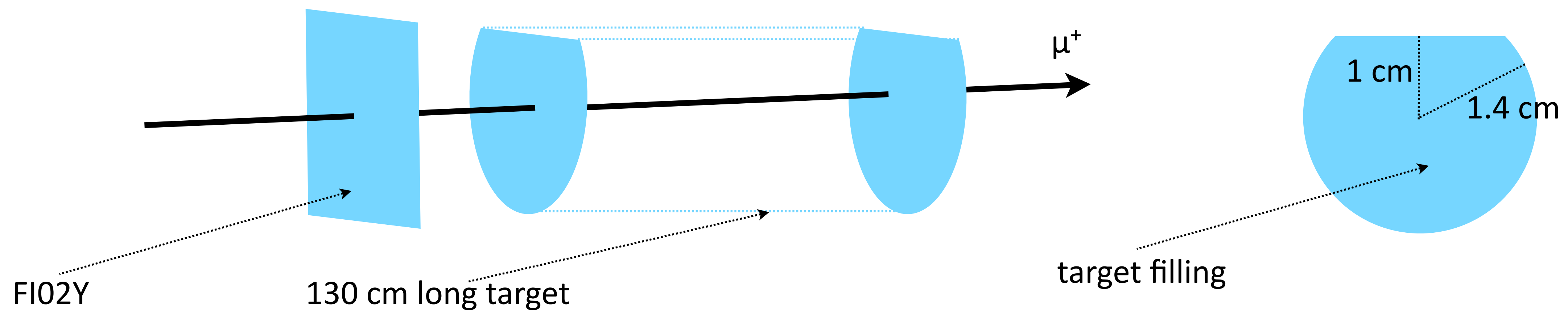
Good Spill Selection





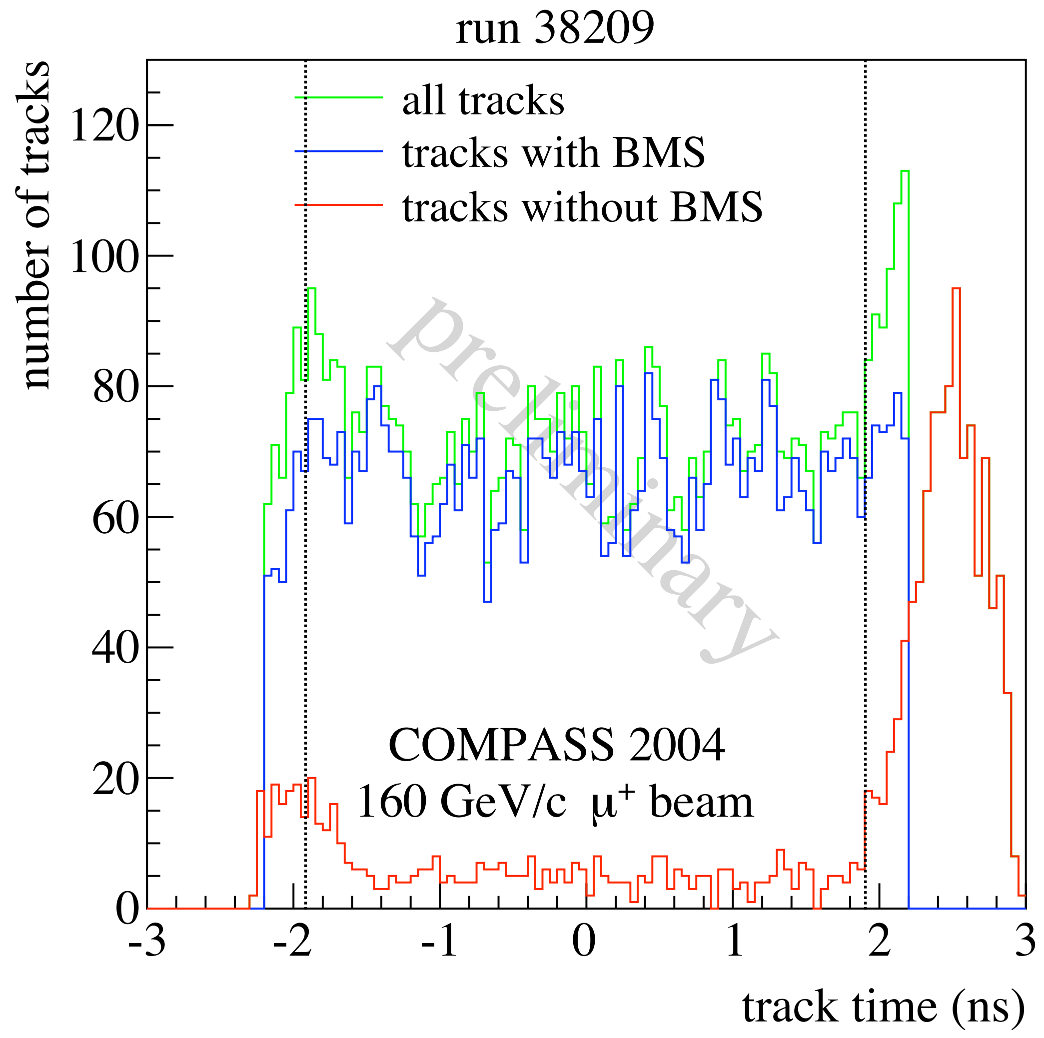
Beam Flux Measurement

- Beam flux measured by a scaler, which counts the number of signals in the scintillating fibre plane FI02Y in front of target .
- Scaler is read out for each event: Determine flux in time window t_1-t_2 (flat top) in each spill
- For luminosity: beam flux through fiducial volume of target (geometrical acceptance 65%)
- Possible inefficiencies / dead times in: FI02Y, OR unit, scaler



Beam Flux Measurement

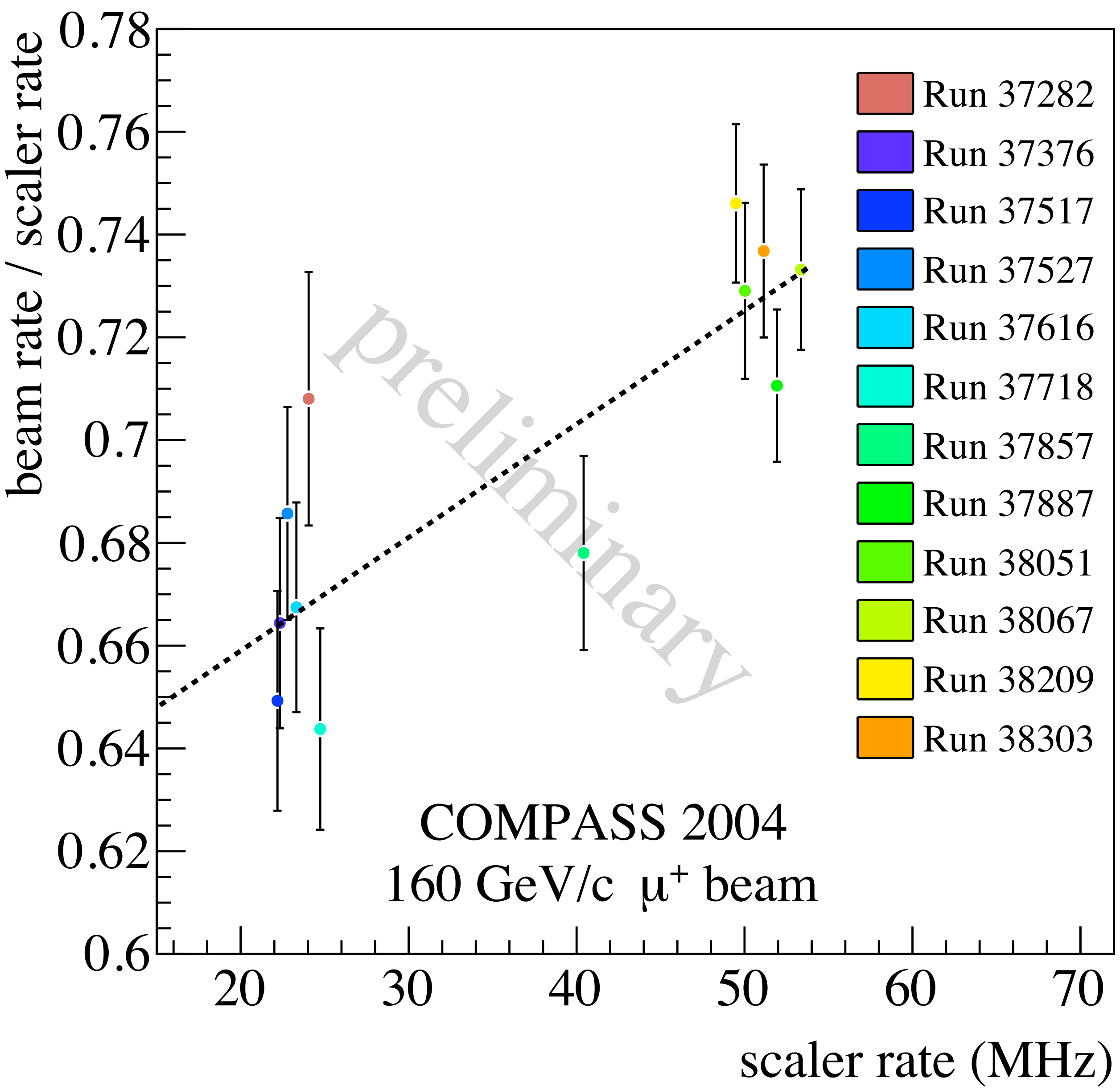
- The dead-time-free beam flux through the fiducial volume is measured from random triggers in 12 runs
- $$\text{beam flux} = \frac{\text{number of beam tracks through fiducial volume}}{\Delta t \cdot \text{number of random triggers}}$$



used time window:
Δt = -1.9 ns .. 1.9 ns

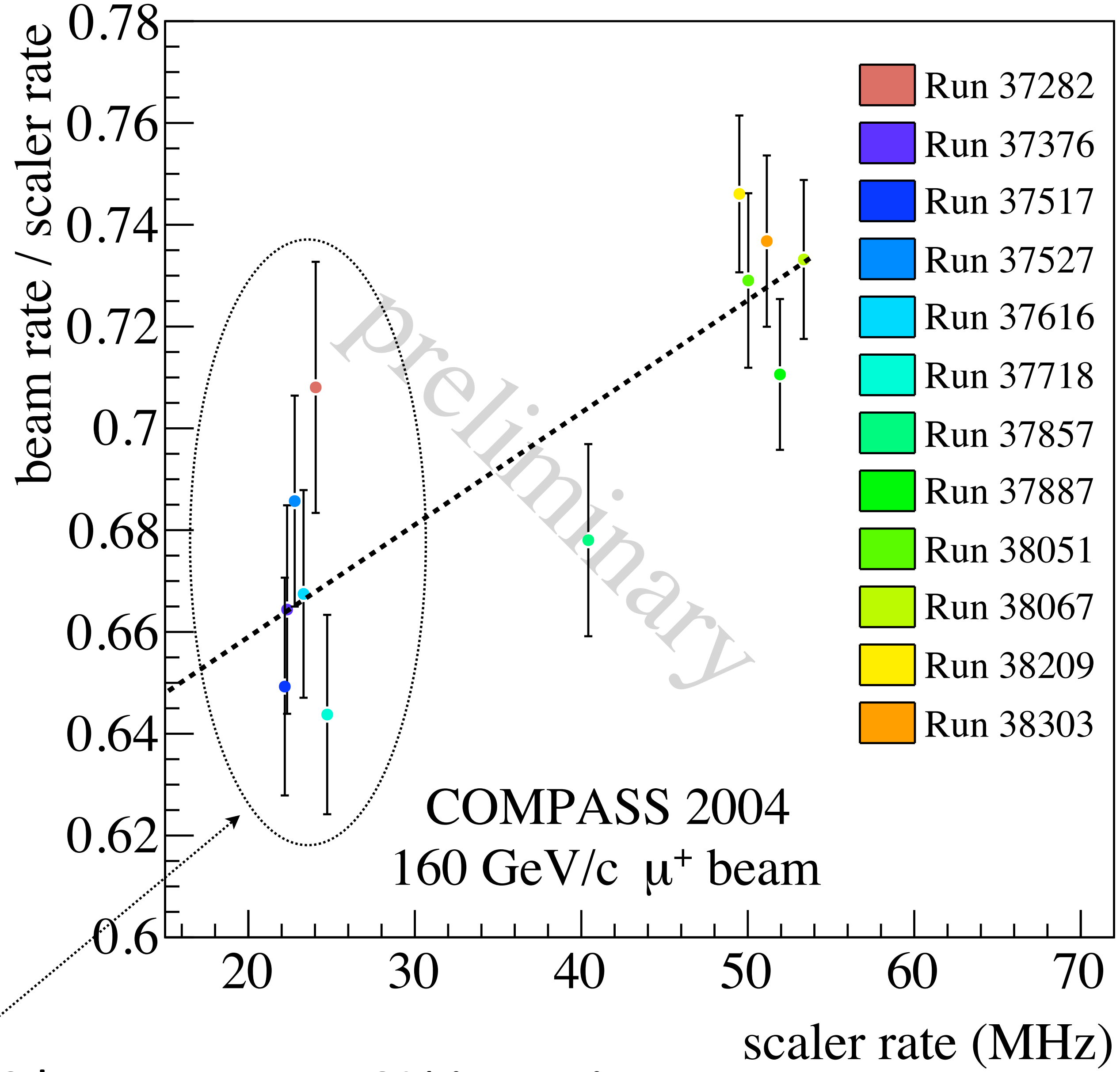
Beam Flux Measurement

- Beam rate is measured by scaler system in each spill
- Systematically better beam rate measurement from beam tracks in random triggers in 12 runs
- use linear parameterization of ratio to calculate beam rate in each spill
- Reason for slope: Dead times



Beam Flux Measurement

- Beam rate is measured by scaler system in each spill
- Systematically better beam rate measurement from beam tracks in random triggers in 12 runs
- use linear parameterization of ratio to calculate beam rate in each spill
- Reason for slope: Dead times



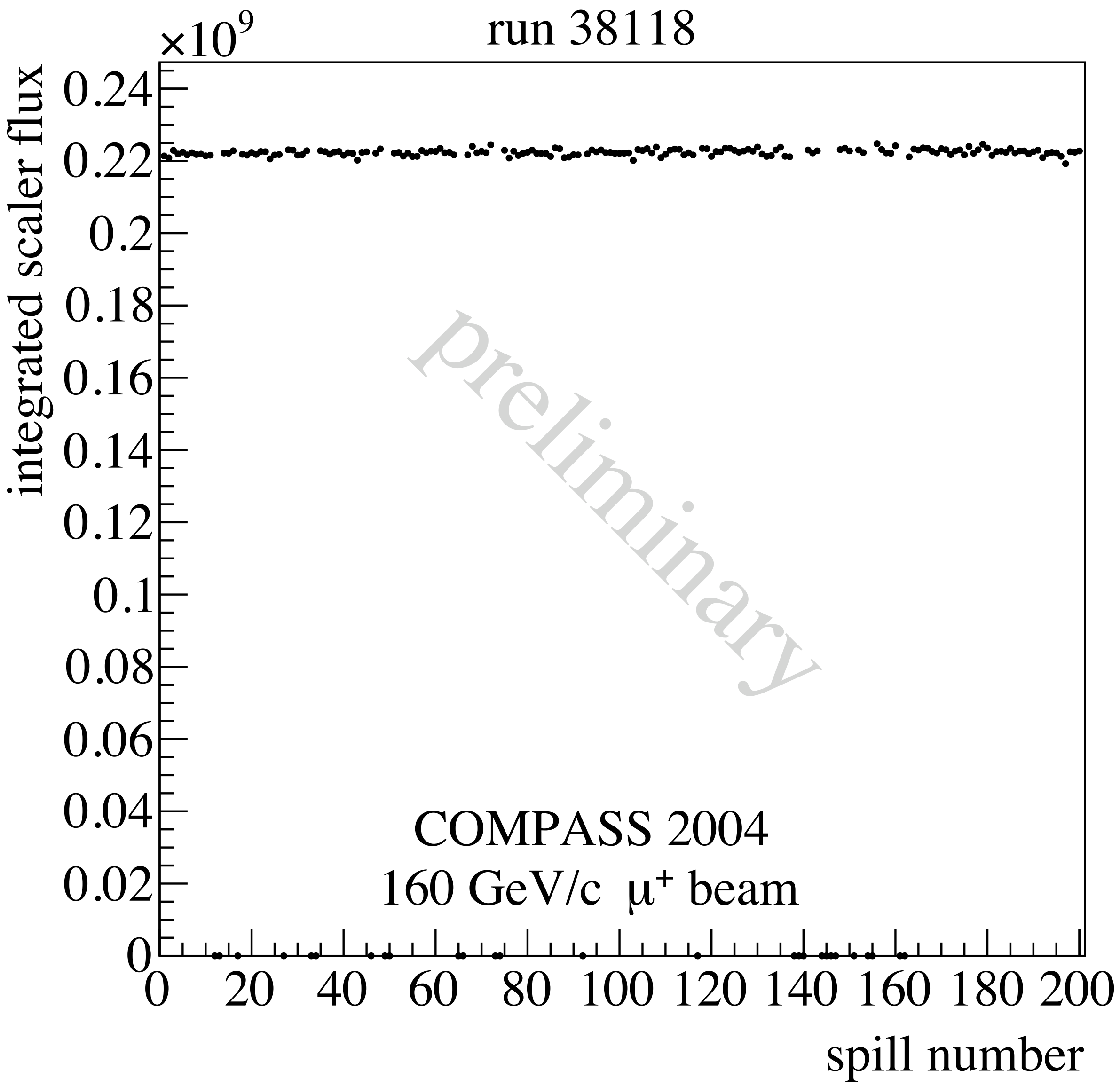
for 2 weeks of 2004 the COMPASS beam was at 50% intensity.
This is half of the used data set used here.

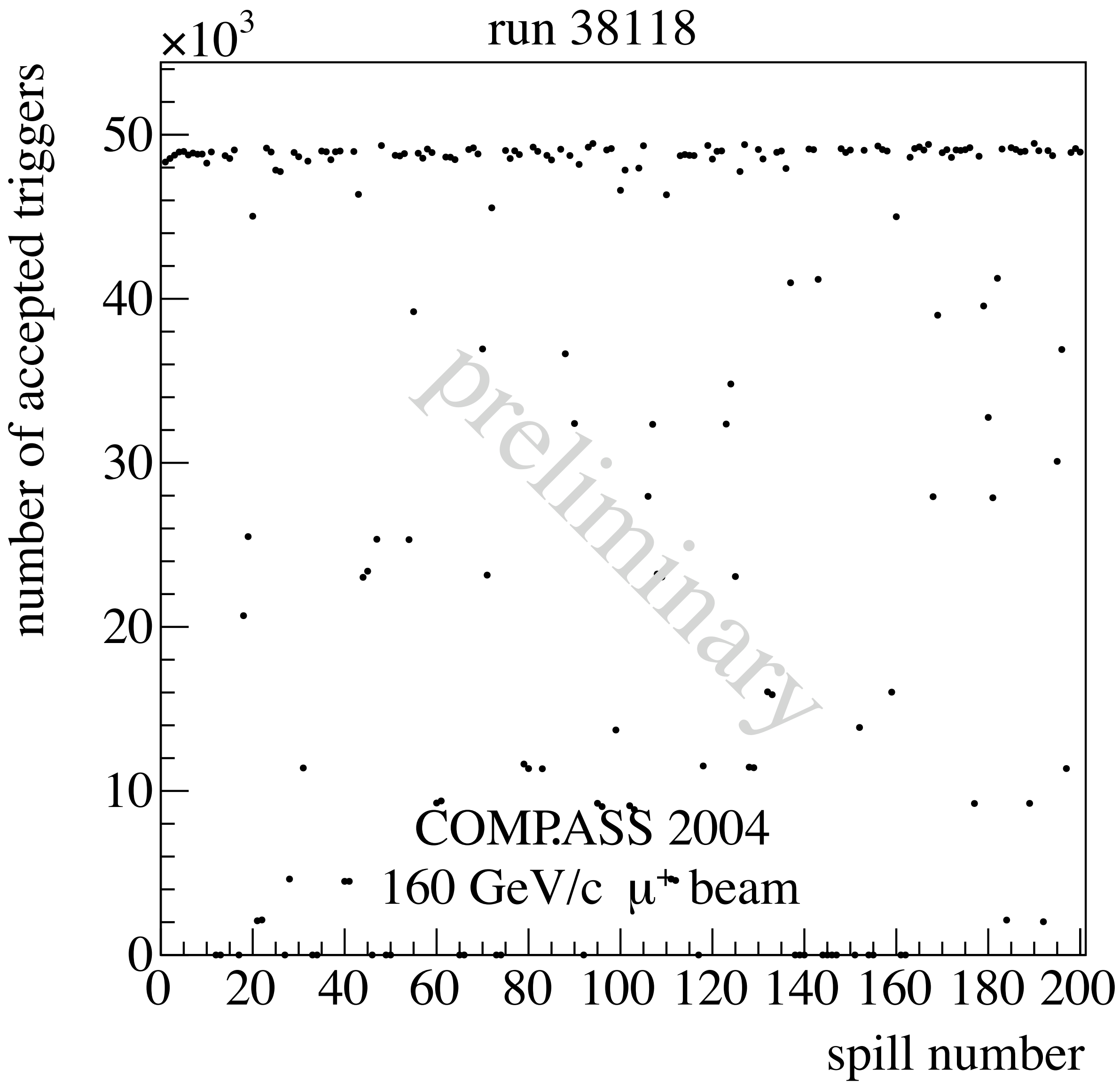
DAQ Dead Time

- The trigger rate in 2004 was around 11-12 kHz
- DAQ dead time: Fraction of data taking time in which no triggers can be accepted because of readout of data from previously triggered events.
- Measured by counting the number of trigger attempts and the number of accepted trigger attempts with scalers.
- Evaluate method on a run with “DAQ throttle”:
  A malfunctioning DAQ computer caused blockages in every other spill (very unusual for COMPASS operation).

DAQ Dead Time

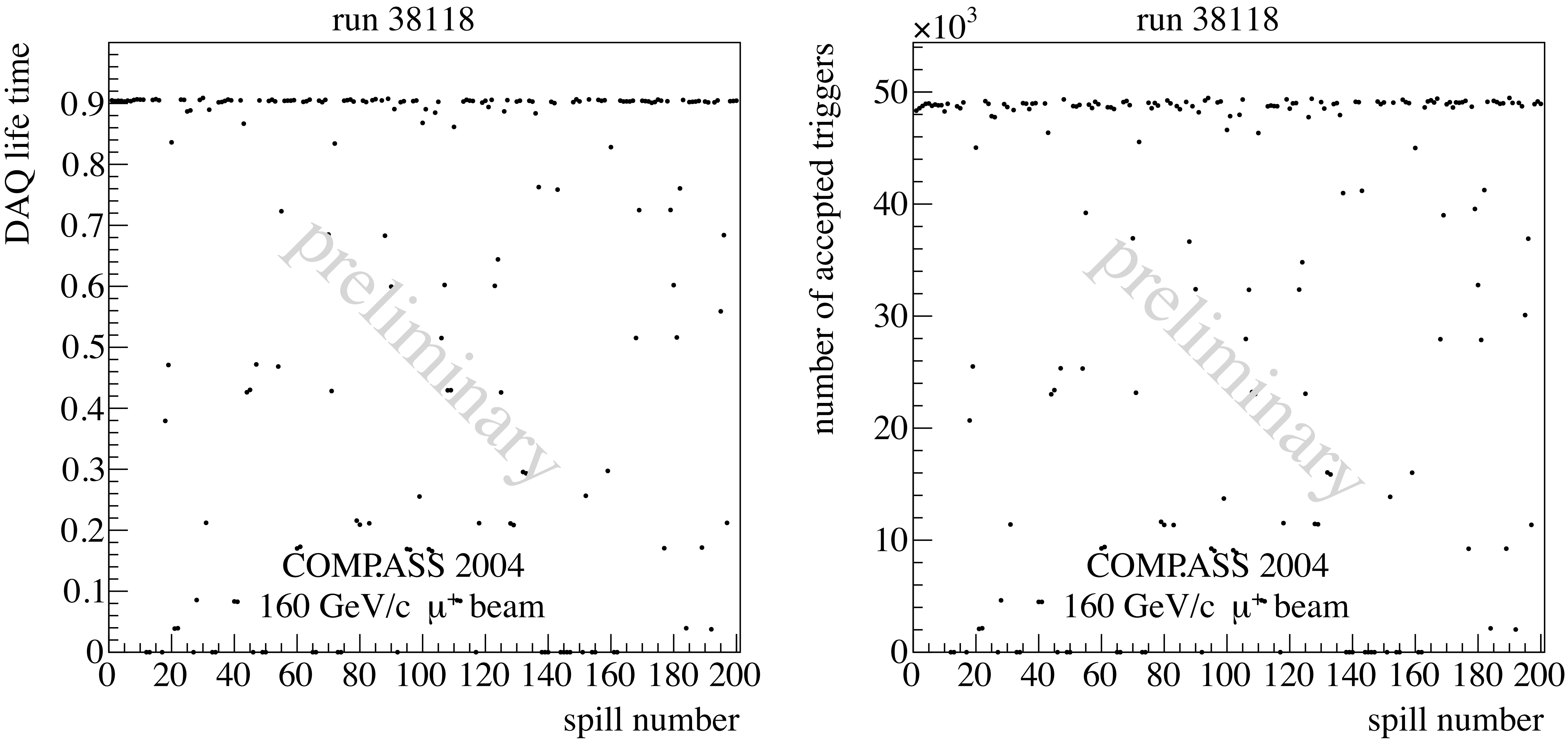
Test on run with DAQ throttle





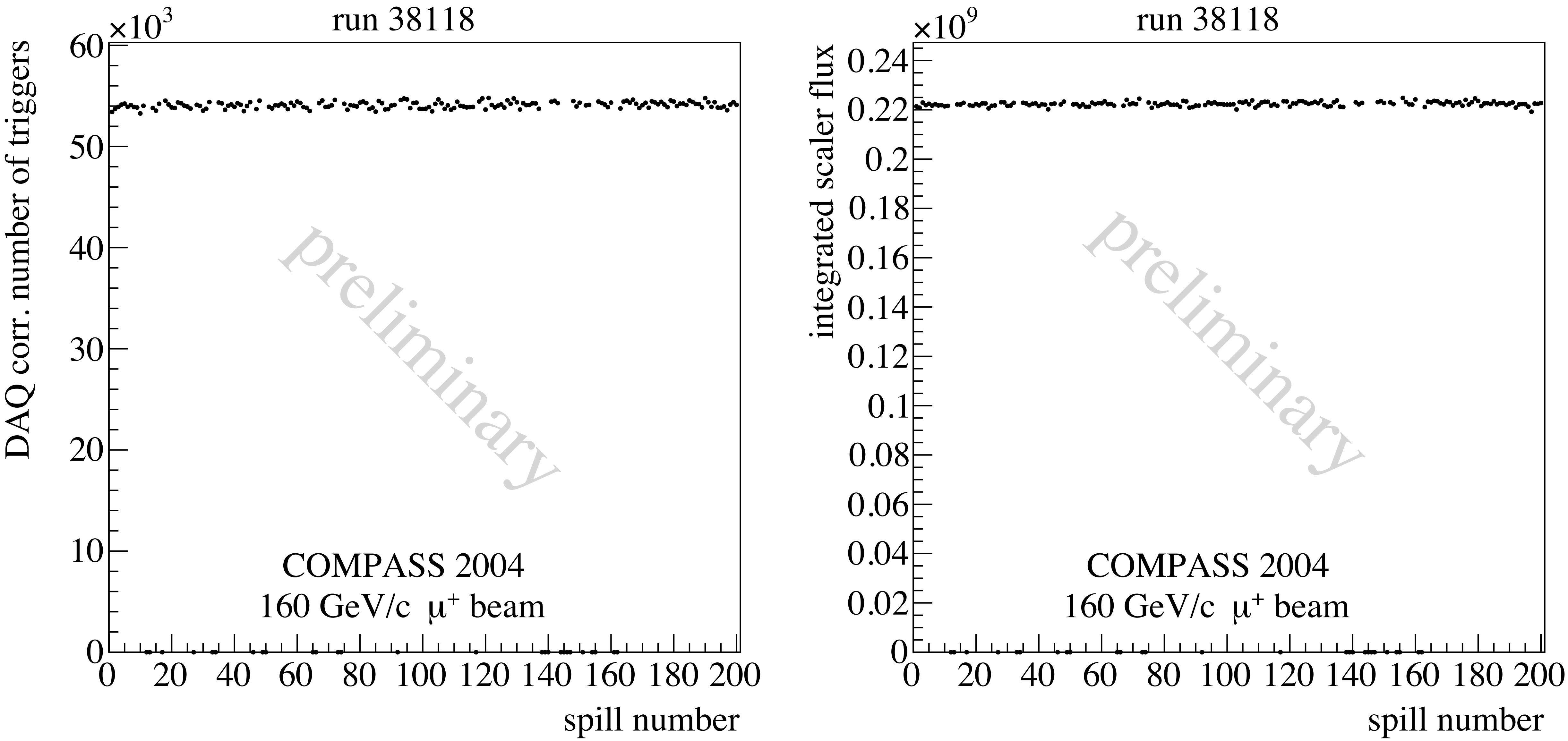
DAQ Dead Time

Test on run with DAQ throttle

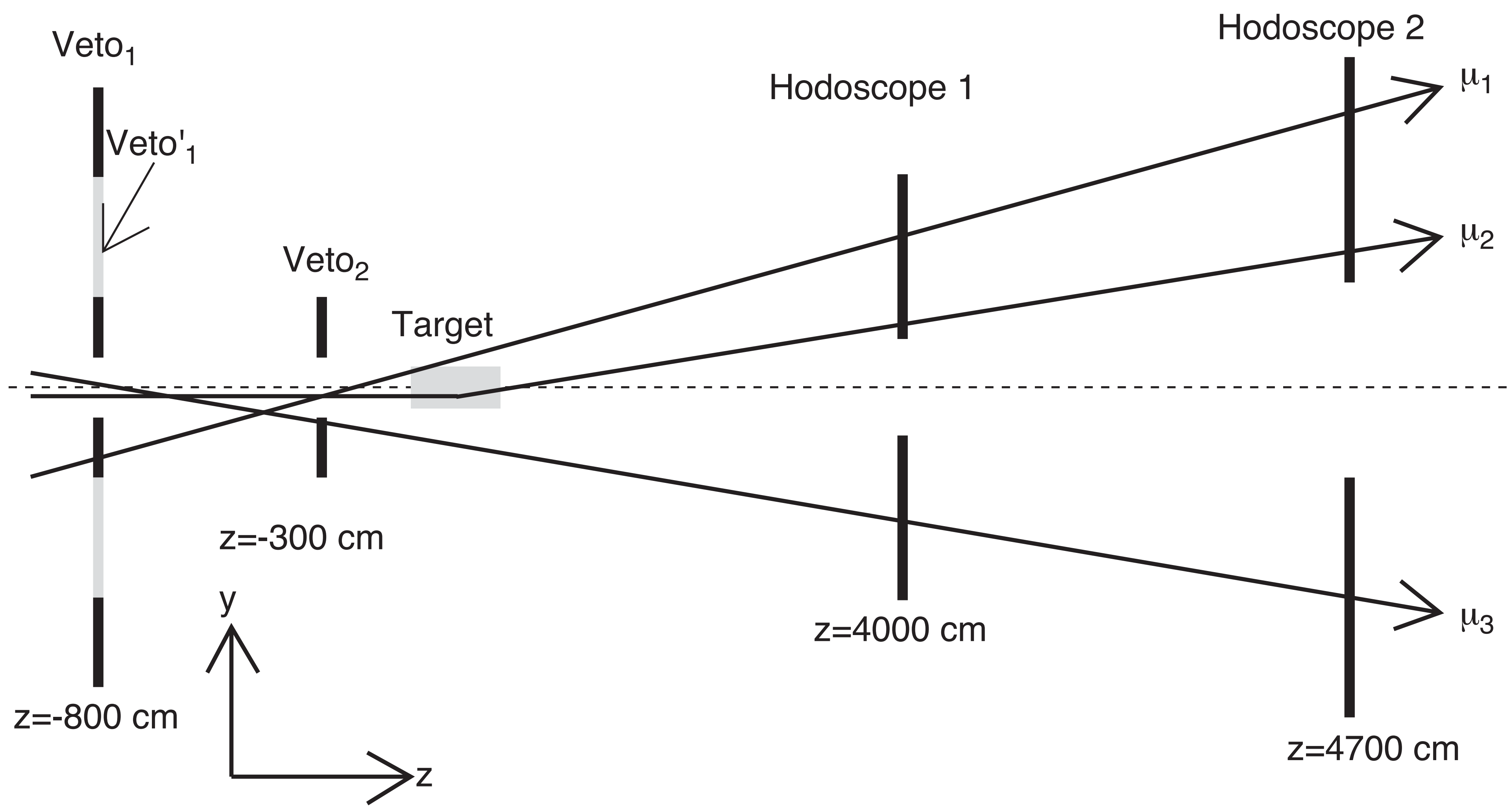


DAQ Dead Time

Test on run with DAQ throttle



μ^+ Veto System



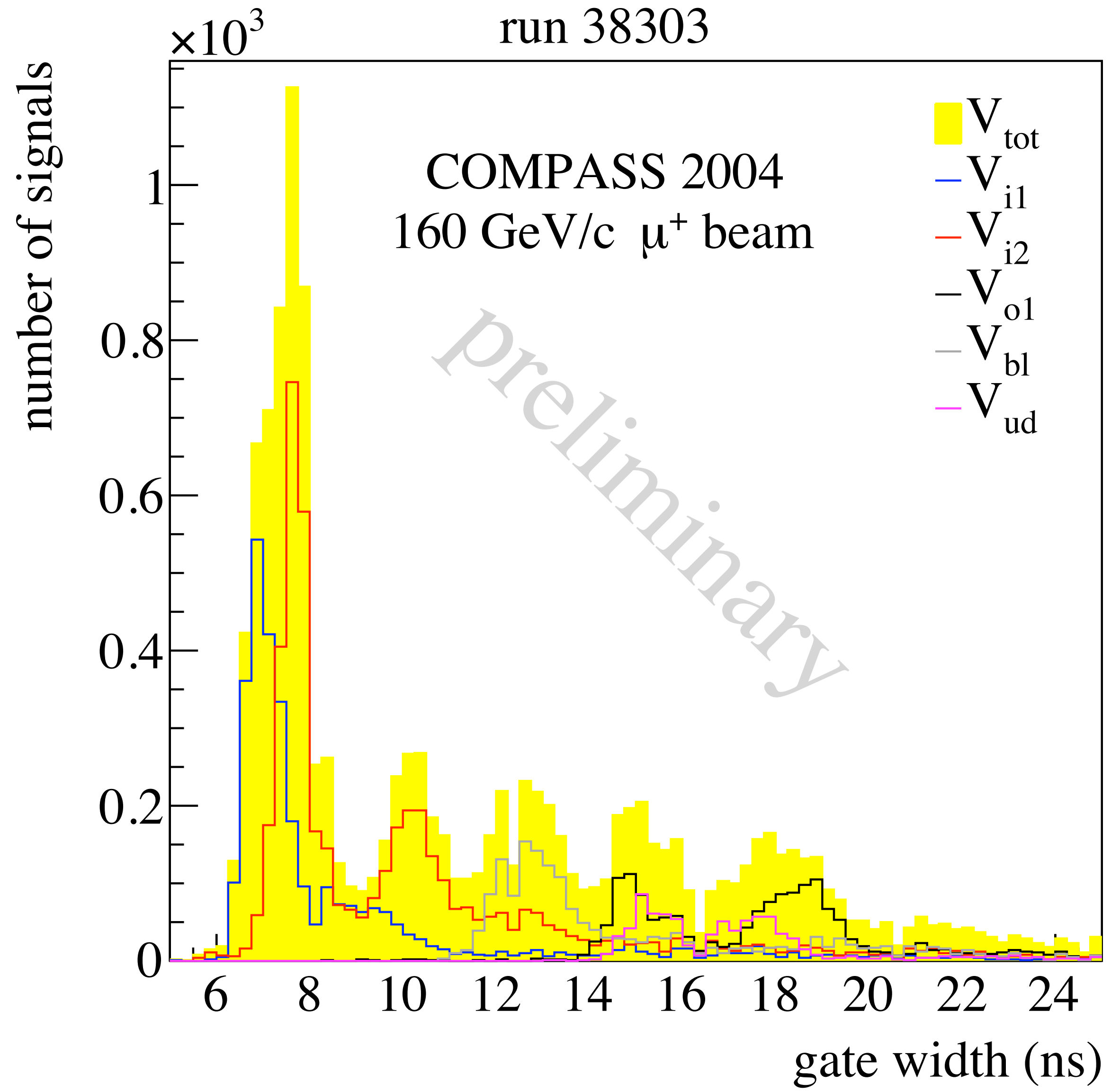
[Bernet et al., NIM A 550 (2005) 217-240]

Veto Dead Time

- Without the veto system, a large fraction of triggers would be due to halo tracks instead of scattered beam tracks.
- The dead time of the veto system is defined as the fraction of data taking time during which the veto signal is high (duty cycle) and hence no triggers can get through.
- The dead time of the veto system V_{tot} has been measured during the 2004 beam time: Compare trigger rates without veto and with delayed veto signal. Result: 20%
- Re-evaluation of V_{tot} dead time using TDC and scaler readings of veto signals:

Veto Dead Time

- V_{tot} is made from logical OR of: V_{i1}, V_{i2}, V_{o1}, V_{bl}, and V_{ud}
- Gate width of V_{tot} is measured with TDC readings of rising and falling edges in random trigger events
- Time correlation of rising edges with TDC reading of sub-system signals to identify sub-system
- Nicely reproduces the gate widths of the individual systems as well as their mixture

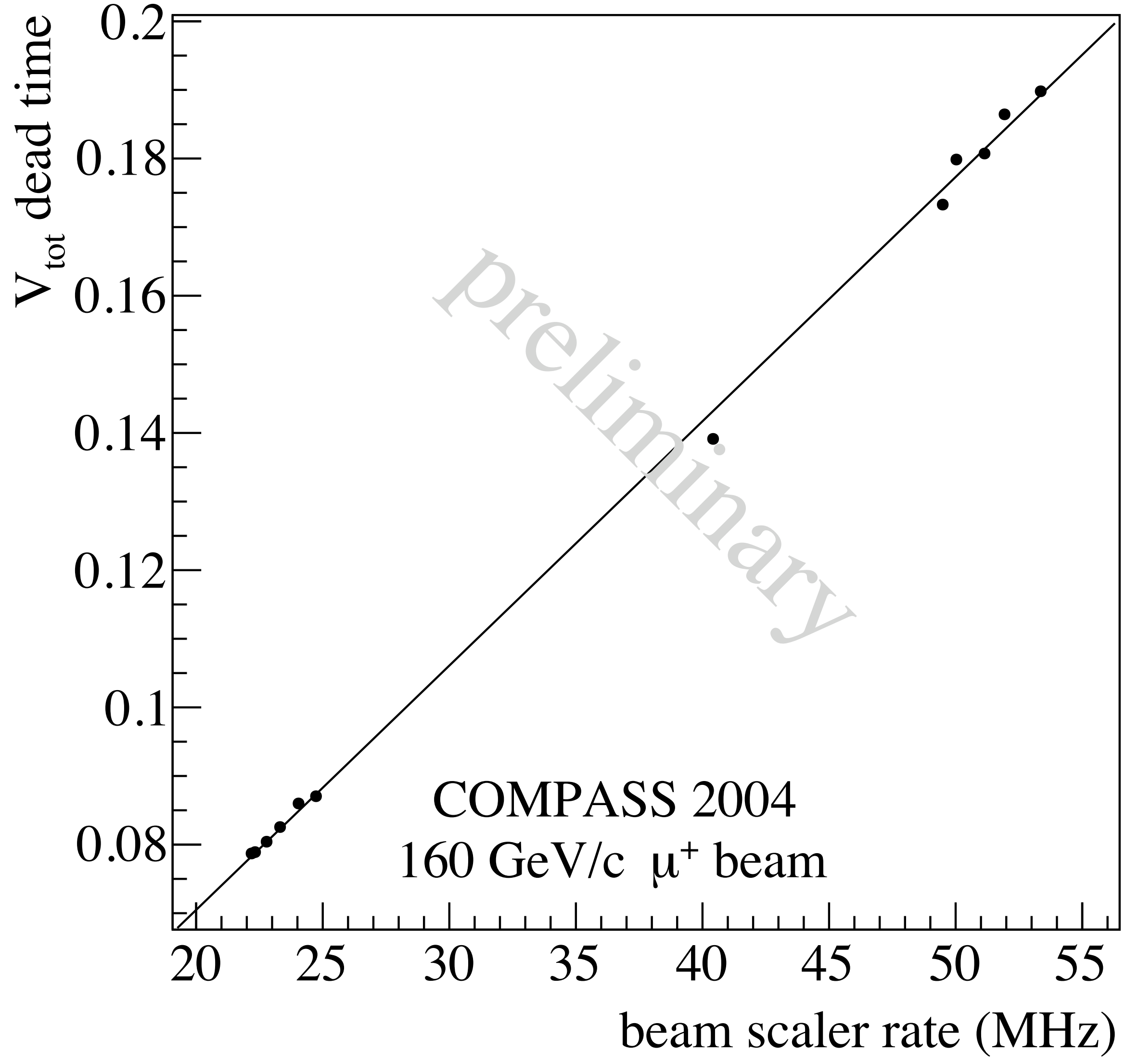


Veto Dead Time

- Number of veto pulses N_{veto} in time window t_1-t_2 is read from scaler on V_{tot}
- Sample N_{veto} times from gate width spectrum to get the active time of the veto signal
- Normalize to t_2-t_1 to get duty cycle, and thus dead time
- Results consistent with previous measurement.

Veto Dead Time

- Number of veto pulses N_{veto} in time window t_1-t_2 is read from scaler on V_{tot}
- Sample N_{veto} times from gate width spectrum to get the active time of the veto signal
- Normalize to t_2-t_1 to get duty cycle, and thus dead time
- Results consistent with previous measurement.



Target Thickness

- Content of target is measured after the run.
  Main nuclear components are ^{2}D, ^{3}He, ^{4}He, ^{6}Li, and ^{7}Li.

- Number of nucleons per unit area: $3.44 \cdot 10^{25}$ cm^{-2} ± 2 %

Luminosity Results

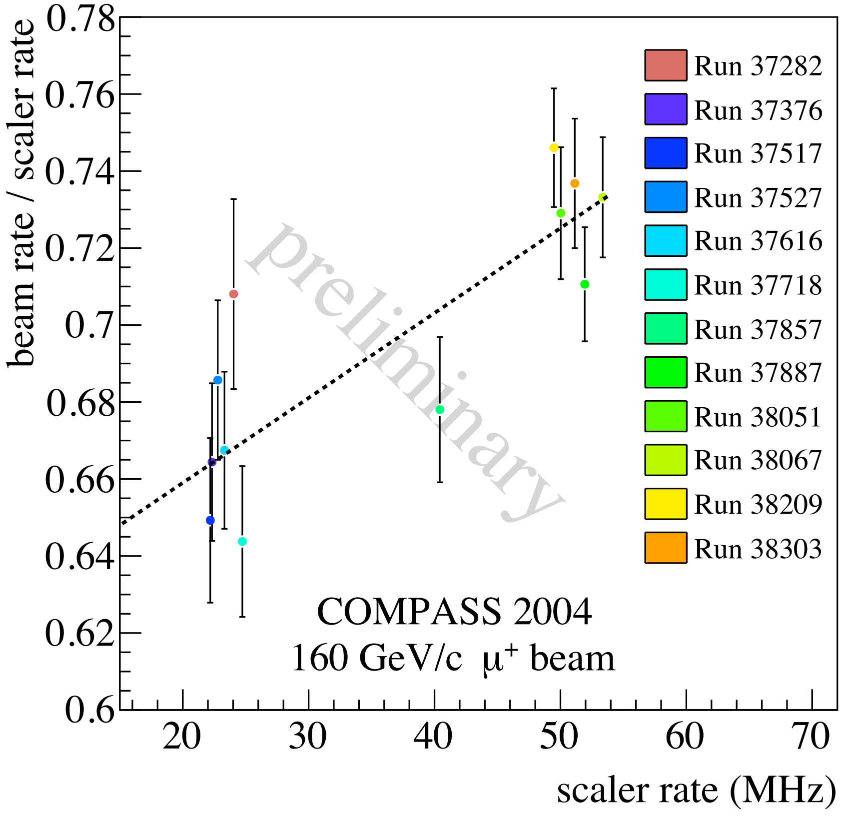
- Results of integrated luminosity in t_1-t_2 time window in good spills in the used data set (30% of 2004 data) corrected for V_{tot} dead time: 122.6 pb^{-1}

- Very conservative estimation of sources of systematic errors:
  - Beam Flux: from spread of points in beam flux ratio
    => 5% on luminosity
  - Veto dead time: From different measurements of the dead time during the beam time and the re-evaluation from random trigger data
    => 3% on luminosity
  - Target material measurement error
    => 2% on luminosity
  - Reconstruction efficiency from width of nominal event number ratio
    => 1.8% on luminosity

Luminosity Results

- Results of integrated luminosity in t_1-t_2 time window in good spills in the used data set (30% of 2004 data) corrected for V_{tot} dead time: 122.6 pb^{-1}

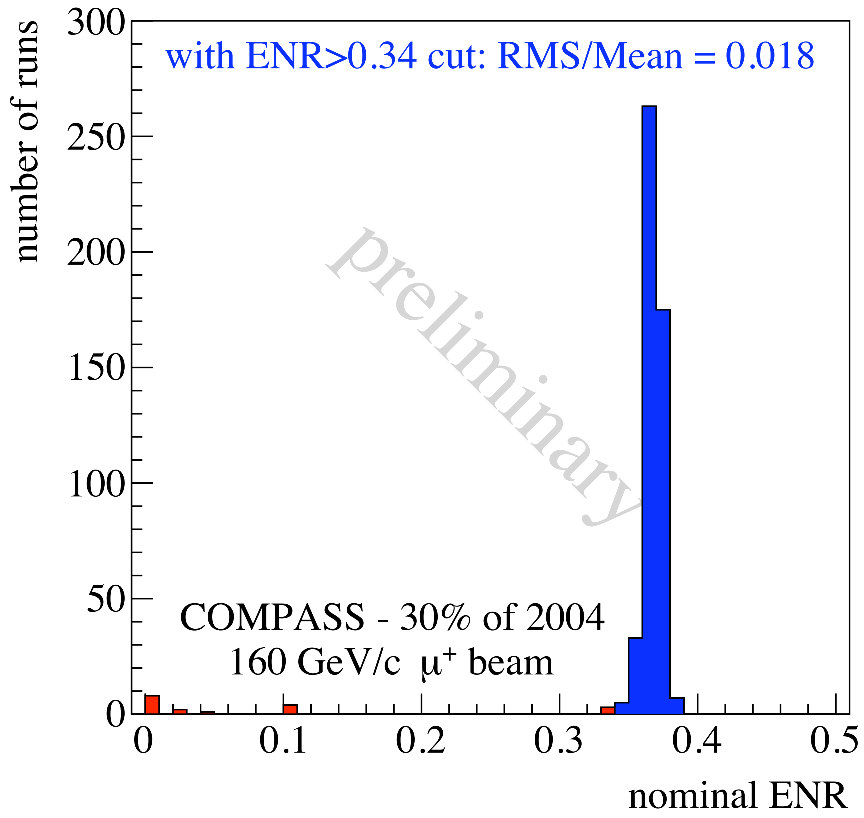
- Very conservative estimation of sources of systematic errors:
  - Beam Flux: from spread of points in beam flux ratio
    => 5% on luminosity
  - Veto dead time: From different measurements of the dead time during the beam time and the re-evaluation from random trigger data
    => 3% on luminosity
  - Target material measurement error
    => 2% on luminosity
  - Reconstruction efficiency from width of nominal event number ratio
    => 1.8% on luminosity



Luminosity Results

- Results of integrated luminosity in t_1-t_2 time window in good spills in the used data set (30% of 2004 data) corrected for V_{tot} dead time: 122.6 pb^{-1}

- Very conservative estimation of sources of systematic errors:
  - Beam Flux: from spread of points in beam flux ratio
    => 5% on luminosity
  - Veto dead time: From different measurements of the dead time during the beam time and the re-evaluation from random trigger data
    => 3% on luminosity
  - Target material measurement error
    => 2% on luminosity
  - Reconstruction efficiency from width of nominal event number ratio
    => 1.8% on luminosity



Conclusion and Outlook

- The luminosity for 30% of 2004 data has been determined for cross section measurements with COMPASS data (122.6 pb^{-1})
  - Data with stable beam and spectrometer conditions have been selected
  - All dead times have been corrected
- The systematic error is of the order of 10%.
- A measurement of the structure function F_2 of the deuteron will show how good the luminosity value really is. Analysis to be released soon!
- The analysis of the cross section for the production of high-p_T hadrons at low Q^2 will be released in the coming months.