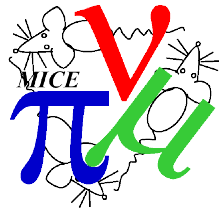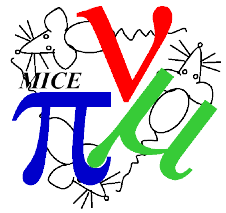# MICE Particle Rate and Beam Loss
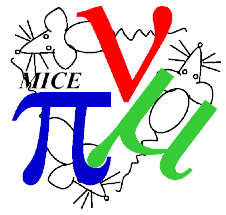
Adam Dobbs, IoP, 31st March 2010

Outline

- Background
  - Neutrino Oscillations
  - Neutrino Factory
- Overview of MICE
  - Purpose
  - MICE Schematic
  - The ISIS Accelerator
- Beam Loss Analysis Methodology
- High Beam Loss (~5V) Results from Nov 2009
  - Beam Loss vs MICE Target Depth
  - Particle Rate vs Beam Loss
- Future Plans

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Neutrino Oscillations

Briefly: It has been experimentally observed (SuperK, SNO, KamLAND, ...) that the neutrino weak flavour eigenstates are a combination of the neutrino mass eigenstates, analogous to quark mixing, and are related by the PMNS matrix:
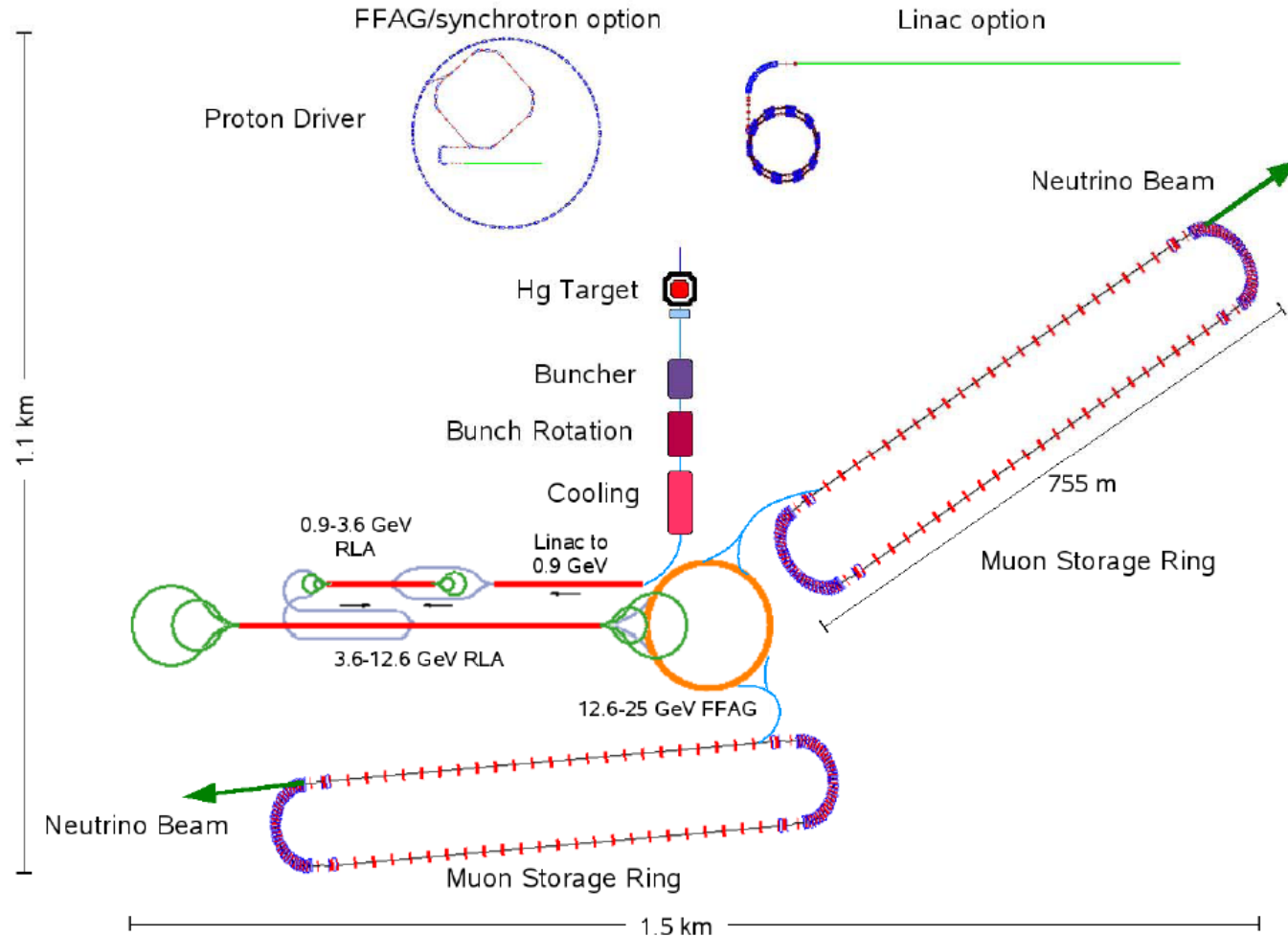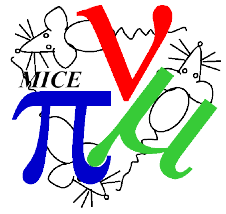
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U_{PMNS} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$$U_{PMNS} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}e^{-i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{-i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{-i\delta} & c_{12}s_{23} - s_{12}c_{23}s_{13}e^{-i\delta} & c_{23}c_{13} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{-\frac{\alpha}{2}} & 0 \\ 0 & 0 & e^{-\frac{\beta}{2}} \end{pmatrix}$$

where $s_{ij} = \sin\theta_{ij}$, $c_{ij} = \cos\theta_{ij}$ and α, β, δ are *CP violating phases.*

The parameters of this matrix are far less well known than those of the corresponding CKM matrix in the quark sector. Their precise determination has broad implications, such as determining the extent of leptonic CP violation.
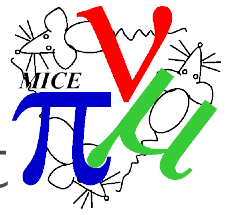
Measuring the PMNS Parameters – The Neutrino Factory

FFAG/synchrotron option

Linac option

Proton Driver

ISS Neutrino Factory Baseline.

Components not to scale.

Hg Target

Buncher

Bunch Rotation

Cooling

0.9-3.6 GeV RLA

Linac to 0.9 GeV

3.6-12.6 GeV RLA

12.6-25 GeV FFAG

Neutrino Beam

Muon Storage Ring

755 m

Neutrino Beam

Muon Storage Ring

1.1 km

1.5 km

See https://www.ids-nf.org/wiki/FrontPage/Document ation?action=AttachFile&do=get &target=IDS-NF-002-v1.1.pdf
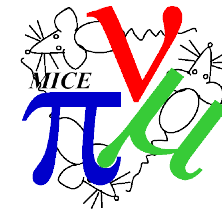
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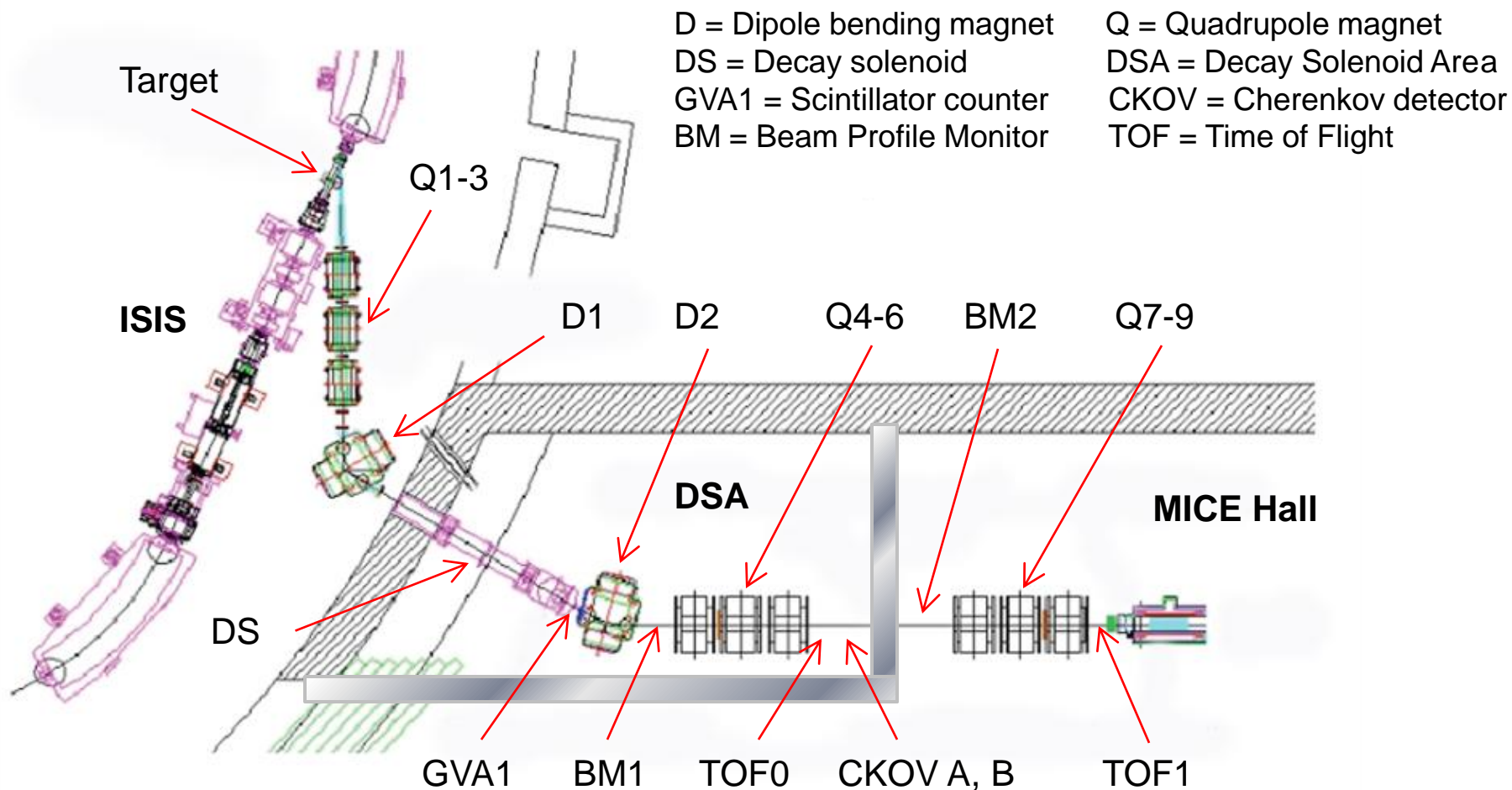31/03/2010

The Muon Ionisation Cooling Experiment

- Emittance reduction (*cooling*) is necessary for the muon beam to be successfully matched into the downstream FFAG accelerators

- Cooling represents one of the major cost and performance factors of a Neutrino Factory

- MICE: a prototype of a single cooling channel for a Neutrino Factory or Muon Collider

- Desired transverse emittance reduction of ~10%, using a tuneable 140 to 240 MeV/c muon beam

- Employs *ionisation cooling* – momentum loss by firing the beam through an absorber, coupled with re-acceleration in the longitudinal direction only

- *Staged* experiment – running while being built up incrementally

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Completed MICE Schematic

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Current MICE beamline

D = Dipole bending magnet
DS = Decay solenoid
GVA1 = Scintillator counter
BM = Beam Profile Monitor

Q = Quadrupole magnet
DSA = Decay Solenoid Area
CKOV = Cherenkov detector
TOF = Time of Flight

Target

Q1-3

ISIS

D1   D2   Q4-6   BM2   Q7-9

DSA

MICE Hall

DS

GVA1   BM1   TOF0   CKOV A, B   TOF1
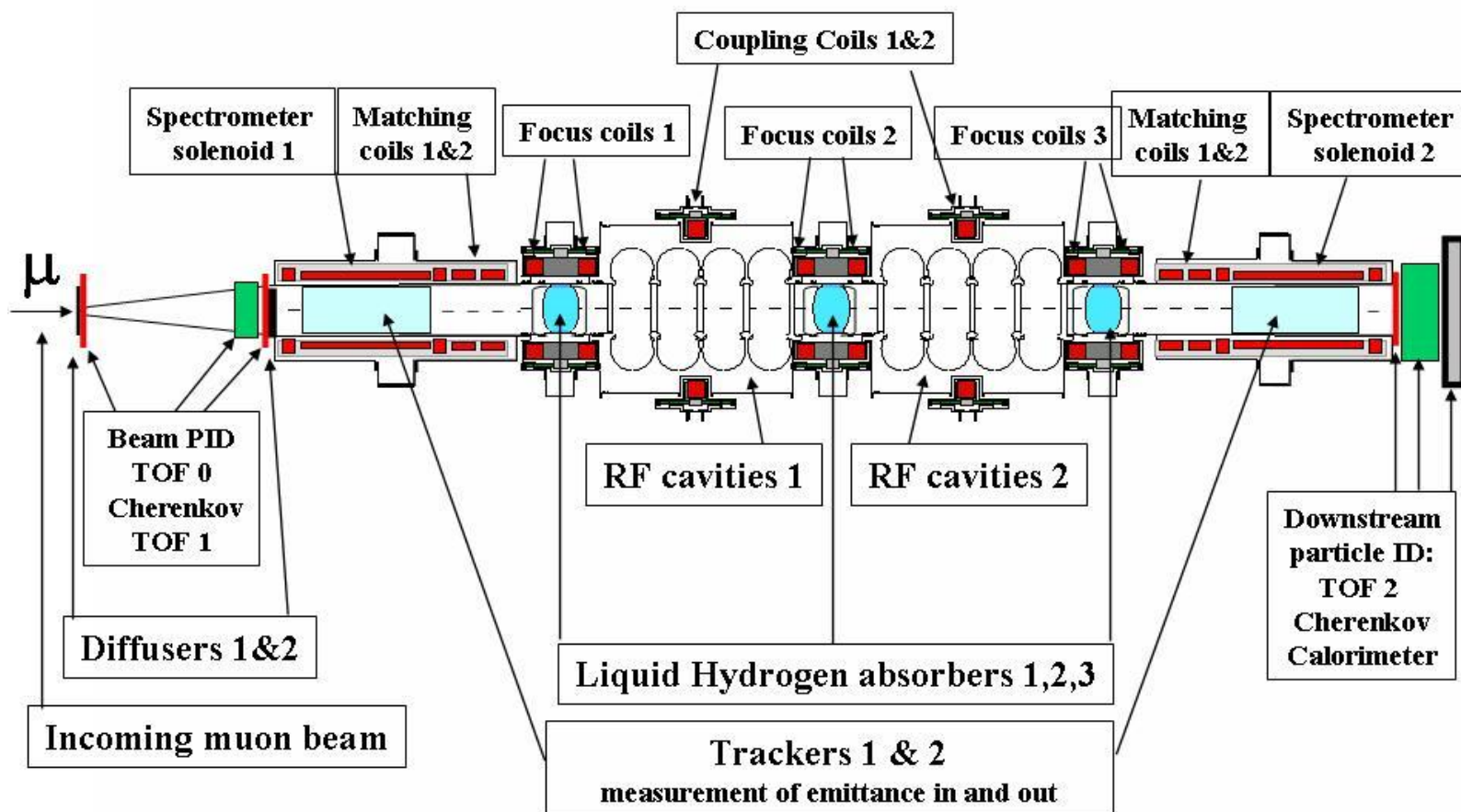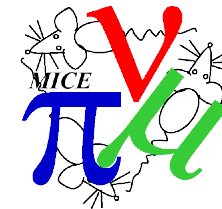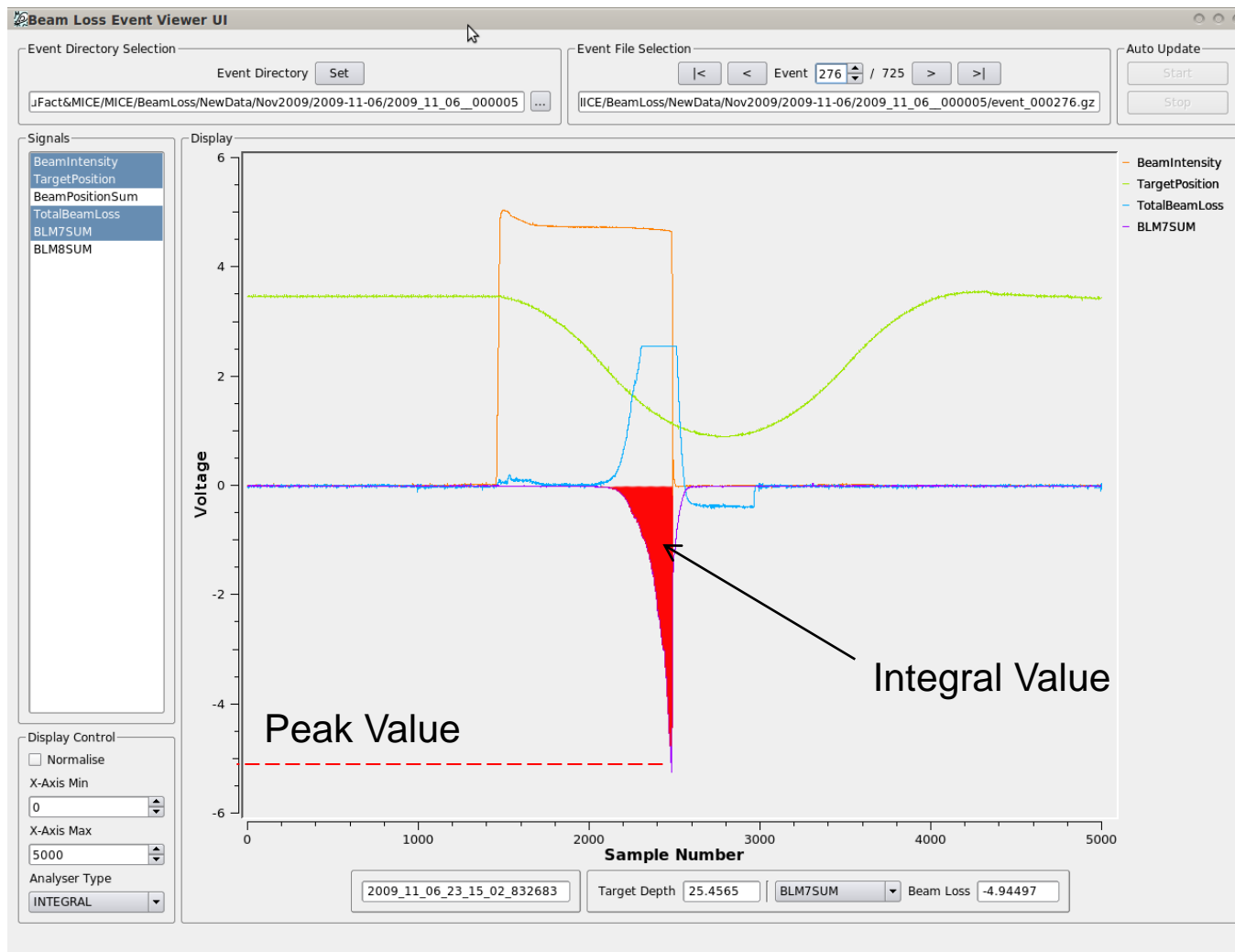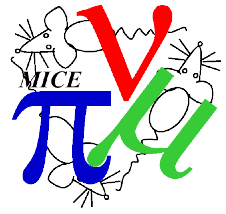
The ISIS Accelerator
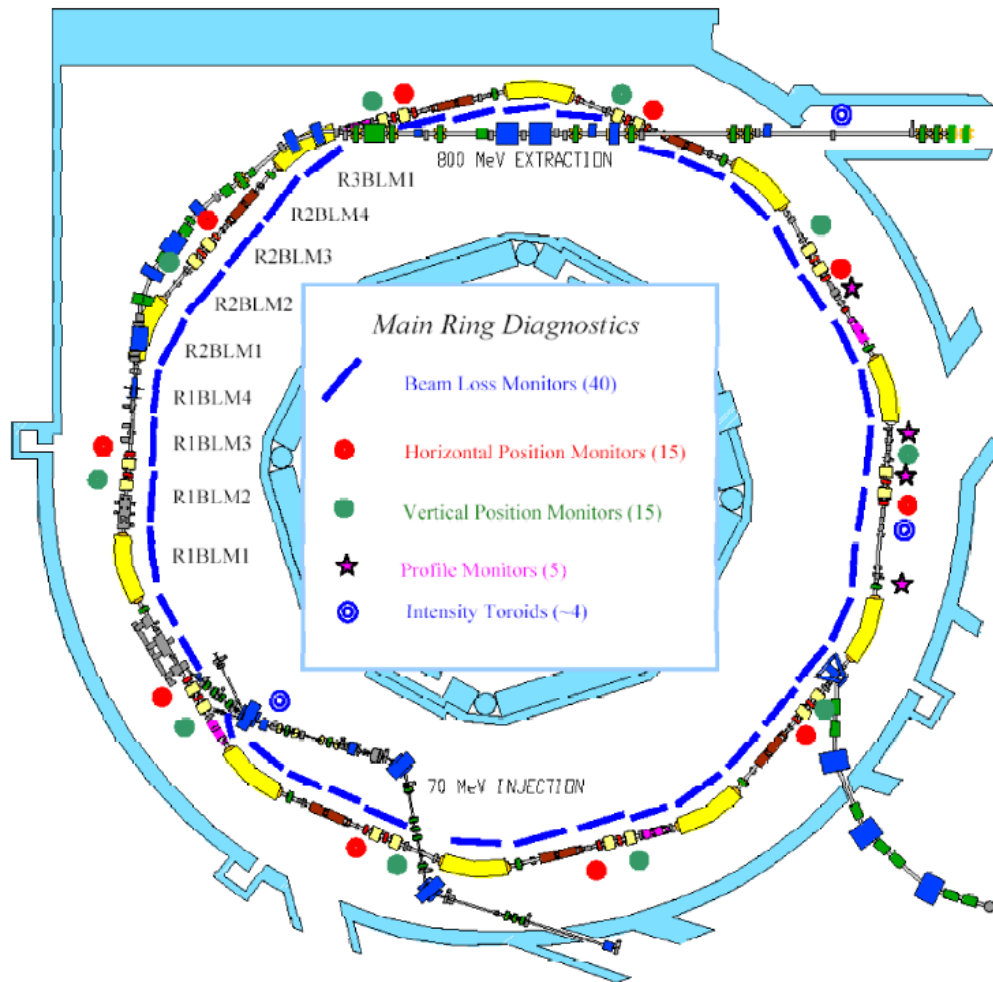
- 800 MeV proton synchrotron

- Primarily used as a Neutron Spallation source

- Beam loss monitored with ionisation chambers

- Potential site for the Neutrino Factory
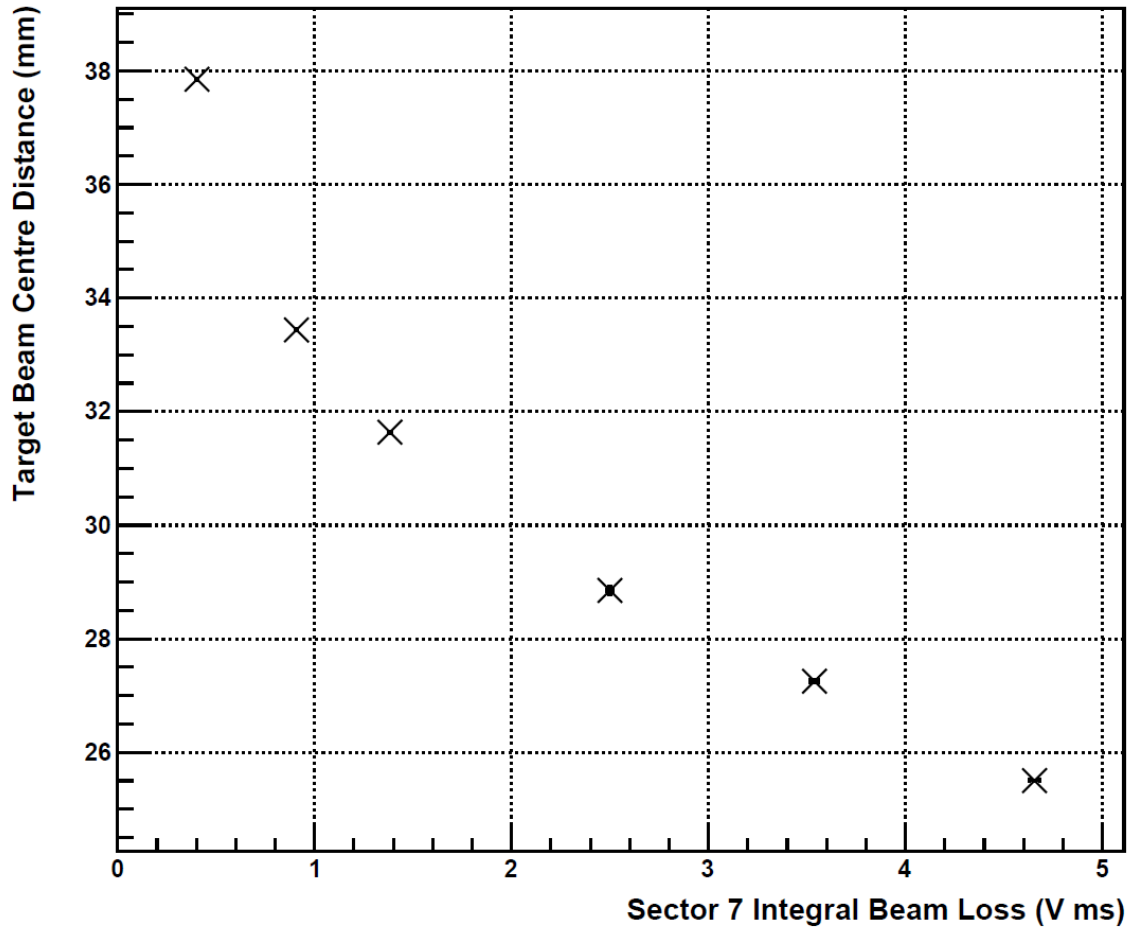
Beam Loss Analysis Methods

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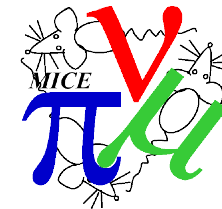
Results: Target Depth Vs Beam Loss

Sector 7 Integral Beam Loss Vs Target Depth for runs 1231 - 1236

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Detector Rates Vs Sector 7 Integral Beam Loss for runs 1231 - 1236

Black = GVA1
Red = BPM1
Pink = BPM2
Green = TOF0
Blue = TOF1

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31/03/2010
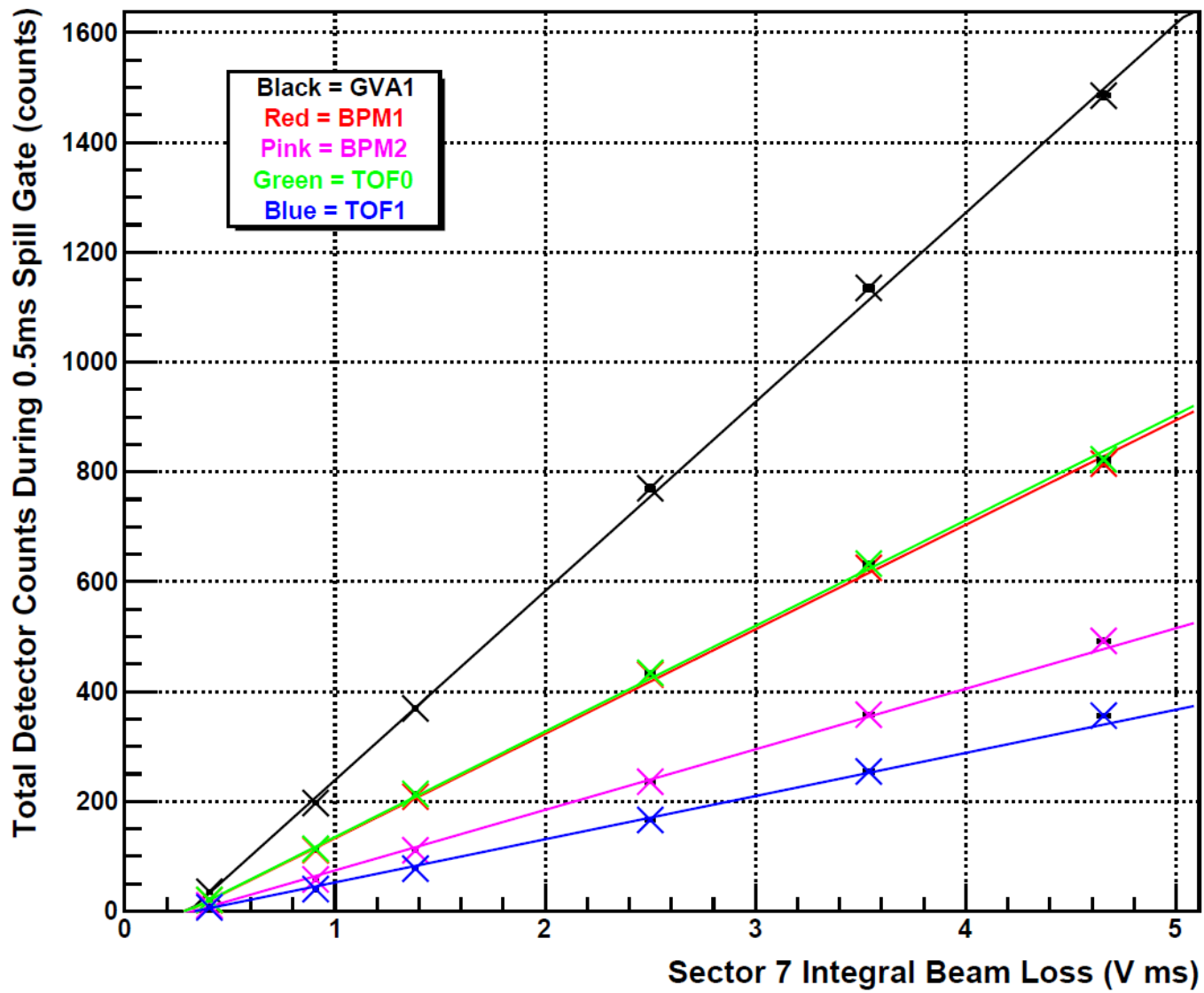
Preliminary TOF Analysis

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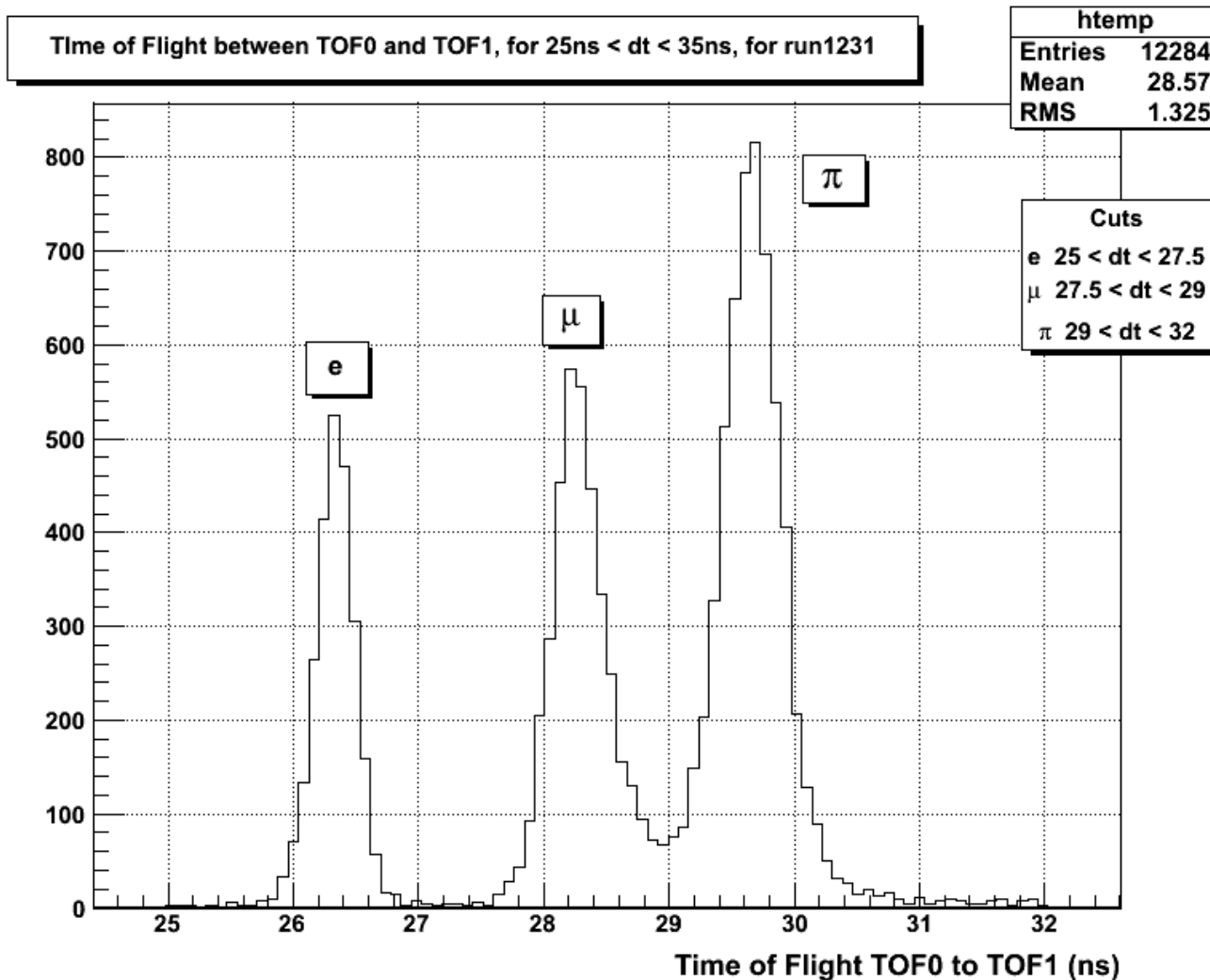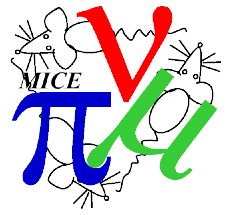
Future Plans

- Another high beam loss study if possible
    - Reproducibility
    - Better statistics (400 – 500 pulses per setting)
    - Tune beam line for muons
- TOF data
    - Get reliable rate vs species plots
- Compare with simulations
- Relate Beam Loss to Protons On Target

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Spares

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Beam Loss vs Particle Rate Analysis Flow Diagram

```
┌─────────────────────┐                    ┌─────────────────────┐
│  Target DAQ data    │                    │   DATE DAQ data     │
└─────────────────────┘                    └─────────────────────┘
         │                                           │
  Data Reduction 1 – fitted peak          Particle rate data extraction
  beam loss analysis, etc                 with ScalersAnalysis
         │                                           │
         ▼                                           ▼
┌─────────────────────┐                    ┌─────────────────────┐
│ Reduced Beam Loss data │                 │  Particle Rate data │
└─────────────────────┘                    └─────────────────────┘
         └──────────────────┐   ┌──────────────────┘

Combine data by matching time stamps
                            │
                            ▼
              ┌─────────────────────────────┐
              │  Combined data (ROOT files) │
              └─────────────────────────────┘
                            │
                 Data reduction 2: extract means and errors
                 for variables on a run-by-run basis
                            │
                            ▼
              ┌─────────────────────────────────────┐
              │ Final plots of beam loss vs particle rate │
              └─────────────────────────────────────┘
```
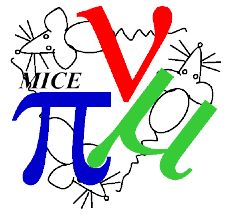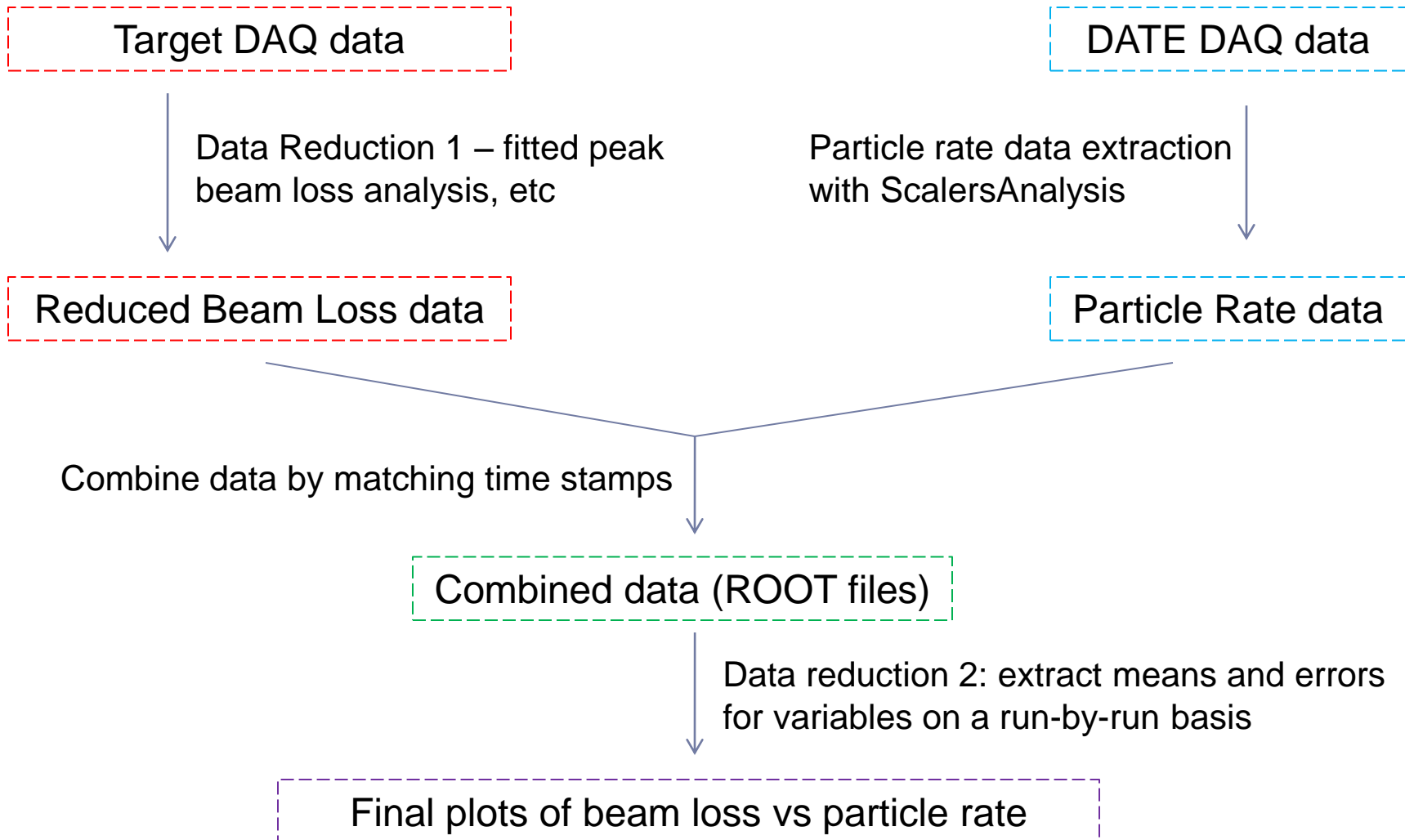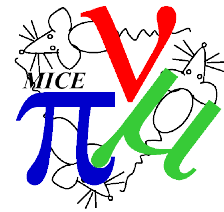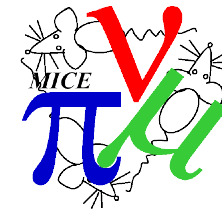
Histogramme of GVA1 Rates for Run 1231

ngva1

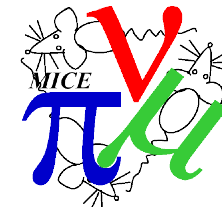| htemp	
Entries	118
Mean	3.081e+06
RMS	1.442e+05
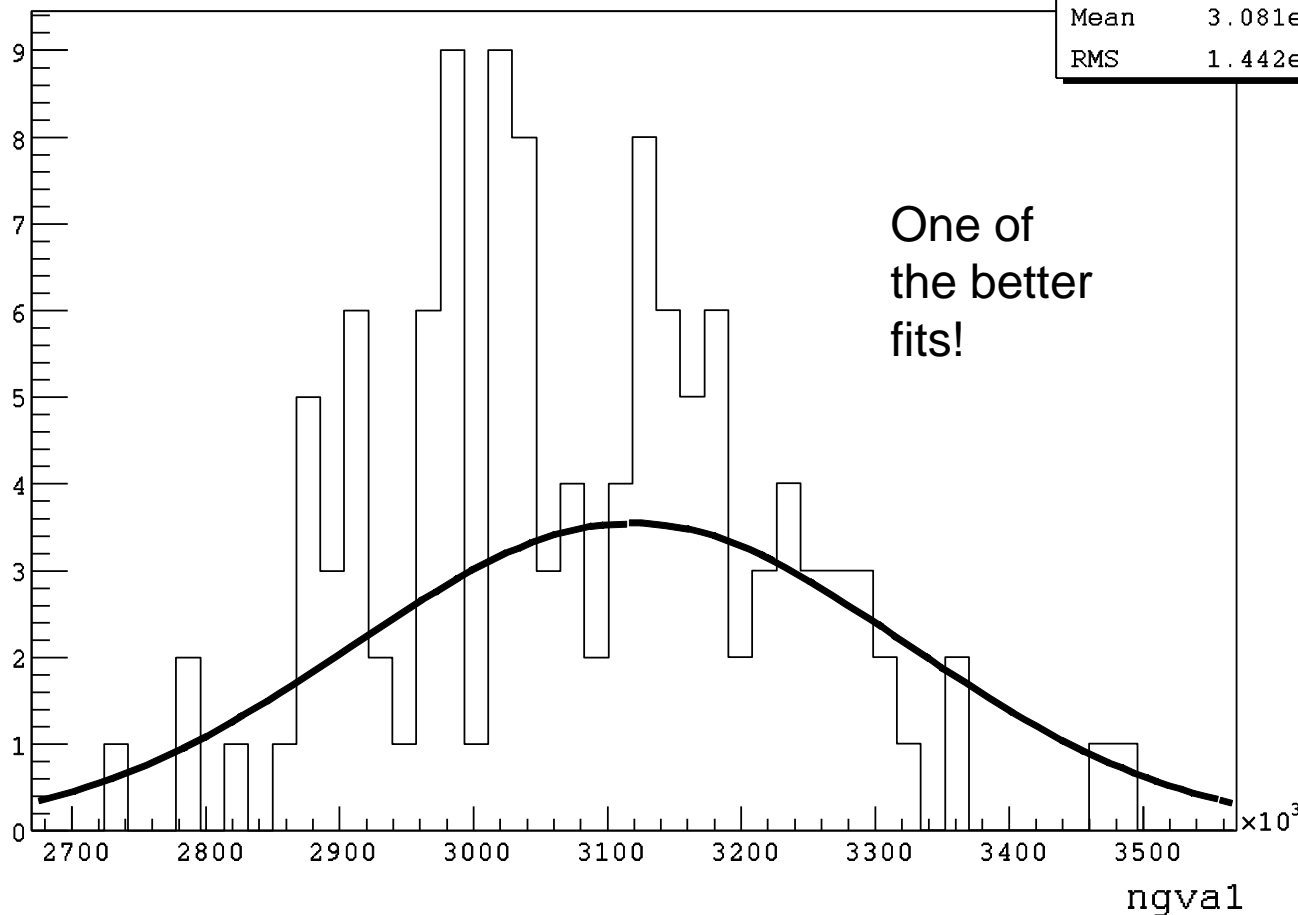
One of the better fits!

ngva1

Combined data (ROOT files)

Data reduction 2: extract means and errors for variables on a run-by-run basis

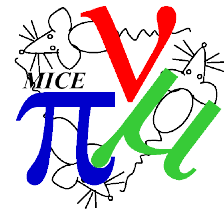Final plots of beam loss vs particle rate

Combined Data Table for Run 1231

```
**************************************************************************************************************************
*   Row   *       blEventTime *      prEventTime *       TgtDepthMM *           BLSec7int *        gval *
**************************************************************************************************************************
*      0 *      1257549277.23 *       1257549277 *      25.513715744 *      -4.66822004318 *        1586 *
*      1 *      1257549282.36 *       1257549282 *    25.5209751129 *      -4.1176199913 *        1521 *
*      2 *      1257549287.47 *       1257549287 *    25.5209751129 *      -4.91044998169 *        1585 *
*      3 *      1257549292.59 *       1257549292 *    25.5040550232 *      -4.85503005981 *        1583 *
*      4 *      1257549297.72 *       1257549297 *    25.5233898163 *      -4.68155002594 *        1477 *
*      5 *      1257549302.83 *       1257549302 *    25.5064697266 *      -4.94497013092 *        1609 *
*      6 *      1257549307.95 *       1257549308 *    25.5088844299 *      -4.10094976425 *        1523 *
*      7 *      1257549313.07 *       1257549313 *      25.513715744 *      -4.51522016525 *        1467 *
*      8 *      1257549318.19 *       1257549318 *    25.5209751129 *      -4.95216989517 *        1493 *
*      9 *      1257549323.31 *       1257549323 *    25.5185451508 *      -4.35855007172 *        1575 *
*     10 *      1257549328.43 *       1257549328 *    25.5209751129 *      -4.90884017944 *        1479 *
*     11 *      1257549333.55 *       1257549333 *    25.5161304474 *      -4.84698009491 *        1530 *
*     12 *      1257549338.68 *       1257549338 *    25.5185451508 *      -4.49002981186 *        1576 *
*     13 *       1257549343.8 *       1257549343 *    25.0041046143 *      -4.67418003082 *        1426 *
*     14 *      1257549348.91 *       1257549349 *    25.5016403198 *      -4.71962976456 *        1480 *
```
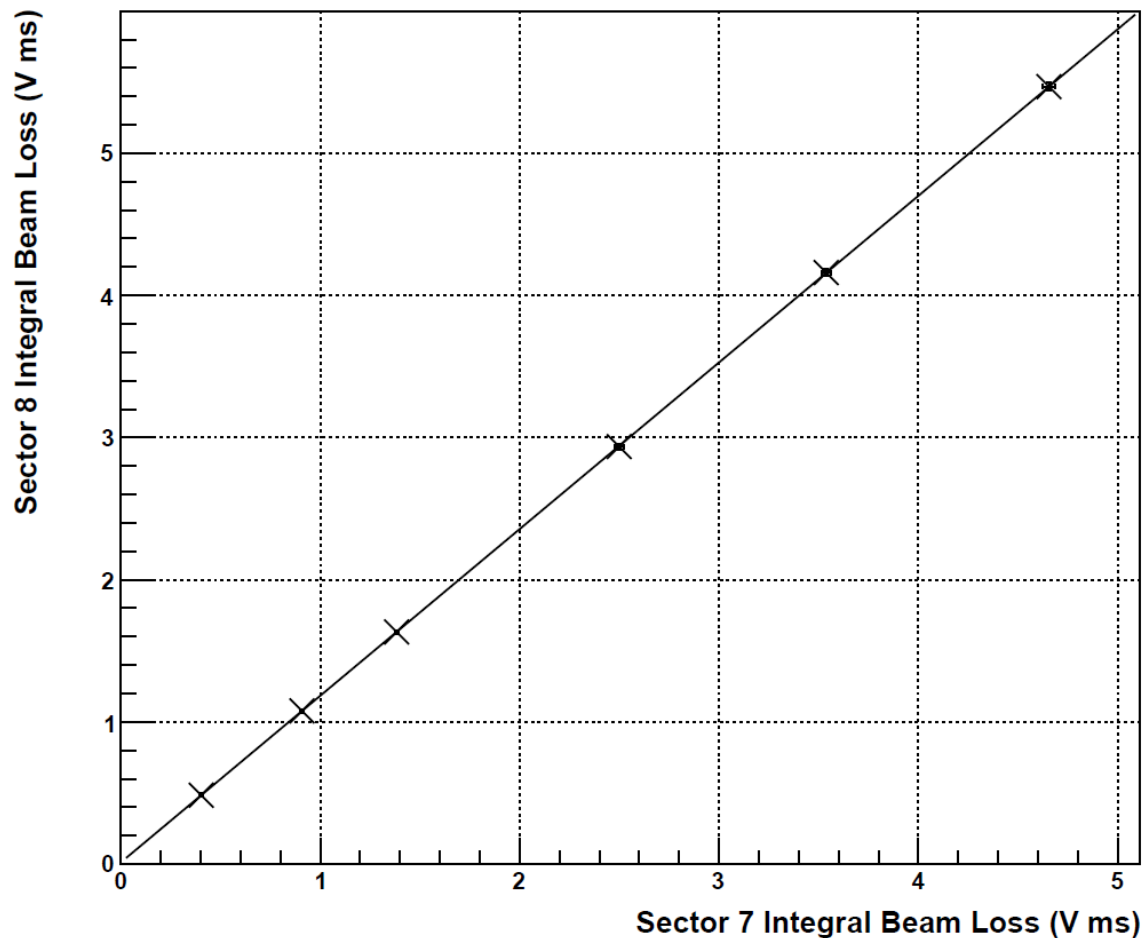
. . .

Reduced Beam Loss data   Particle Rate data

Combine data by
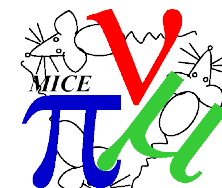matching time stamps

Combined data (ROOT files)
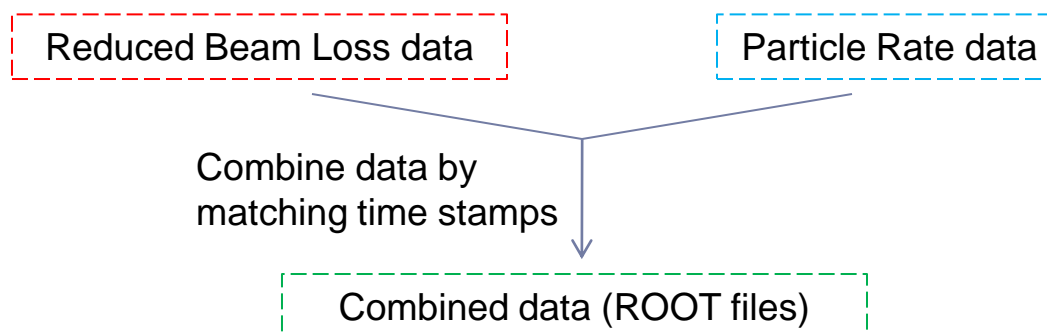
Results: Sector 7 vs 8 Beam Loss

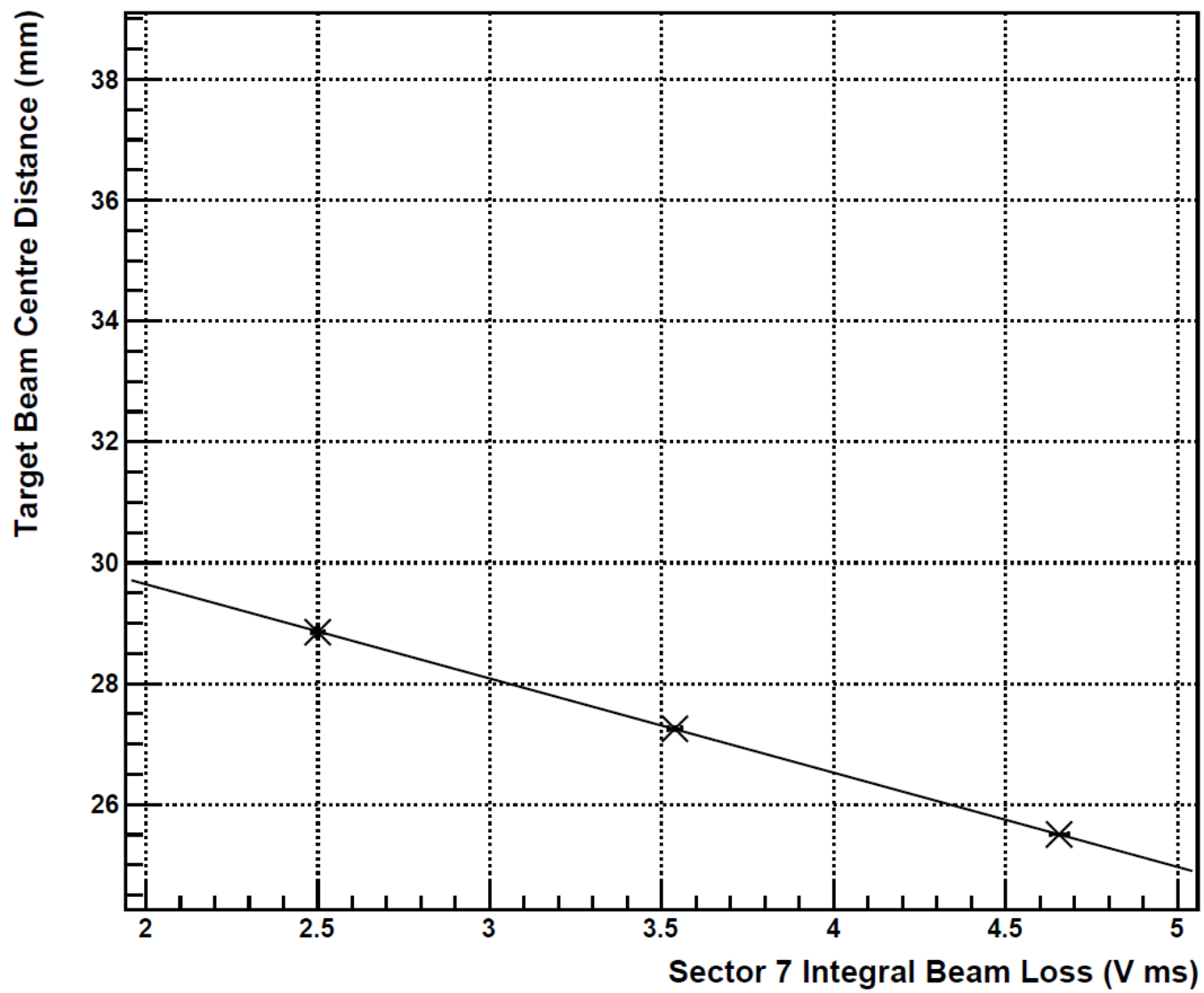Sector 7 Vs Sector 8 Integral Beam Loss for runs 1231 - 1236

One point = the mean values of the beam loss and particle rate for a run

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Sector 7 Integral Beam Loss Vs Target Depth for runs 1231 - 1236

Linear at higher beam losses

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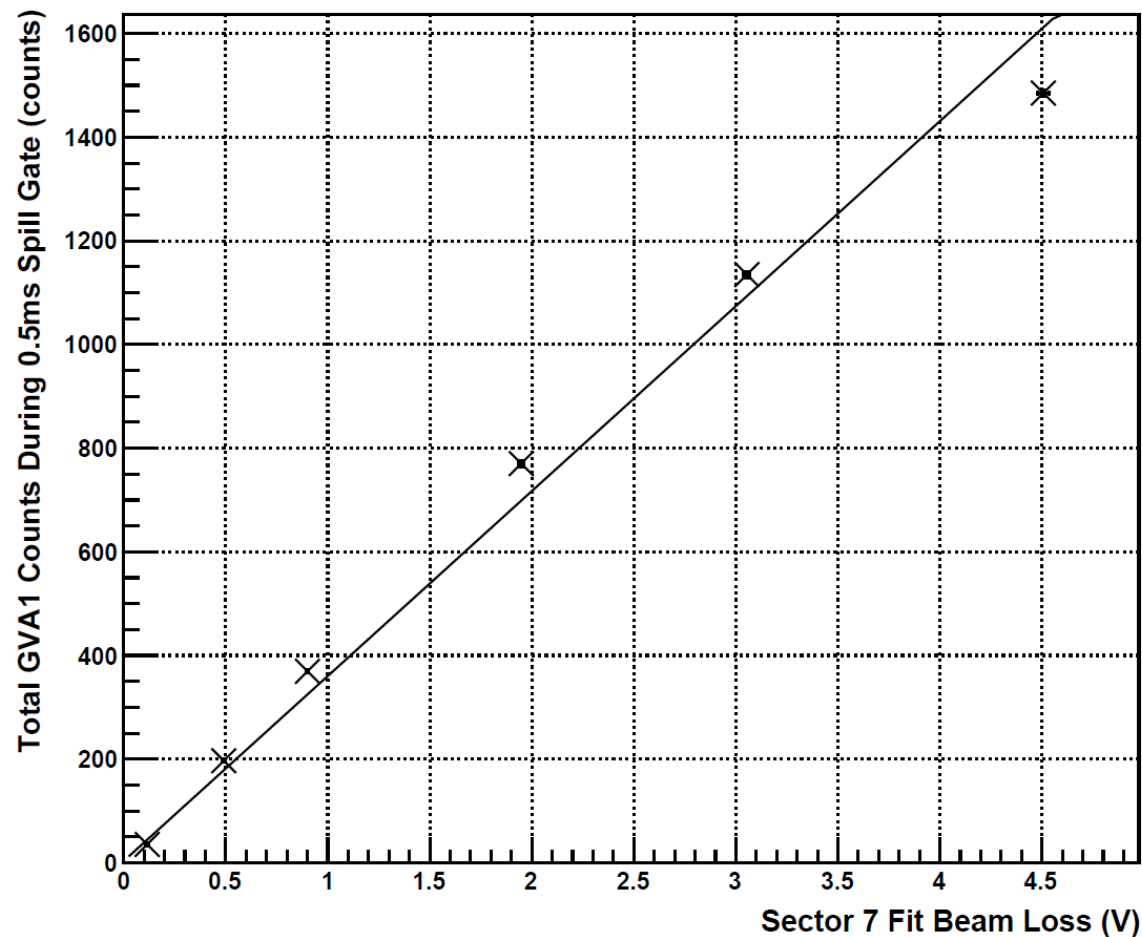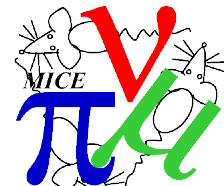
Results: Particle Rate vs Beam Loss

GVA1 Rate Vs Sector 7 Fit Beam Loss for runs 1231 - 1236

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BPM1 Rate Vs Sector 7 Integral Beam Loss for runs 1231 - 1236

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