MuSIC status report 2011

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On behalf of the MuSIC Collaboration

NuFACT11 at UniGe 4th August, 2011

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What is MuSIC and what do we do with it?

Current status: construction

Current status: experimental

Current status: simulation

Next steps

Why do we need intense muon beams?

High energy physics:

- cFLV needs >10^{11} muon/sec
- Neutrino factories needs >10^{12} muon/sec
- Muon collider needs >10^{14} muon/sec

Current best is 3.5x10^{8} muon/sec at PSI from a 1.2MW(1) proton beam

MuSIC aims to reach or beat that using a 400W proton beam

(1)Psi website: http://aea.web.psi.ch/beam2lines/beam_mue1.html

Physics at MuSIC

- Searches for charged Lepton Flavour Violation (cFLV) in $\mu \rightarrow eee$
- Using FFAG as muon storage rings for use in high energy muon beams
- Feasibility studies for COMET/PRISM
  - Proof of proton to muon efficiency
  - Testing of the capture solenoid
- μSR

What is MuSIC?

(Muon Science Innovative Commission)

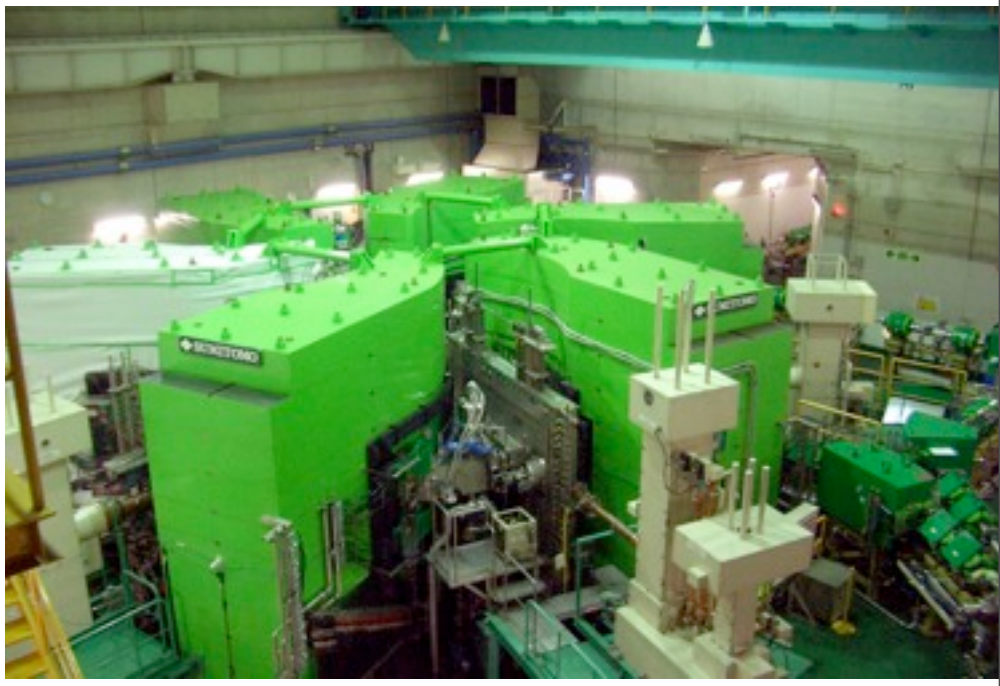
Being build at the RCNP

Uses the 400W proton cyclotron

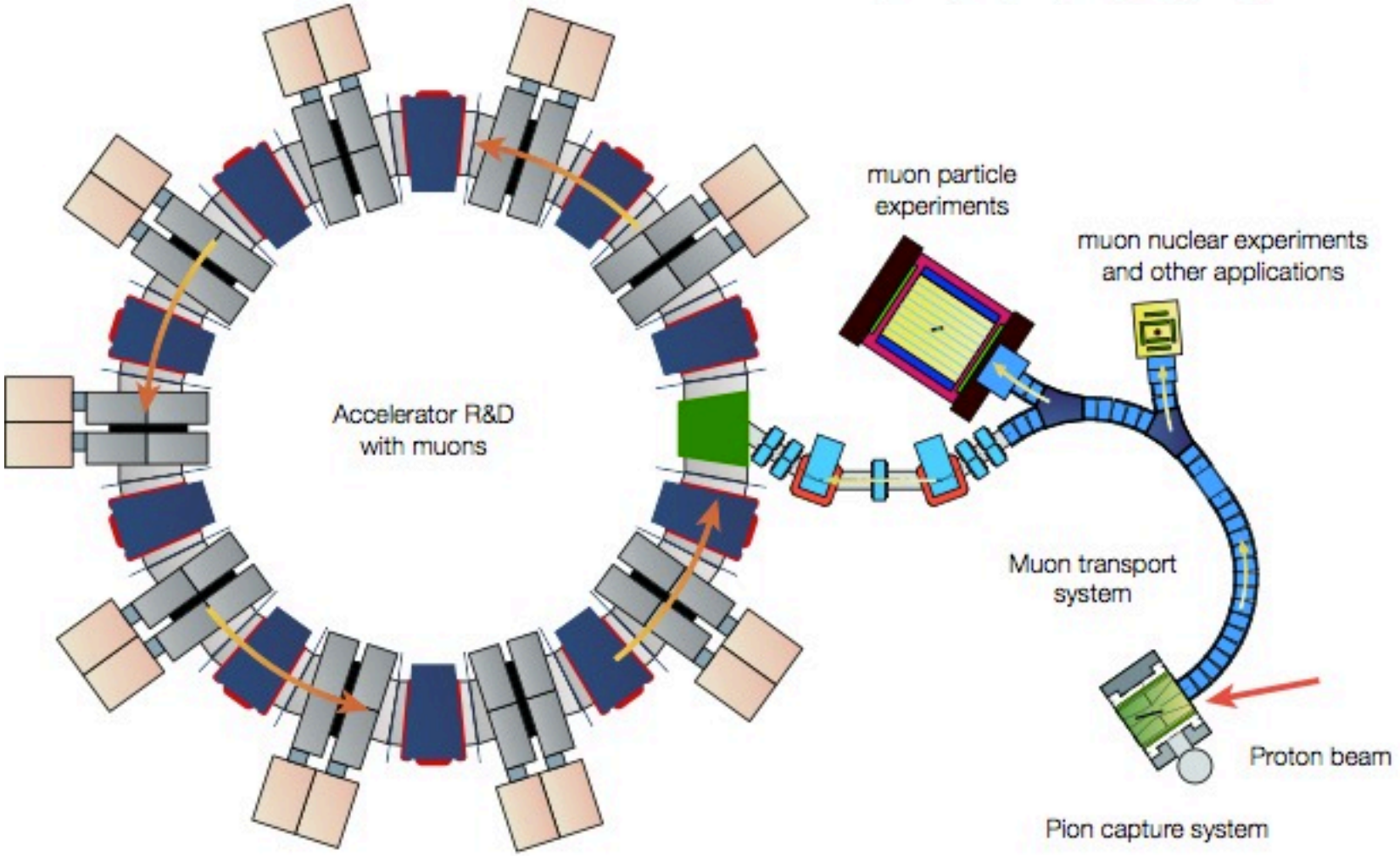
Will be the world's most intense muon source

- Aim of producing more than 10^8 muon/sec

Uses a novel system to maximise the efficiency of muon production

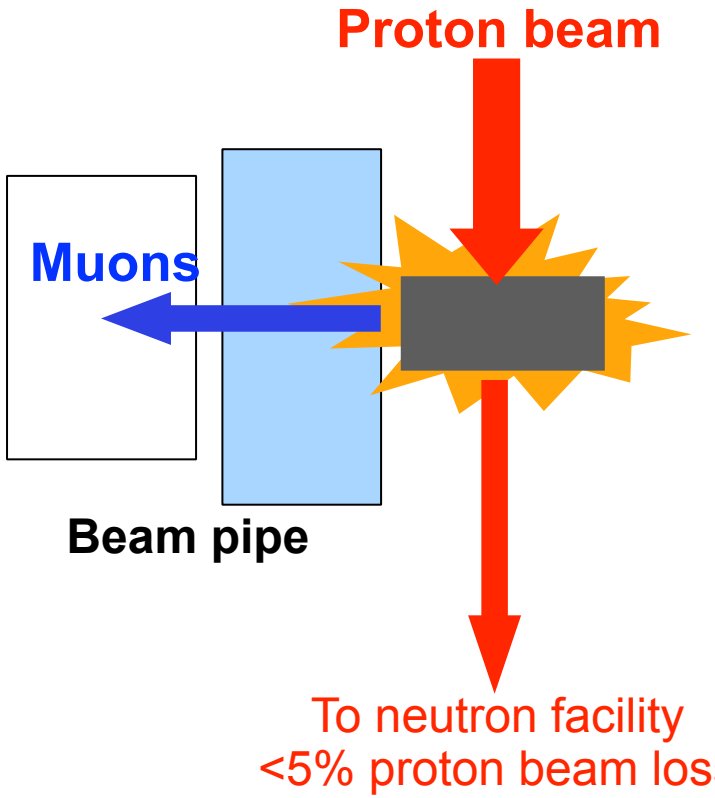


MuSIC


muon particle
experiments
muon nuclear experiments
and other applications
Accelerator R&D
with muons
Muon transport
system
Proton beam
Pion capture system

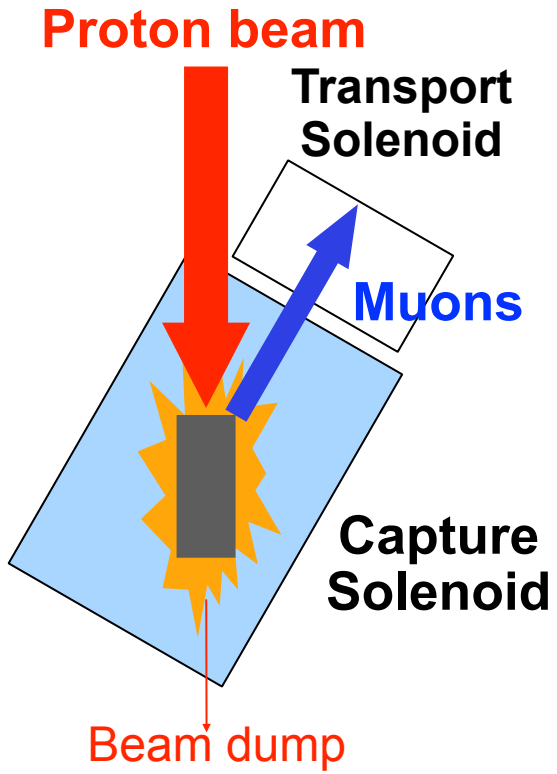
MuSIC: what's so novel?

Conventional design



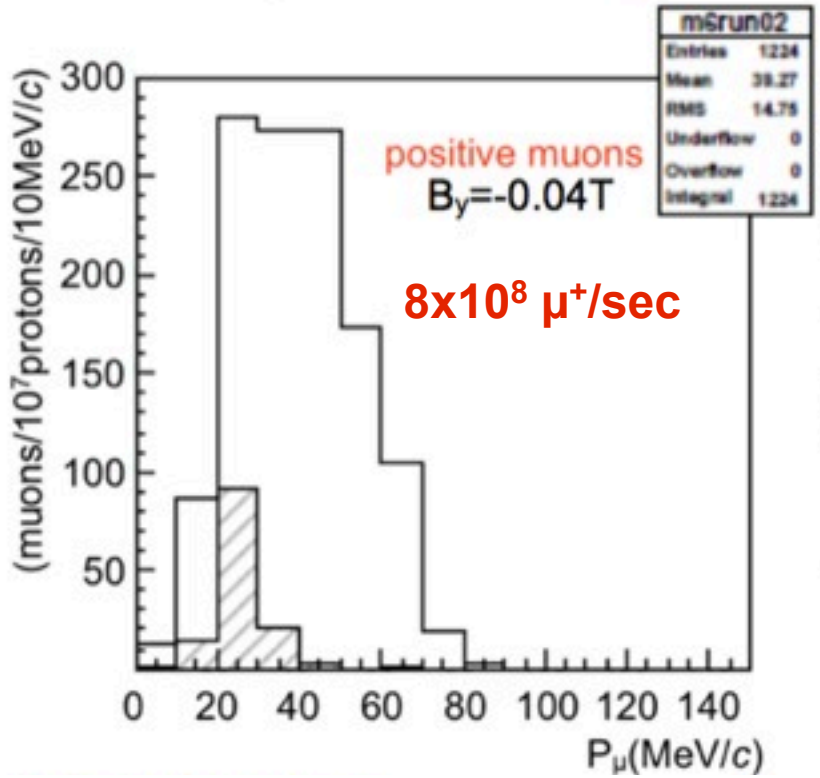
- Graphite target t=20mm φ=70mm
- Use only a fraction of the beam
- Small solid angle (400mSr for the Super Omega beamline)
  (values based on J-PARC MUSE)

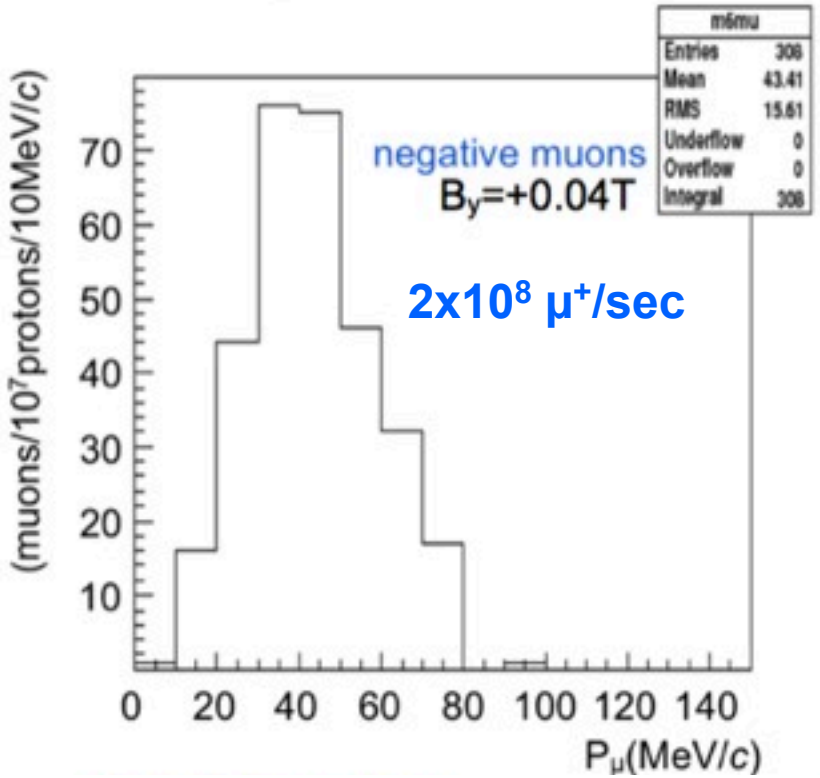
MuSIC's design



- Graphite target t=200mm φ=40mm
- Use all of the beam
- 2πSr solid angle (only backwards particles collected)

Simulated muon yields





Simulated using MARS and G4Beamline

Muons counted at the end of the transport solenoid (180º) generated with a 1μA, 400MeV proton beam

Yields of $2x10^6$ and $5x10^5$ muon$^{[+,-]}$/$W_{\text{proton beam}}$

MuSIC: comparison

	PSI[(1)] (μE4)	MuSIC	COMET[(2)]	NuFACT[(3)]
Muon intensity (/sec)	3.5×10^{8}	$10^{8\text{-}9}$	10^{11}	$10^{12\text{-}13}$
Muon momentum (MeV/c)	85-125 (total range)	20-70	20-70	170-500
Time structure	Continuous	Continuous	Pulsed	Pulsed
Proton beam power/energy (W/GeV)	1.2M / 0.590	400 / 0.4	56k / 8	4M / 8
Beam current (μA)	1.8	1	7	Not given
Production target	Graphite	Graphite	Tungsten	Mercury jet
Capture Solenoid Max Field Strength (T)	5.0	3.5	5.0	20

(1) Based on: "A New High-intensity, Low-momentum Muon Beam for theGeneration of Low-energy Muons at PSI", Prokscha, T.; Morenzoni, E.et al. (Hyperfine Interactions, Volume 159, Issue 1-4, pp. 385-388)

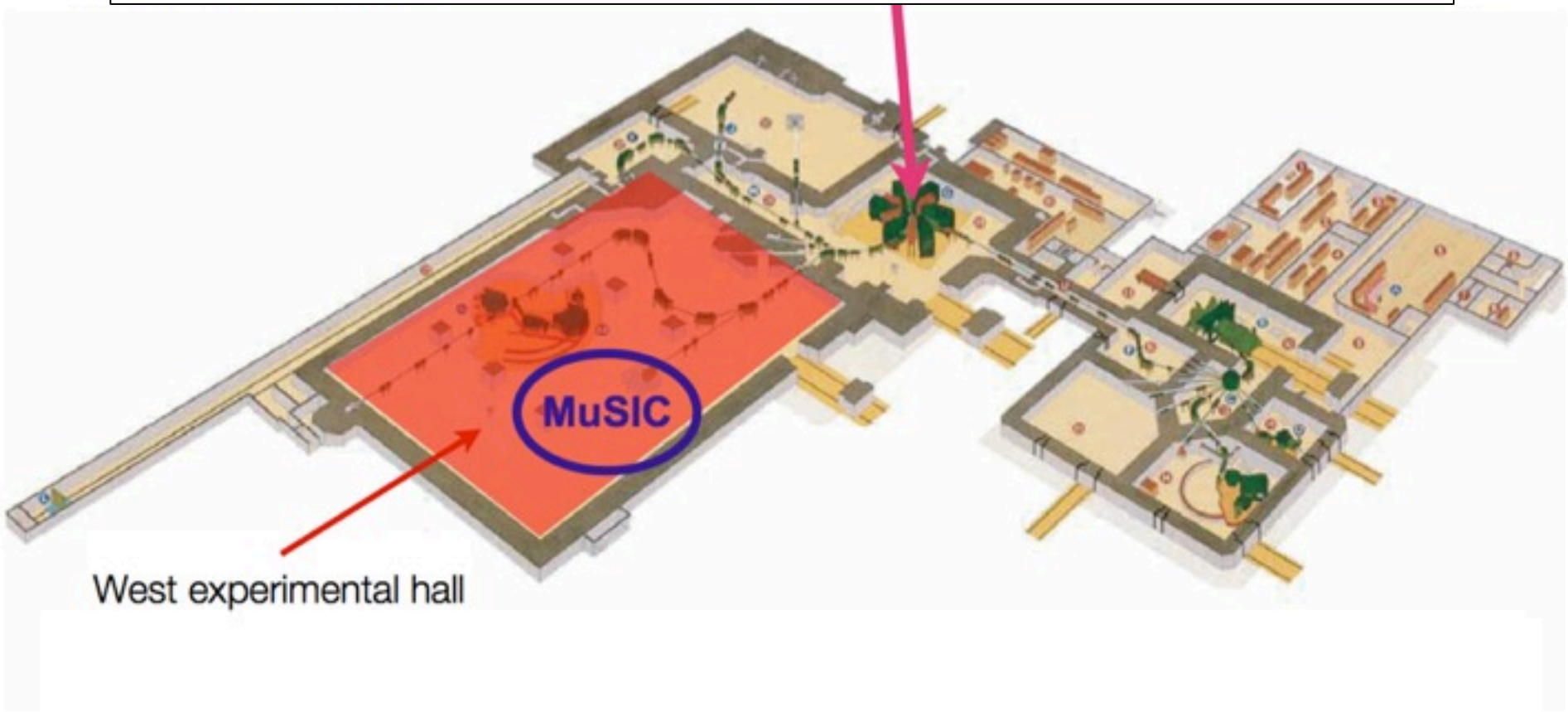
(2) COMET CDR

(3) Based on The Muon Collider/Neutrino Factory Target System, H.Kirk and K.McDonald (Aug.14,2010) and Study-II report

The RCNP, Osaka

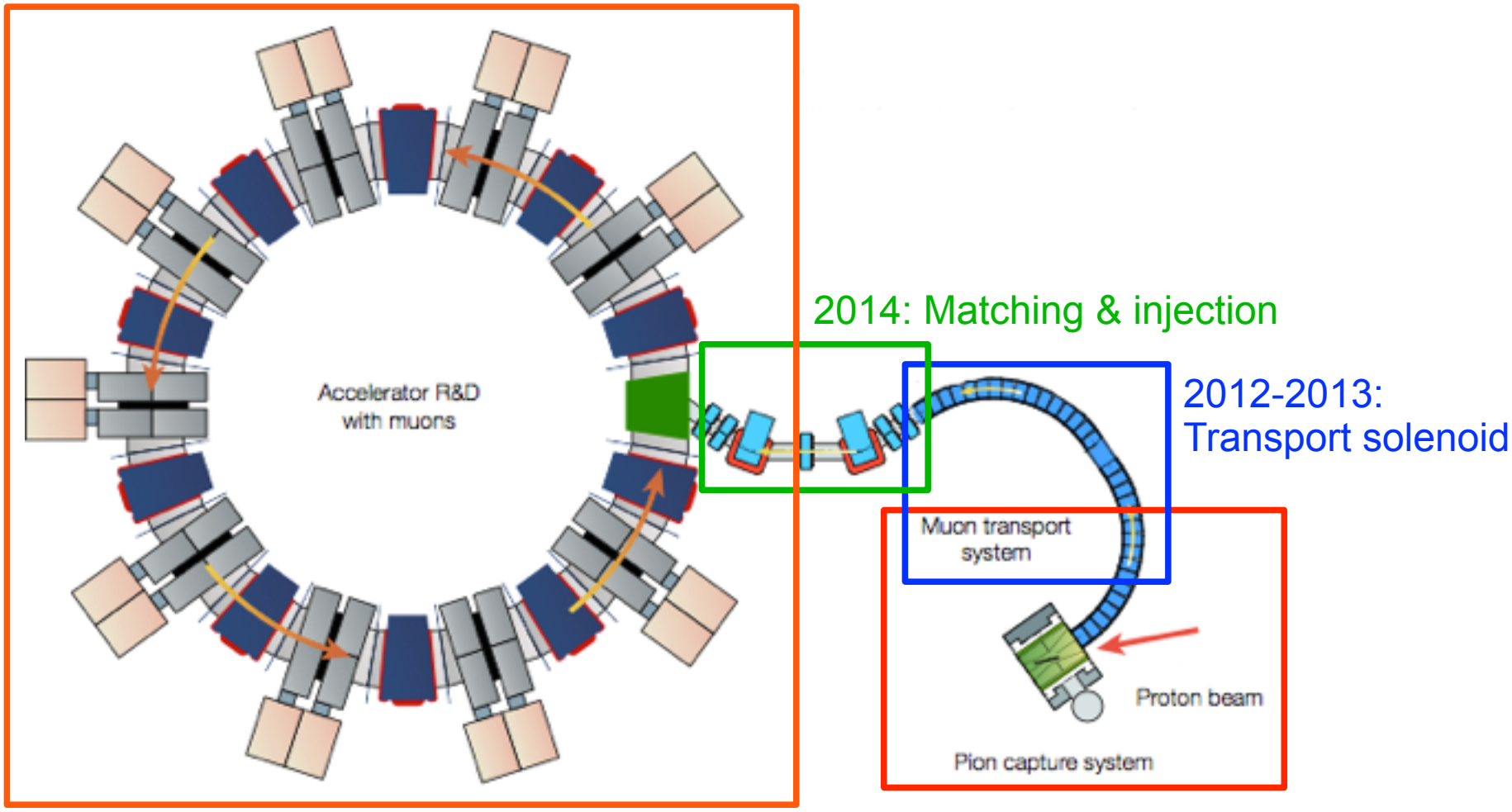
(Research Centre for Nuclear Physics)

400W cycltron generating 400MeV protons at 1μA (planned expansion to 5μA in the near future).
This above the pion production threshold.



The schedule

Originally scheduled as a 5 year project
Below is hopeful and budget dependent



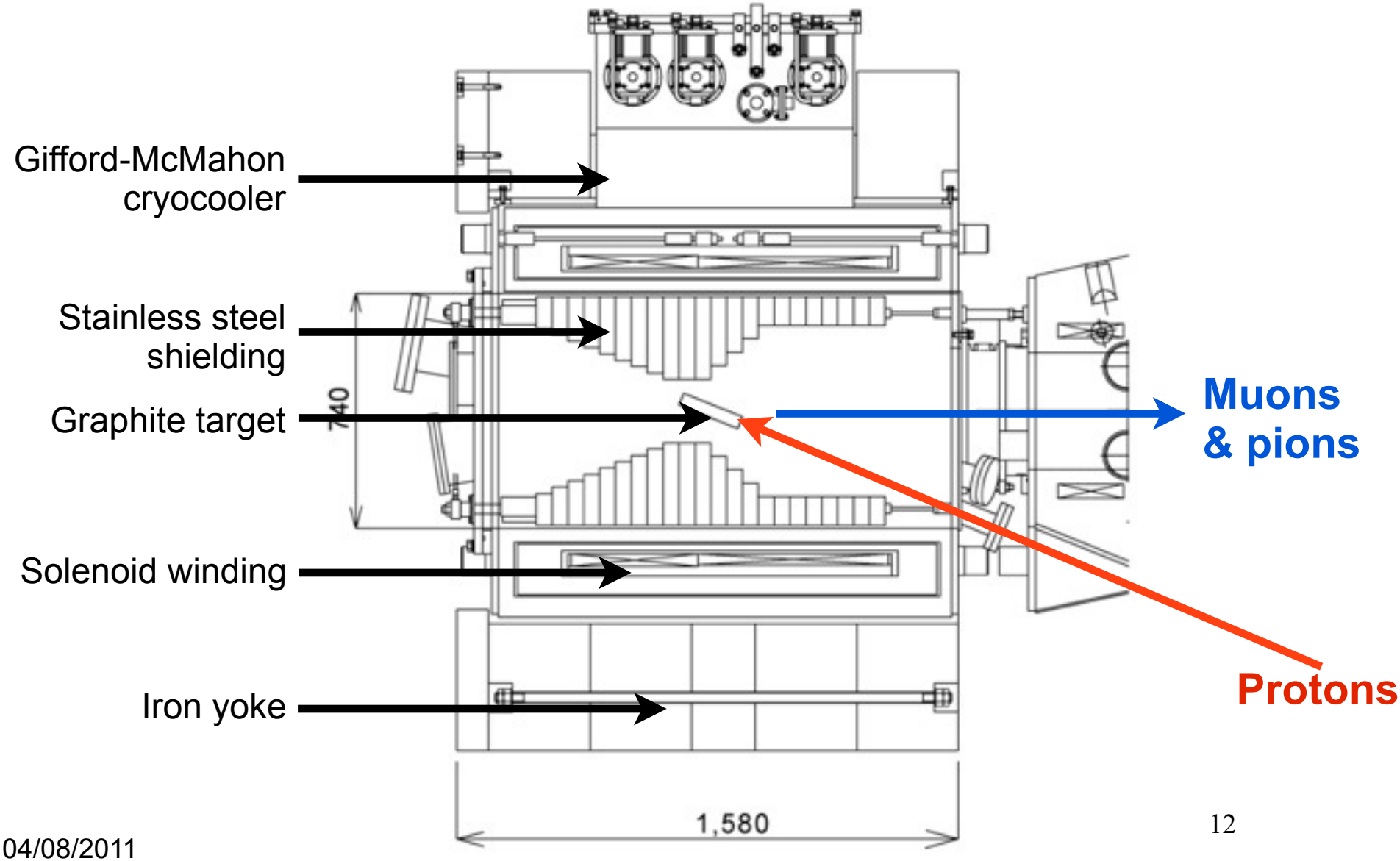
2014: Matching & injection

2012-2013:
Transport solenoid

2015-2016: Muon FFAG storage ring

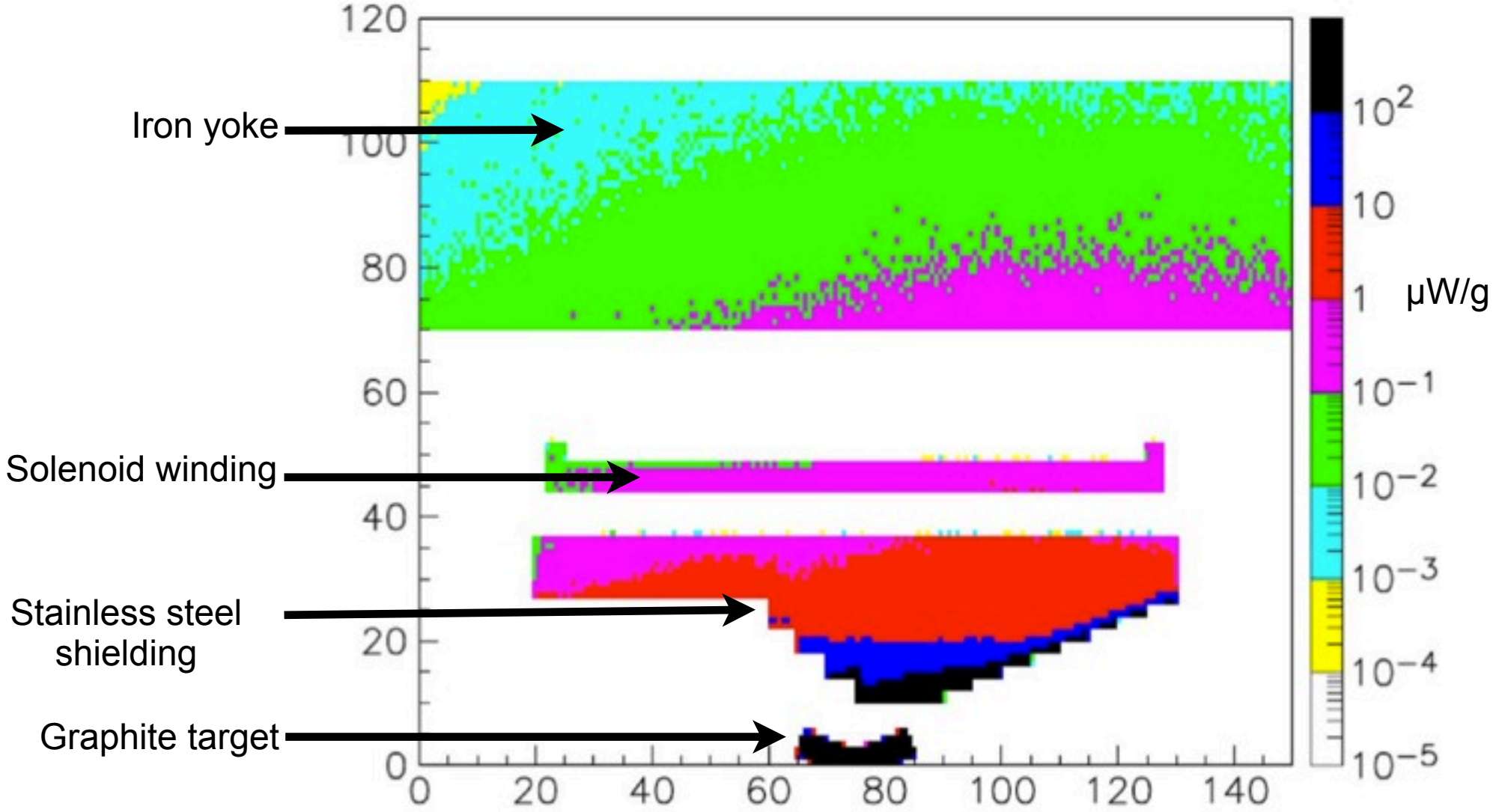
2009: Pion capture solenoid
Complete and operated

Pion capture solenoid design (3.5T field)

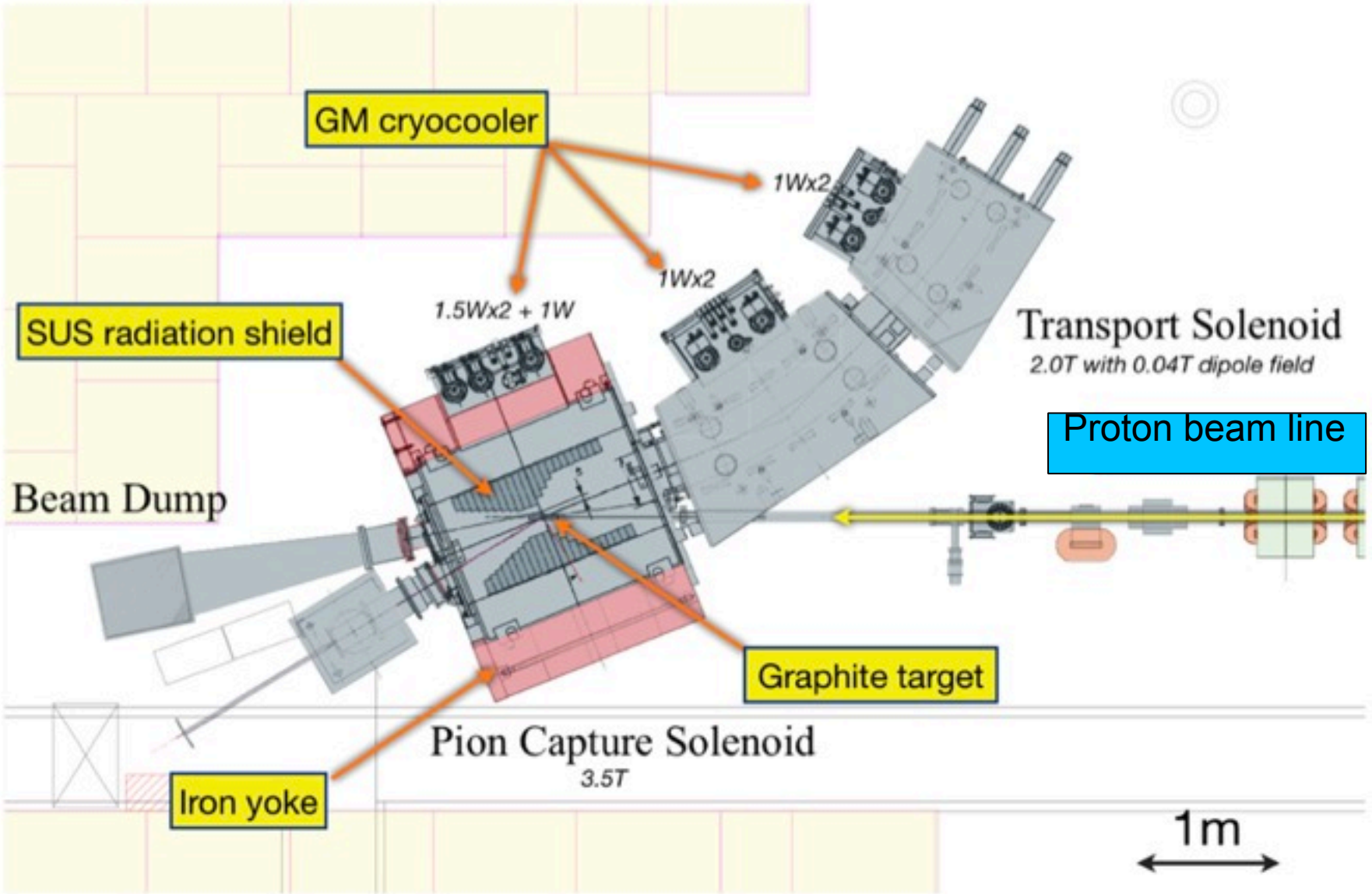


Capture solenoid heating

(Total heating ~1W for a 1ton cold mass)



The current situation



MuSIC, a photo

Use so far

3 periods of beam time:

- 48 Hours starting 29th July 2010
- 72 Hours starting 13th February 2011
- 60 Hours starting 18th June 2011

Used a reduced beam:

- 6pA current
- 392MeV energy (still above pion threshold)
- 2.4mW power

Beamtest (29th-30th July 2010)

The aim was to make an initial measurement of the particle flux

2 detectors were installed and successfully run

- A simple scintillating counter
- A multi-strip counter

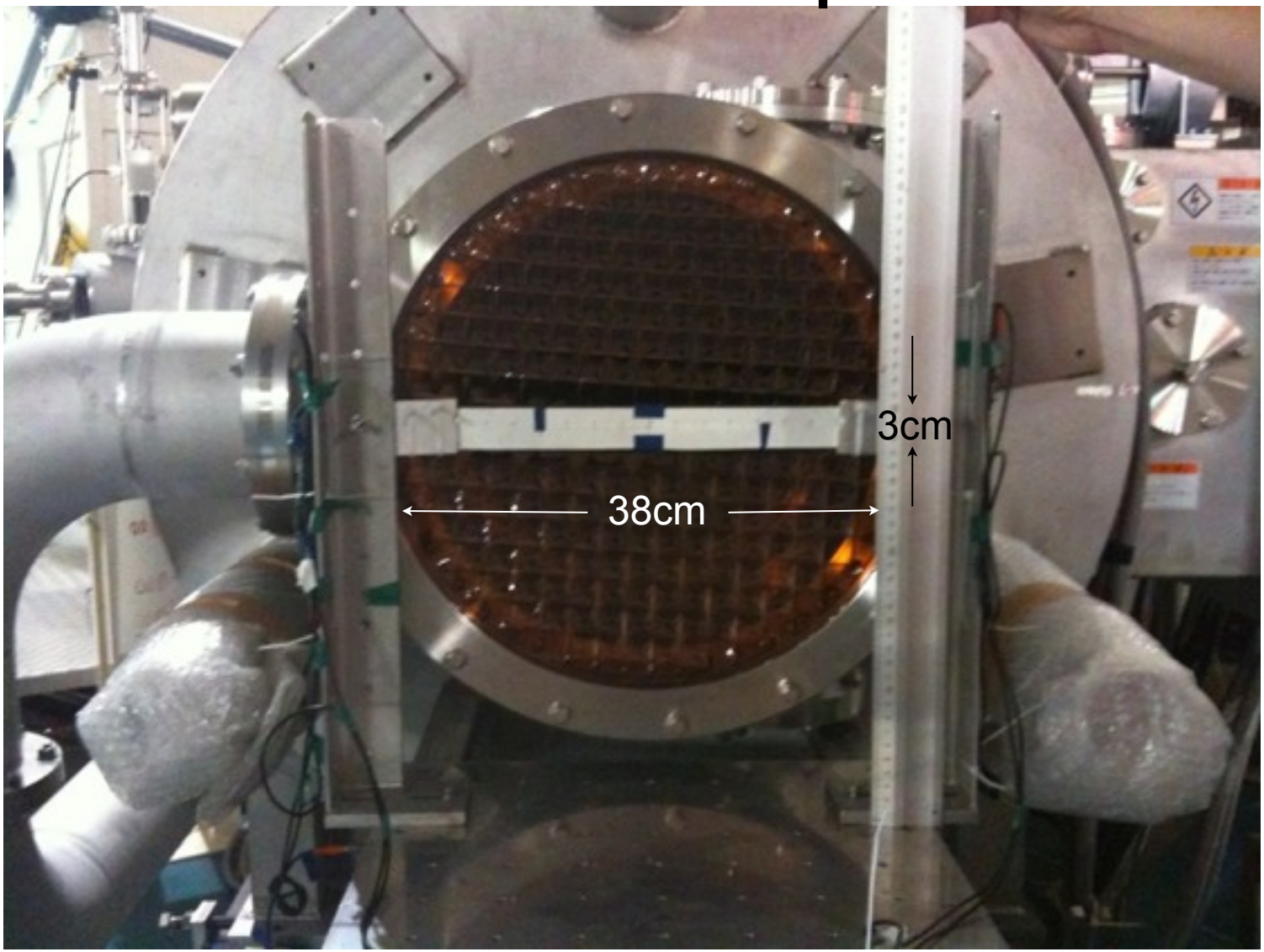
Read out from the detectors was via MPPC

DAQ composed of a NIM & CAMAC system

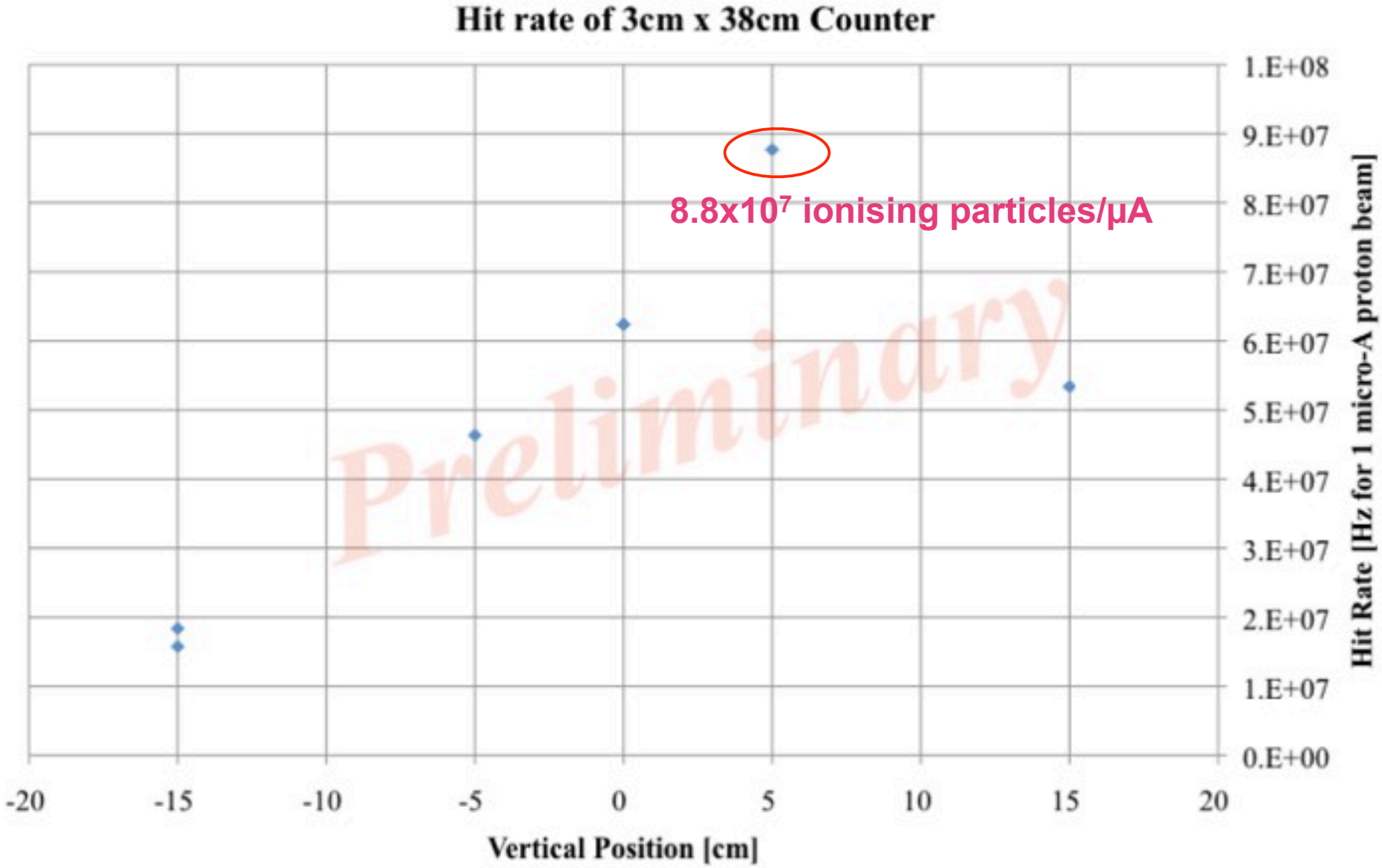
The vertical distribution of particles was measured

- Total flux has a peak of 8.8×10^7 ionising particles/μA

The set-up



Vertical hit rate distribution



Beamtest (13th-15th February 2011)

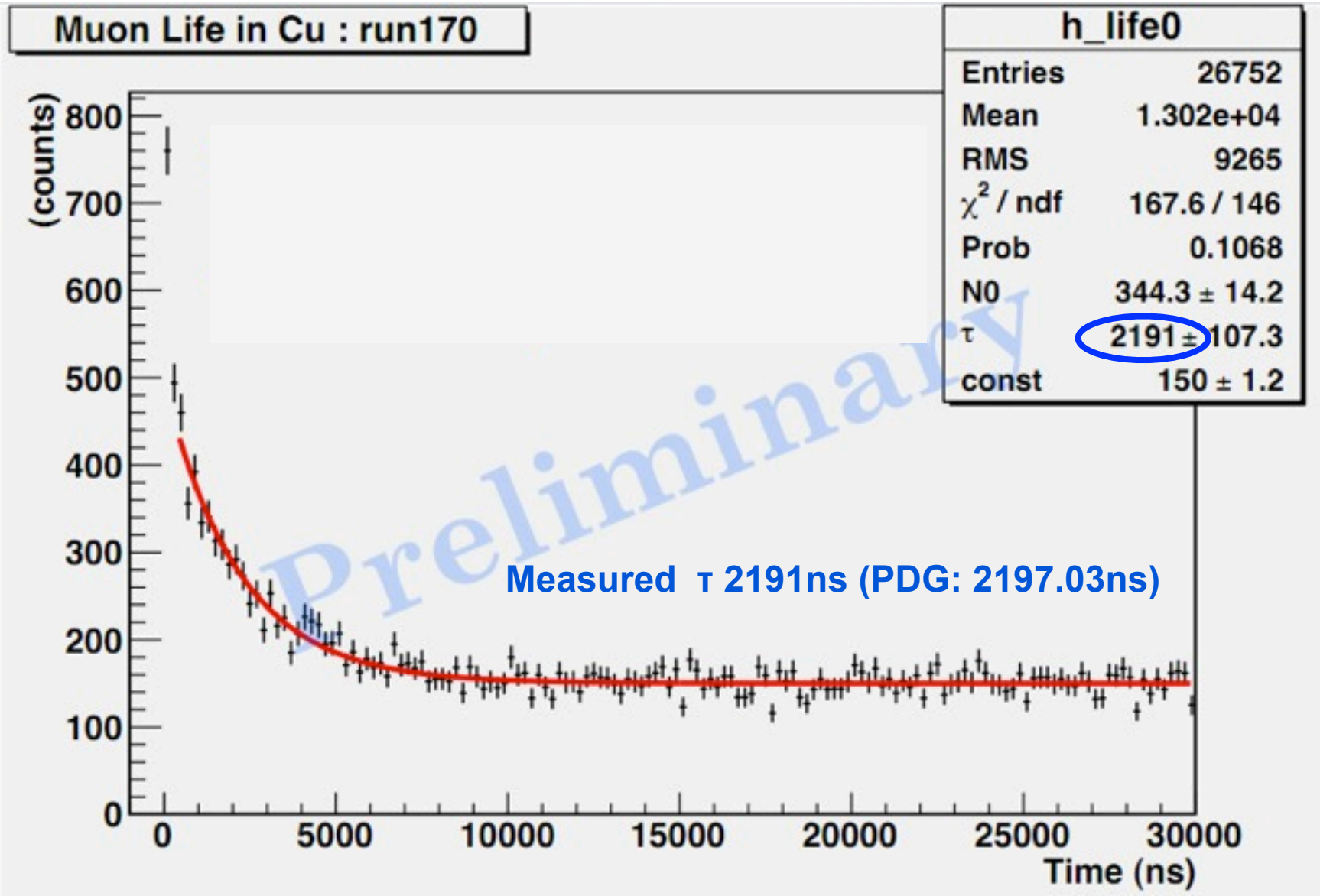
The aim was to measure the muon component of the beam

2 new detectors were used:

- 2 scintillation strips for measuring the muon lifetime
- A thicker circular scintillator

The muon lifetime was measured for Cu and Mg but only with low statistics

Muon decay lifetime



Beamtest (19th-21st July)

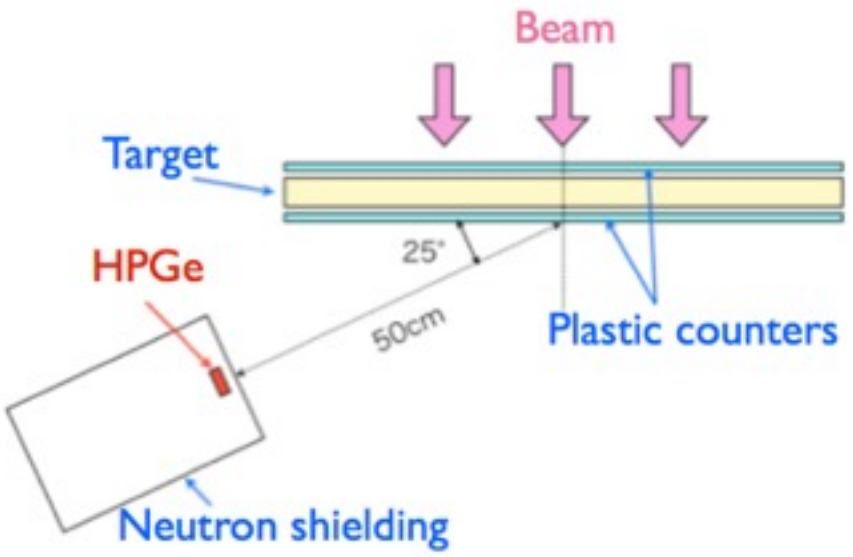
Purpose: muon yield estimation

By μ^+ lifetime measurement

- Target: Cu, Mg
- Counters
  - Plastic scintillators
  - MPPC read-out

By μ^- X-ray measurement

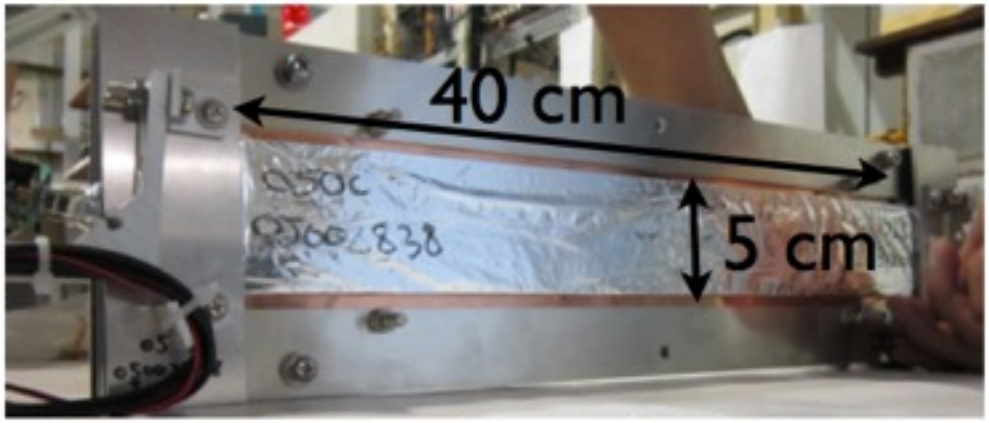
- Mg target
- Ge detector



	Plastic scintillator	Cu target	Mg target
Thickness (mm)	3.5	6	20
Area (mm2)	380x50	370x80	370x80

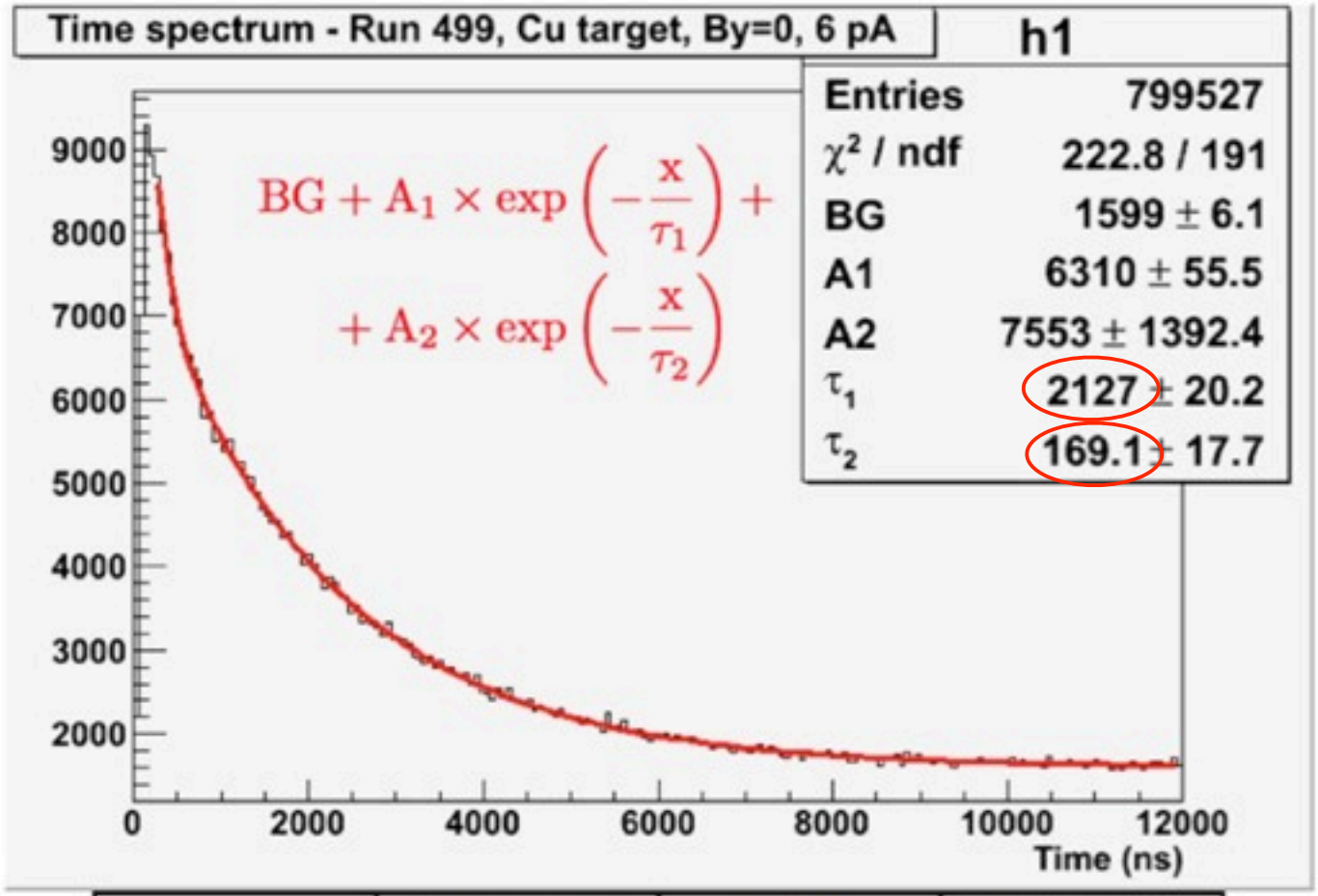
Slide courtesy of Tran Hoai Nam, Osaka University

The detector



Slide courtesy of Tran Hoai Nam, Osaka University

Muon lifetime measurement



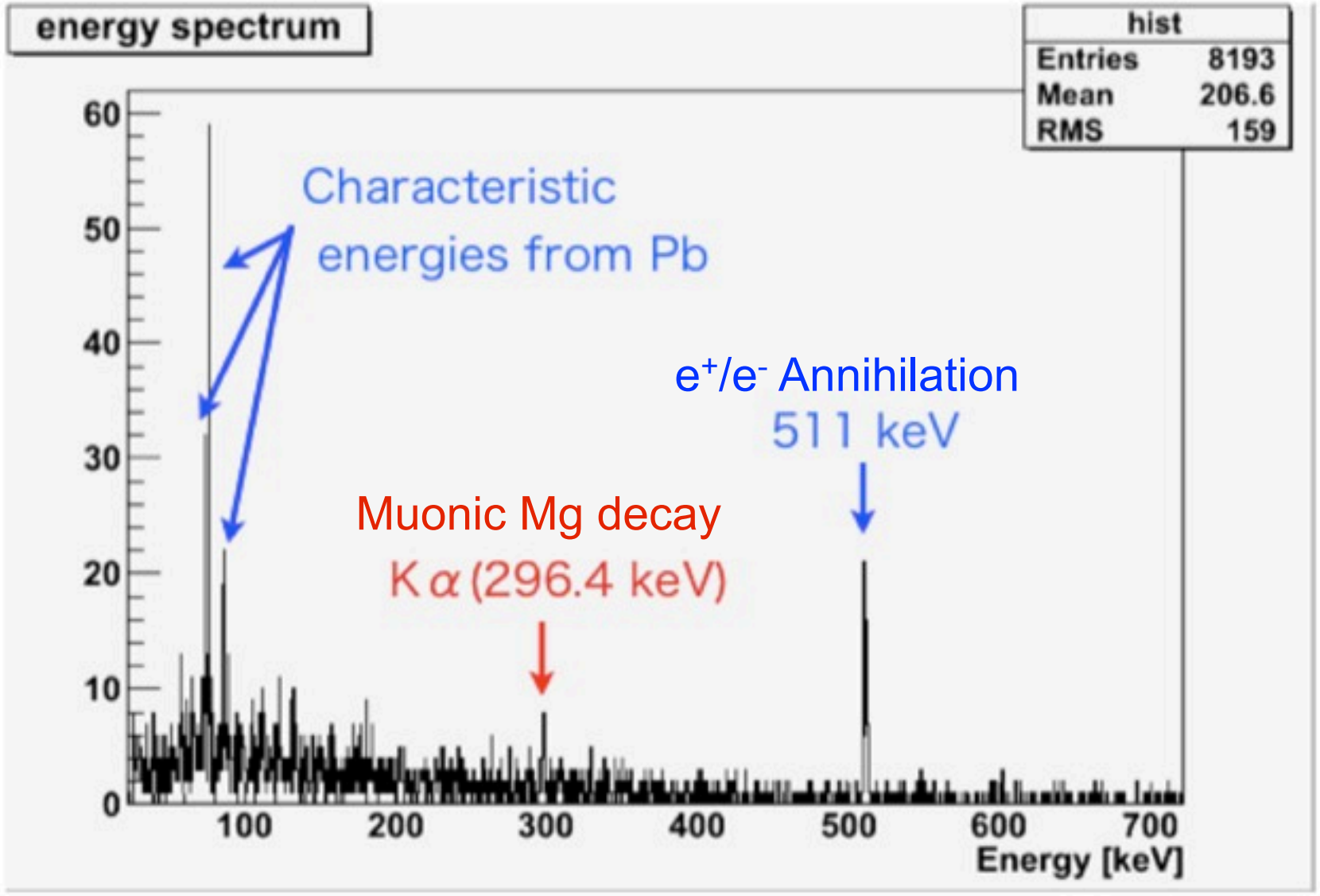
	Free muon*	Cu**	Plastic scint.**
τ (ns)	2197.03 ± 0.04	163.5 ± 1	2026.3 ± 1.5

*http://pdg.lbl.gov

**DOI: 10.1103/PhysRevC.35.2212

Slide courtesy of Tran Hoai Nam, Osaka University

X-ray spectrum (Mg target)



Slide courtesy of Tran Hoai Nam, Osaka University

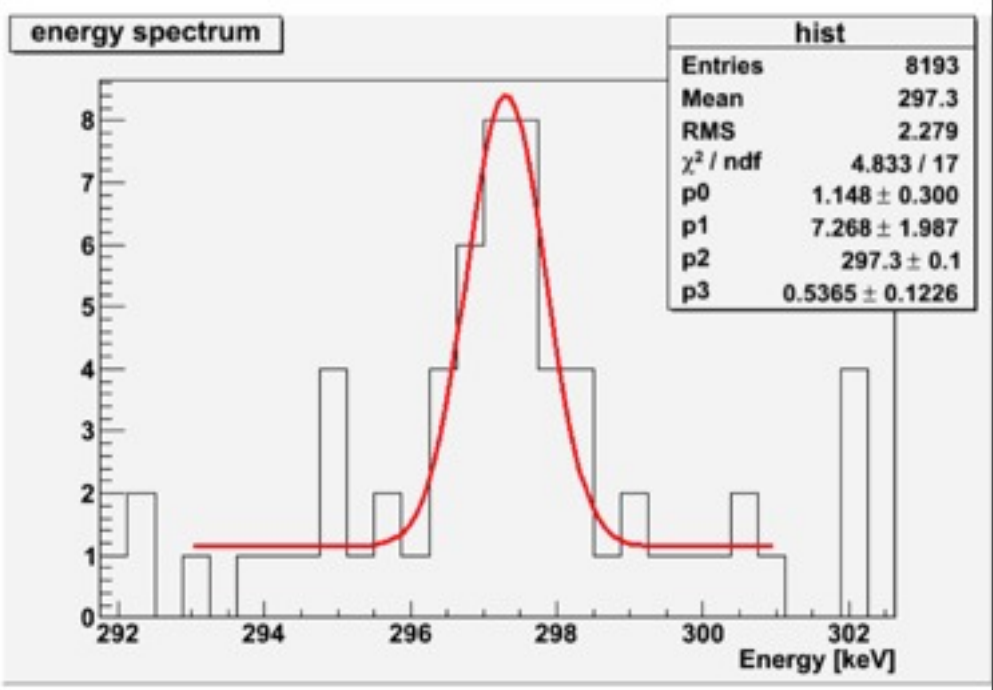
Estimation of the muon yield (preliminary)

Muonic decay:

- 2000 μ^+/sec with 6pA
  - 3.3×10^8 μ^+/sec using 1μA
- 8.5 muon/$W_{\text{proton beam}}$

Muonic x-ray:

- 26 photons at the Kα peak (6pA)
  - 10^8 μ^-/sec using 1μA



Kα (296.4 keV) peak

Slide courtesy of Tran Hoai Nam, Osaka University

MuSIC: simulation

This is an ongoing project

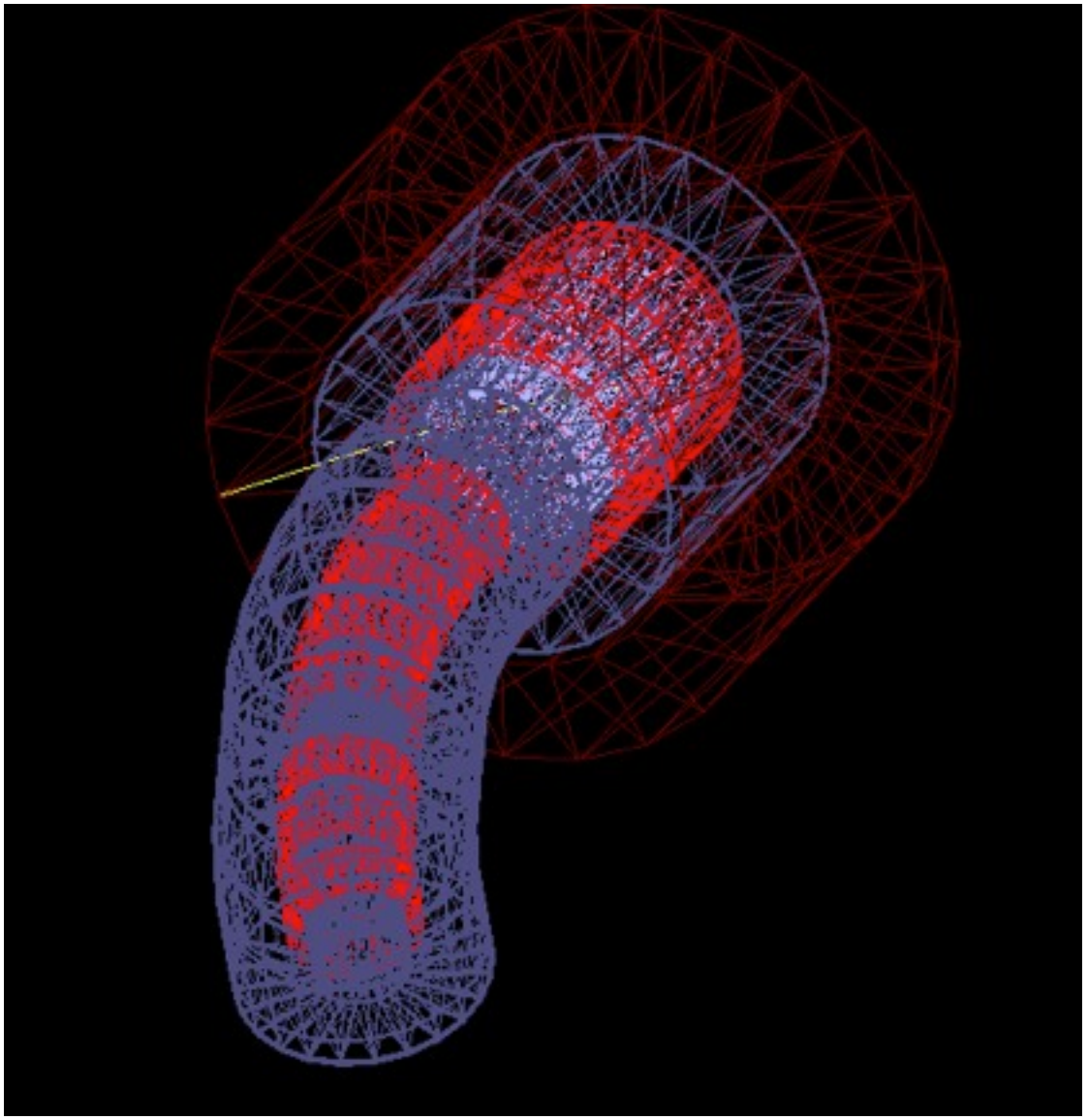
There is currently a simple implementation in G4beamline already used for:

- Calculating acceptance angles
- Calculating muon yields

Working on a more detailed simulation in geant4 for:

- Studying run 3 results and interpreting yields
- Calculating neutron background
- Future studies, eg: μ→eee

MuSIC: simulation in G4beamline



The future

Finish analysis of run 3 and make a definitive statement on the muon/proton yield

Planned run for October 2011 aiming to measure the background neutron flux

Planned run for early 2012 at 100nA prior to ramping to 1μA

Extend the transport solenoid to full 180º

Conclusions

MuSIC has already had a successful year of running

Aiming finish the commissioning soon

Will soon be operating with a 1μA beam

Will hopefully be the most intense muon beam in the world!

MuSIC has the highest yield of muons/$W_{\text{proton beam}}$

MuSIC: 8.5×10^5 muon/$W_{\text{proton beam}}$

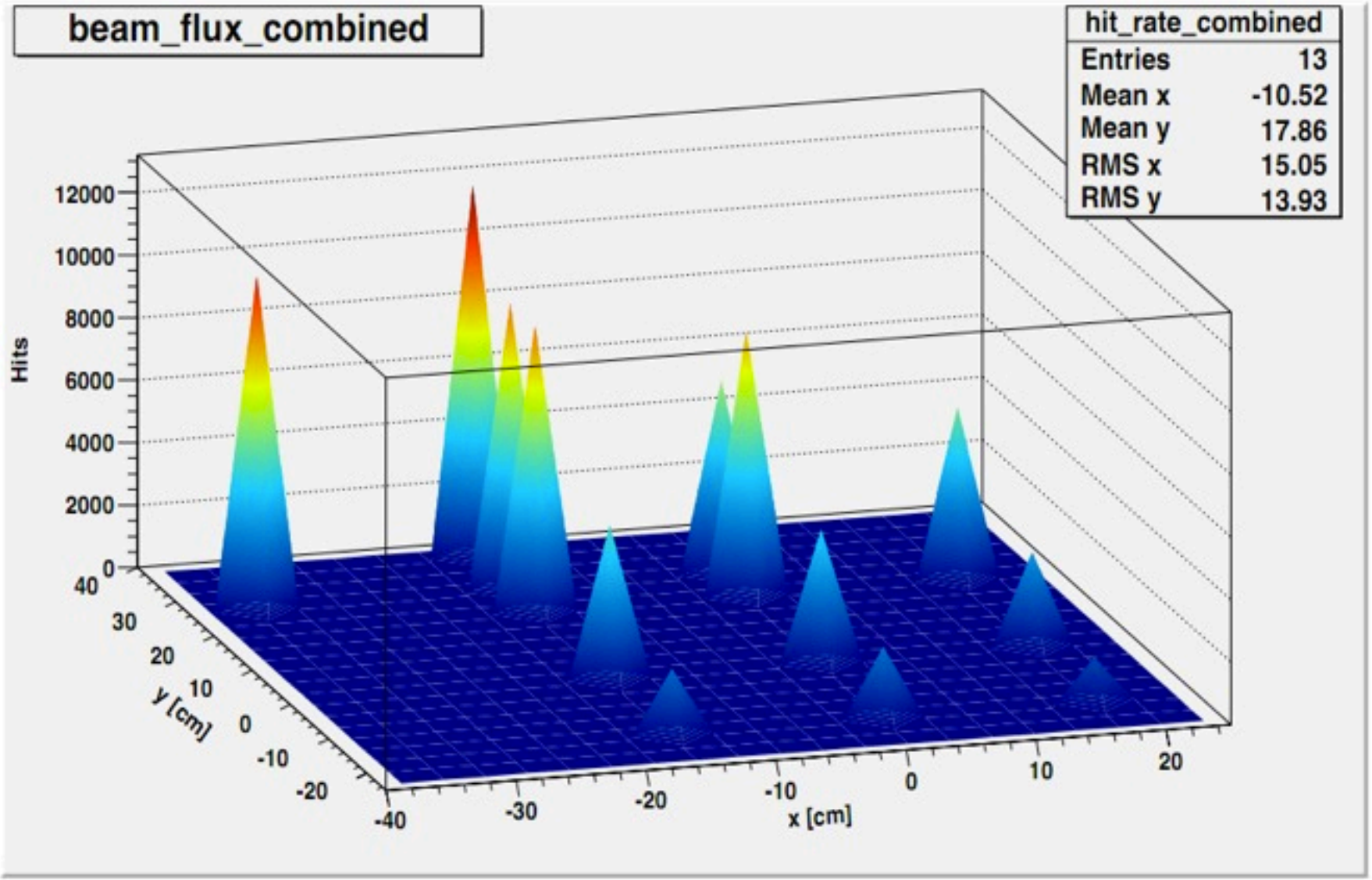
Target: $[5 \times 10^5, 2 \times 10^6]$ muon$^{[-,+]}$/$W_{\text{proton beam}}$ (180º)

PSI: 292 muon/$W_{\text{proton beam}}$

Thank you!

Any questions?

Measured 2D charged particle flux distribution



Simulated 2D charged particle flux distribution (g4beamline)