Experimenter contributions to Main Injector improvements

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All Experimenters' Meeting June 21st, 2004

- **Instrumentation**
  - **understanding and fixing the Flying Wire System**
  - **Beam Loss Monitor System**
- **Main Injector in 2005**
  - **NuMI and pbar stacking in a same cycle**
- **MINOS experimenters involvement**
  - **craving for protons**
  - **Digital Damper System**
  - **Multi-batch studies**
  - **Main Injector "beam quality" input to NuMI Beam Permit System**
  - **Barrier RF stacking**
  - **BPM's in the NuMI extraction region**

The Flying Wire system

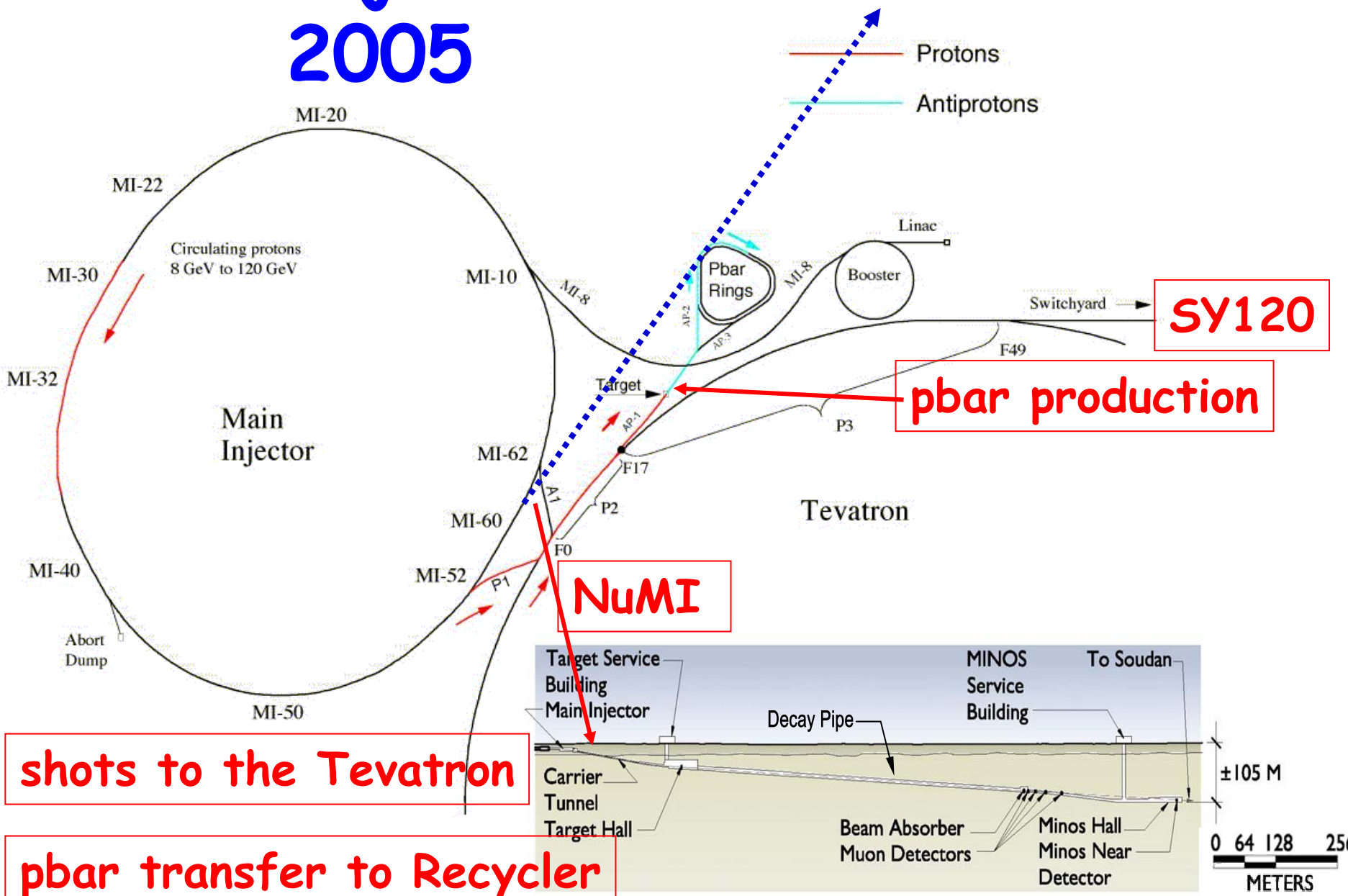
- **Early experimenter contributions from**

  - Hyejoo Kang (MINOS, Stanford University post-doc)
    - beam measurements, debugging of the system with a scope
  - Lorenzo Feligioni (D0, Boston University graduate student)
    - analysis of SDA data for proton and pbar shots
- **We had two major problems**
  - a spread in the measurements for the vertical wire well beyond its expected resolution
  - strong nonlinearity for proton coalesced bunches, resulting in a fake emittance growth
- **The problems were fixed by a collaboration of AD Instrumentation Dept., Technical Division (Yuriy Pischalnikov) and PPD (J. Krider, C. Lindenmeyer, P. Wilson)**
  - developed a better way to hold the wire (clamping instead of soldering)
  - switched to a low gain, large output current capability PMT
  - implemented remotely placeable light attenuators to increase dynamic range

Beam Loss Monitors

- the system consists of 249 argon filled glass ion chambers
- the present readout is using for some of its functions the same multi-bus system which is part of the current BPM system, that we are in the process of replacing
- the system can provide integrated losses over the acceleration cycle for only 1 BLM/house (typically 1/12)
- when running multi-batch at high intensity we need to keep a record of beam losses in MI at least around all the Lambertson locations ➥ we need integrated signals for a good fraction of the loss monitors
- ***we are in the process of starting an upgrade of the electronics, coordinating this effort with a similar one which is proceeding for the Tevatron system***
- **This will be a collaboration between AD Instrumentation Dept., PPD/EE (A. Baumbaugh) and PPD/CDF (J. Lewis)**

Main Injector in 2005



Supporting antiproton stacking and NuMI in Main Injector

- **One additional extraction region at MI60 for NuMI**
  - additional kickers and Lambertsons magnets
- **Mixed mode operation of the machine, with a same acceleration cycle shared by antiproton stacking and NuMI**
  - from present single batch to multi-batch mode operation
  - 2 separate single turn extractions in a same cycle
- **Operation of Main Injector at high intensity**
  - $> 3\times10^{13}$ protons/cycle, about a factor 6 higher than present
- **Reliability of operation**
  - instrumentation upgrade, monitoring and control of beam losses

NuMI craving for protons

- **It all began with the First Proton Driver Study in 2001** *(W. Chou, P. Kasper, M. Velasco)*
  - "historical" talks to MINOS Collaboration by Bob Webber and Peter Kasper in Sept. '01
    - ***Getting protons to NuMI … it's a worry***
- *B. Choudhary, T. Fields, G.W. Foster. J. Griffin, P. Lucas, A. Marchionni, P. Martin, D. Michael, E. Prebys, S. Pruss* **"Accelerator Improvement Options for NuMI Proton Intensity",** August 2002
- Bob Webber "**Kicker Gap control in the Fermilab Booster: the problem and status**", December 2002, MINOS Collaboration Meeting
  - ***Stan Wojcicki*** *"If I were a graduate student… I would consider working on this subject"*

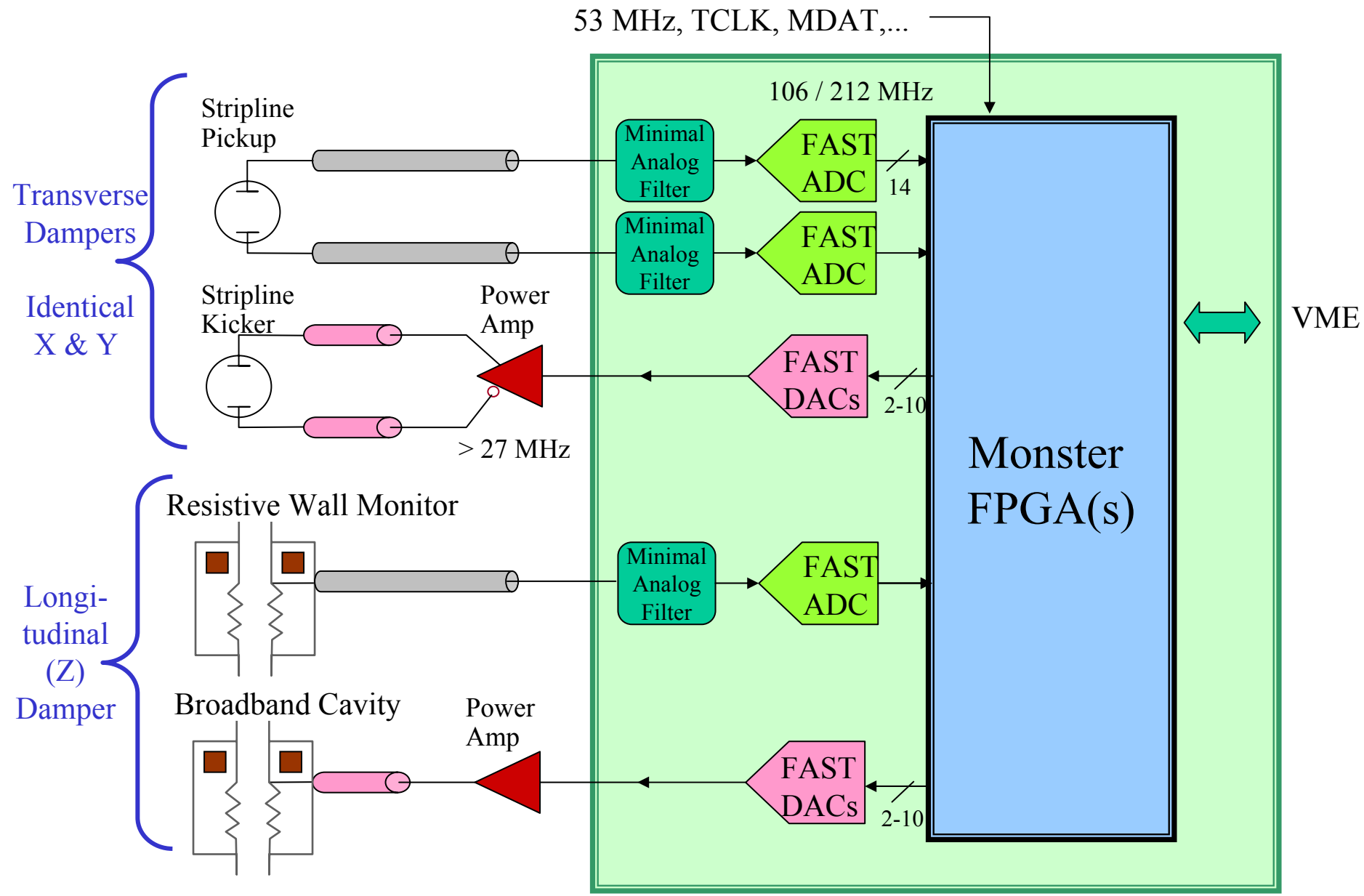
- a **Proton Committee** established by the Directorate in 2003, chaired by D. Finley, with the participation of MINOS (D. Michael) and MiniBoone (J. Conrad)
  - report available at *http://www.fnal.gov/directorate/program_planning/studies/index.html*
- **MINOS Collaboration** is considering the work on "protons" as one of the most important service obligations and is exhorting new people to get involved

Bunch-by-bunch Digital Damper System

- **The system consists of beam pickup signals (RWM, stripline) with relative kickers and of a single digital board serving both transverse and longitudinal dampers**
  - **pickup signals digitized at 212 MHz, with 14 bit resolution**
  - **digital pipelined processing in a large FPGA**
  - **damper kicks digitally synthesized by a 424 MHz DAC**
- **FPGA prototype board installed in spring '03**
  - **first tested with transverse dampers**
    - **have been essential to achieve an intensity of 3.3×10^{13} in MI at 8 GeV**
  - **after '03 shutdown longitudinal dampers have been made operational for proton transfers to the Tevatron and for pbar stacking cycles**
- **Final FPGA boards ready, cabled up and beginning to work !**
- **Experimenter contributions from**

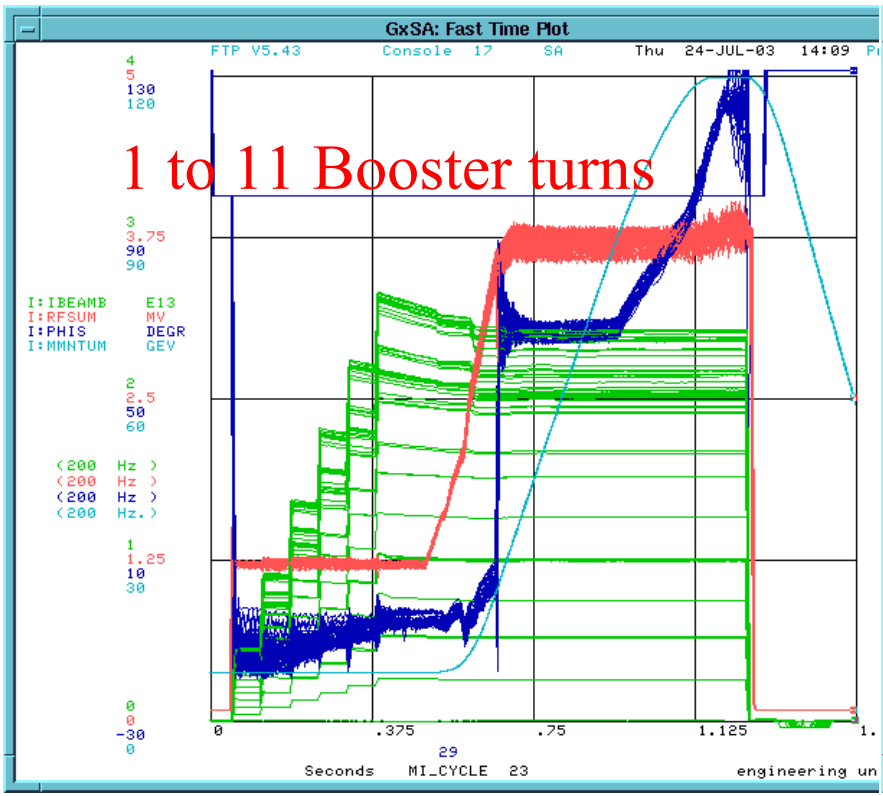
  - **Bill Ashmanskas (CDF, Chicago U.-Argonne-Cornell U.)**
  - **Hyejoo Kang (MINOS, Stanford University post-doc)**
  - **Phil Adamson (MINOS, University College London/ FNAL Main Injector Guest Scientist)**

All-Coordinate Digital Damper

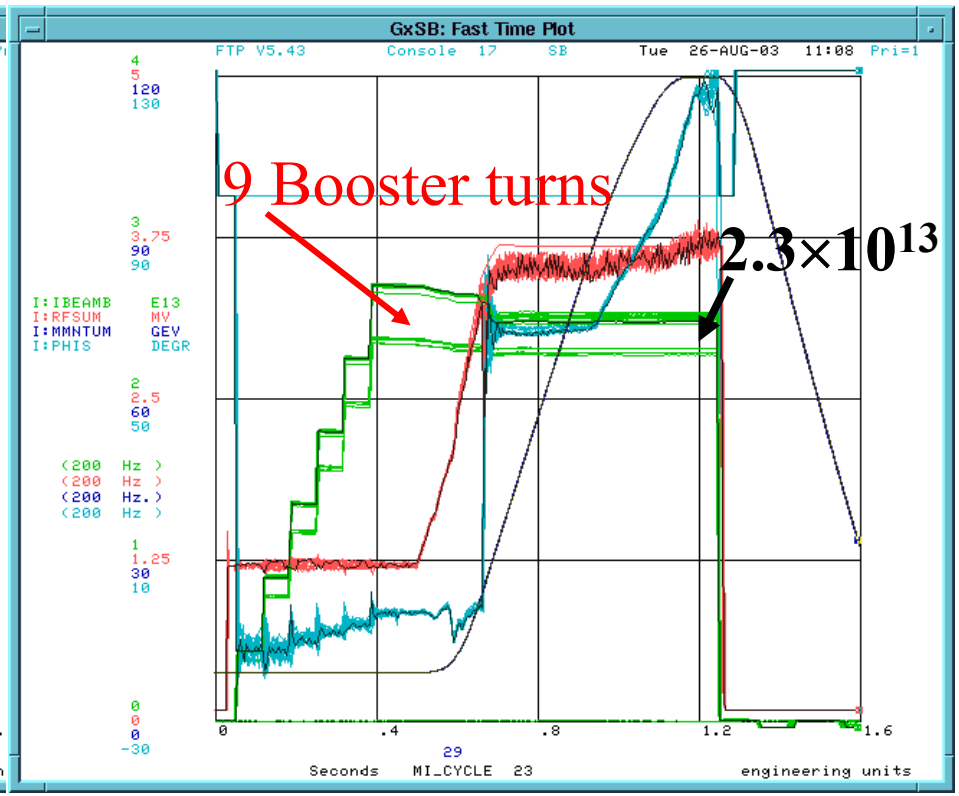


Multi-batch w/o and with transverse dampers

w/o dampers



with dampers



@ 8.9 GeV/c:

ν_X=26.43, ν_Y=25.42, ξ_X=-20, ξ_Y=-16

@ 8.9 GeV/c:

ν_X=26.44, ν_Y=25.47, ξ_X=-5, ξ_Y=-5

Multi-batch studies

- **With 6 batches in Main Injector**
  - achieved an intensity of 3.3×10^{13} ppp at 8 GeV
  - accelerated up to 2.5×10^{13} ppp to 120 GeV
  - testing Booster cogging in multi-batch mode
  - transverse emittance measurements with Flying Wires
  - successfully extracted 1 batch to the pbar target
- **Experimenters contributions from**

  - Phil Adamson (University College London/ FNAL Main Injector Guest Scientist)
  - Hyejoo Kang (Stanford University post-doc)
  - Sanjib Mishra (University of South Carolina professor/FNAL Main Injector Guest Scientist)
  - Karen Wu (University of South Carolina graduate student)
  - Bob Zwaska (University of Texas at Austin graduate student)

MI beam quality inputs to NuMI Beam Permit System

- We are implementing a "**beam quality**" signal from Main Injector to be fed into the NuMI beam permit system
  - this is needed to avoid beam losses in the NuMI beamline due to poor quality beam extracted from MI, because of some accident conditions in MI
- **"Beam quality" signal built from the following requirements**
  - no beam present during the rise time of the NuMI kickers
    - use signal from batch-by-batch intensity monitor
  - NuMI kicker repeatability within 2% (EE department)
  - extraction position, both horizontal and vertical, within 2 mm
  - central momentum regulation at flattop within 1×10^{-3} (already taken care of by LLRF and MECAR)
  - MI beam quality (no losses at flattop in the 608 and 612 regions)
- **Contributions from**
  - Andrew Godley (University of South Carolina post-doc)
  - Sanjib Mishra (University of South Carolina professor/FNAL Main Injector Guest Scientist)

Barrier RF cavity

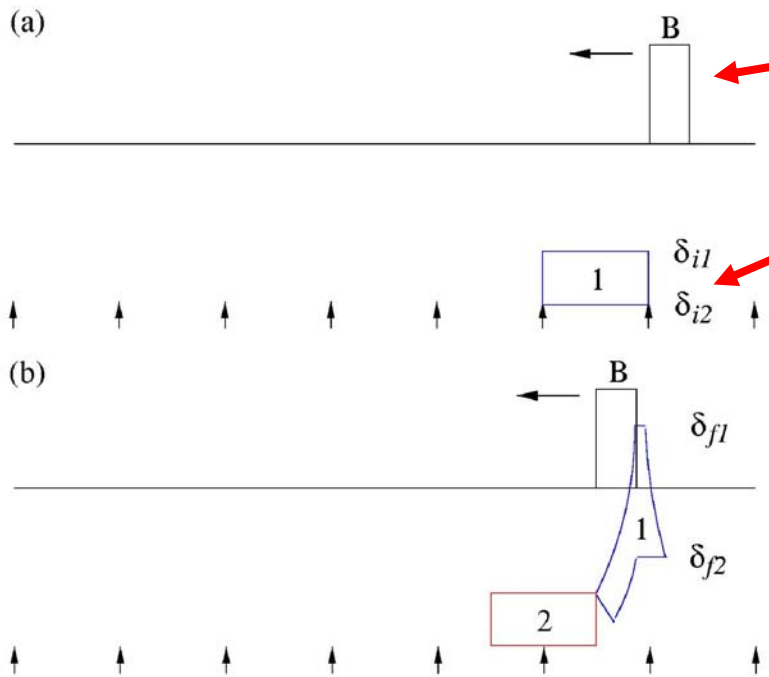
… a Fermilab-KEK-Caltech collaboration

RF barriers are generated by an inductive device, which uses 7 Finemet (nanocrystal magnet alloy) cores and fast high voltage MOSFET switches

- **Contribution from**
  - Hai Zheng (Caltech post-doc)

Barrier RF stacking

J. Griffin, K.Y. Ng

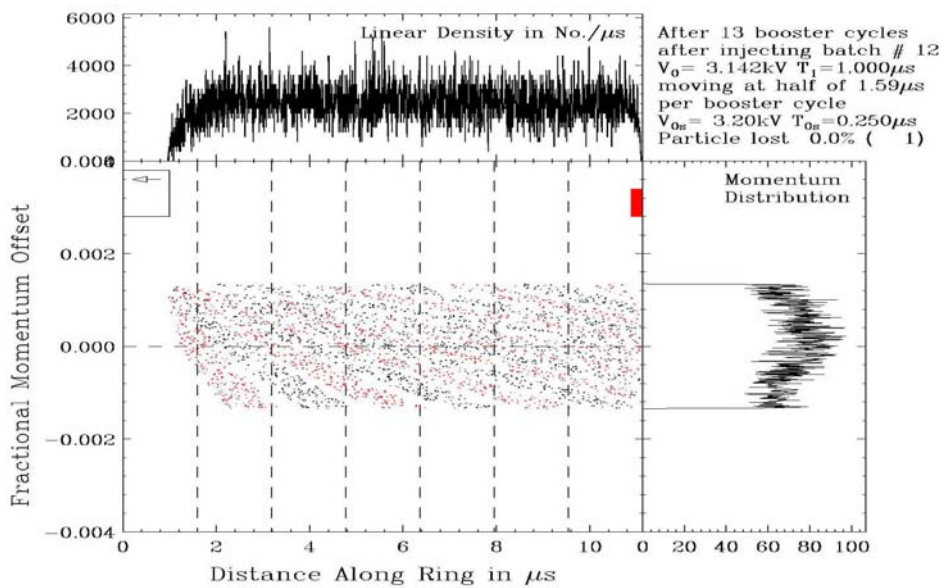


left moving barrier

Booster batch injected at negative momentum offset

One Booster cycle later

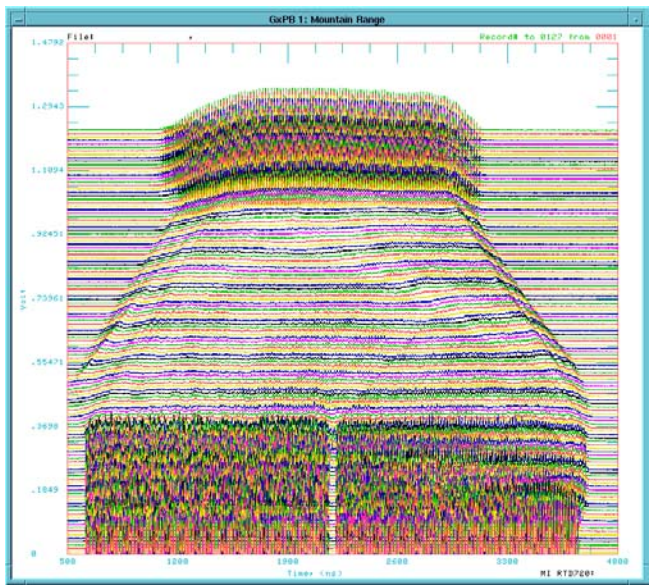
2 Booster cycles after the injection of the 12th batch

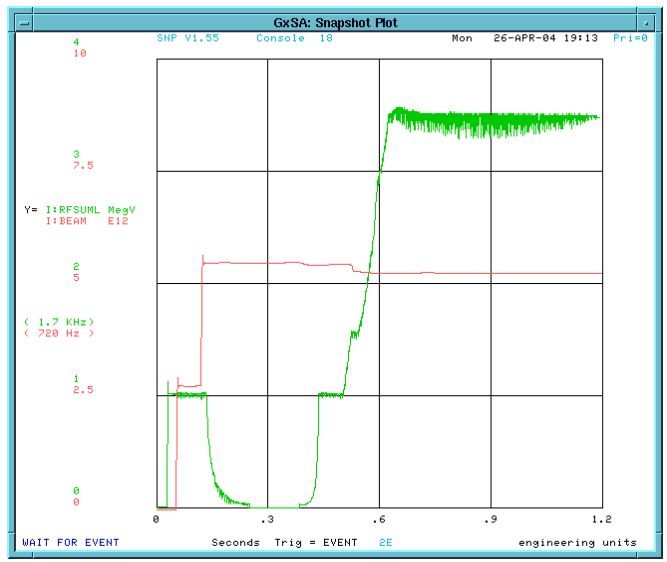


Momentum spread of Booster beam has to be < 6 MeV

Status of Barrier Bucket stacking

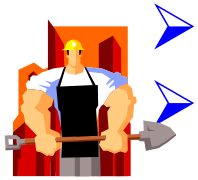
- **The off-momentum barrier bucket stacking requires 2 sets of barrier buckets (one fixed, another moving)**
  - We have currently installed 1 RF cavity with a power supply able to generate a set of square bipolar barrier buckets
  - **We have more high voltage switches on order for another cavity (needs to be built)**
- We have started beam studies where we inject 2 Booster batches, compress them ***adiabatically*** with the barriers, then recapture the beam with 53 MHz and accelerate it to 120 GeV





BPMs in the NuMI extraction region

- The AD Instrumentation Dept. instrumented 3 horizontal BPM's, along with a vertical one, located in the NuMI extraction region, with **NuMI style BPM electronics**, capable of batch-by-batch position measurements
  - they will be used on the last turn, to connect the orbit information in Main Injector to the orbit down the NuMI line
- **Expected contribution in understanding the performance**
  - Phil Schreiner (Benedectine University professor)
  - Vickie Frohne (Benedectine University professor)



My personal Summary

- **Experimenter contributions to accelerator improvements**
  - **dangerous ?**
    - **well … up to now we have not heard of a Tevatron quench induced by an experimenter clicking on the wrong button**
  - **fruitful ?**
    - **lots of Main Injector/NuMI commissioning work done with the help of MINOS collaborators**
  - **intellectually challenging ?**
    - **if you do not believe it … try to work on the digital damper system ! Or try to think where else this system might be useful !**
  - **sexy ?**
    - **you can seduce your g/f (b/f) in the Control Room by showing her (him) that you are able to wipe out a bunch of her (his) choice with the transverse dampers**
- **In the years to come we will see the consequences of spreading out knowledge on accelerator techniques among experimenters**
  - **we might end up with a bunch of guys asking for $$$ to build a muons on neutrinos collider, and they might even know how to build it …**