Laserwire Emittance Scanner at LINAC4, CERN

Gary Boorman

NATIONAL INSTRUMENTS LabVIEW CERTIFIED ARCHITECT

John Adams Institute for Accelerator Science

at Royal Holloway, University of London

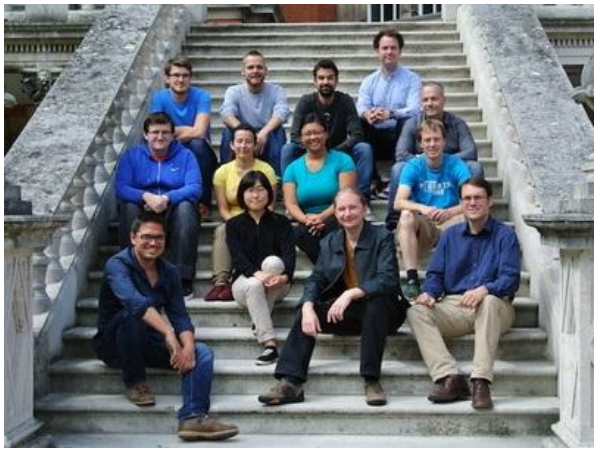
ROYAL HOLLOWAY UNIVERSITY OF LONDON

Outline

- JAI@RHUL
- LINAC4
- Laserwire Emittance Scanner
  - H^- Laserwire Principle
  - Hardware
  - Control and DAQ Software
  - Experimental Results
- Proposed 160 MeV system
- Conclusion

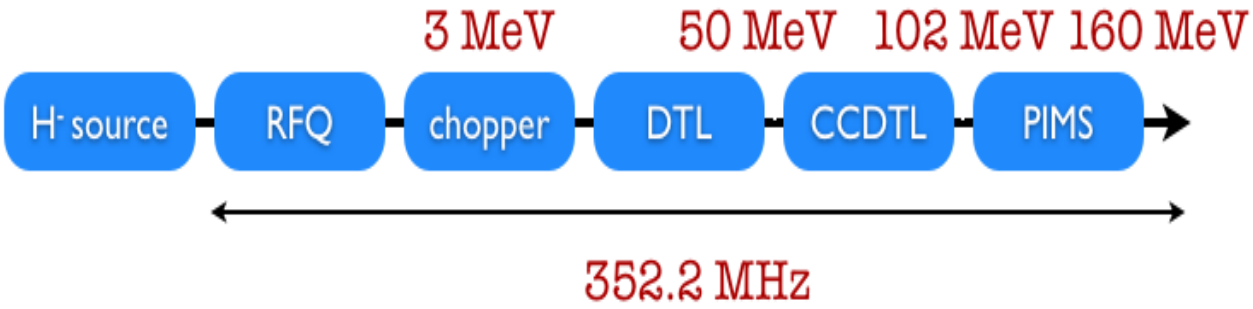
JAI@RHUL

- BDSIM: simulation software for accelerators and beamlines
- Beam Diagnostics:
  - Beam Position Monitors
  - Laserwires for electron/positron storage rings and H^- accelerators
  - CDR/TDR for stability measurements
  - Control and Integration
- Dept has a *LabVIEW Academy*



LINAC4

- LINAC4 is a 160 MeV H^- accelerator to increase LHC luminosity (via proton synchrotron booster) to replace LINAC2 (proton injector)
- Beam: pulse current 40 mA; RF 352.2 MHz; bunch length 400 µs; pulse rate 0.83 Hz
- Built and tested in stages (3, 12, 50, 100, 160 MeV) – currently upgrading to 100 MeV

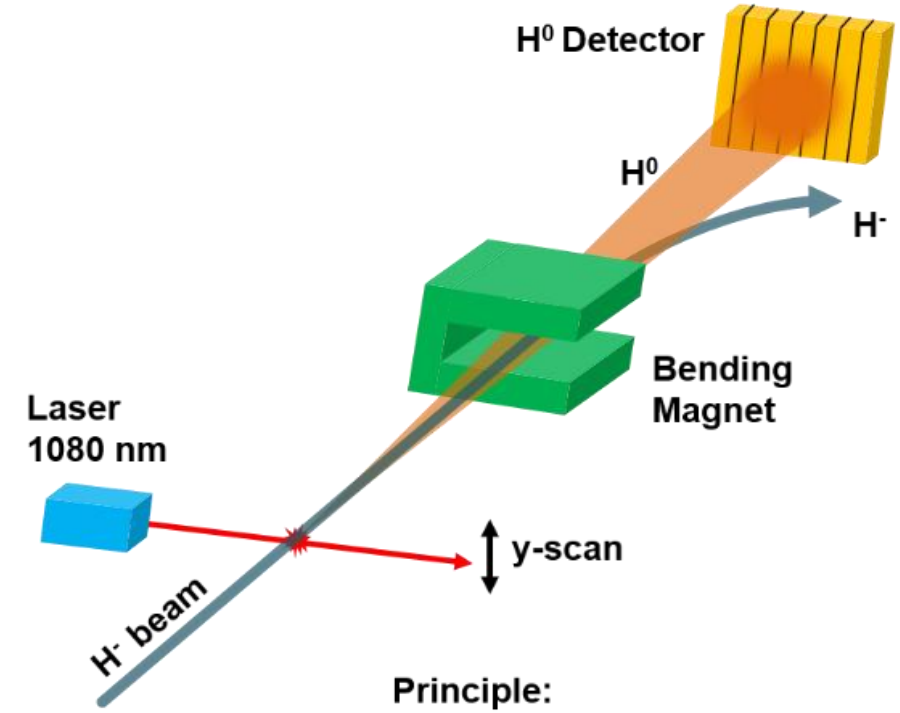


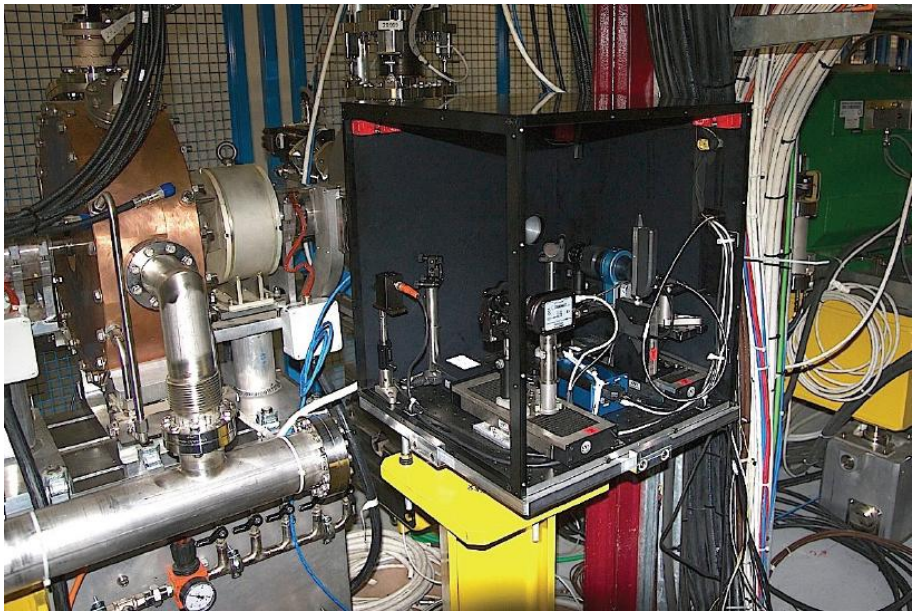
H^- Laserwire Principle I

- Emittance is the 'spread' of a particle beam, for LINAC4 is nominally 0.4 π mm mrad
- H^- is a hydrogen atom with an extra electron, with a binding energy of 0.75 eV
- Use a laser to detach the extra electron
- Neutral atoms (H^0) go to diamond detector; remaining H^- follow path through dipole; (detached electrons steered to Faraday cup)

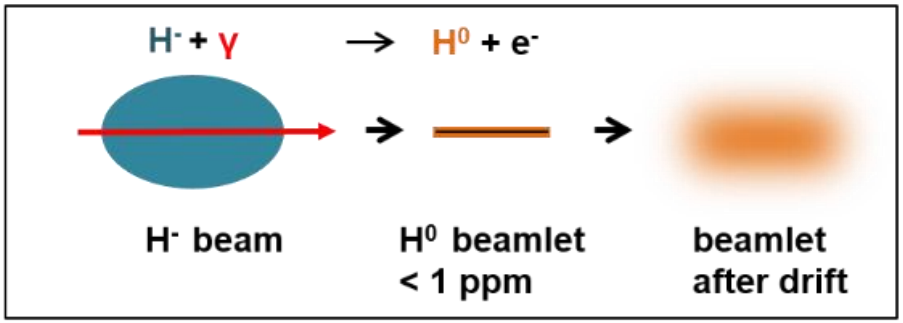
Non-invasive method, unlike wire or grid

H^- Laserwire Principle II





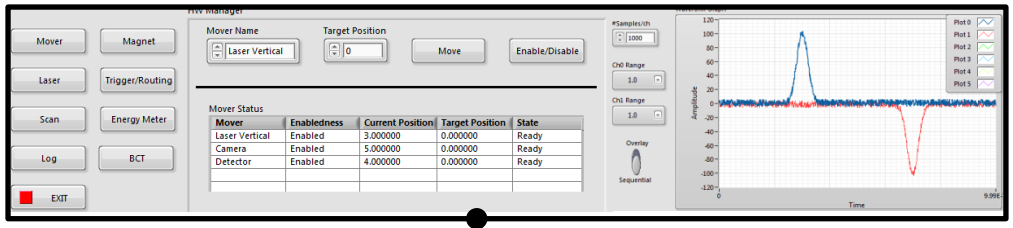
Principle:



Laserwire Scanning

- Measure the H^0 profiles in detector plane to obtain the angular distribution
- Scan the laser through the beam to sample the transverse phasespace
- Laser is pulsed at 60 kHz, enabling several detector samples per LINAC4 bunch
- Detector: 10^4 electrons per H^0 » 1 V into 50 Ω

Laserwire Schematic



Network

PXI Controller

Trigger Distribution

Digitizers

serial

USB

FESA

Bunch trigger

Laser trigger

Power Meter

3

BCT

H^0

Detector

Beam

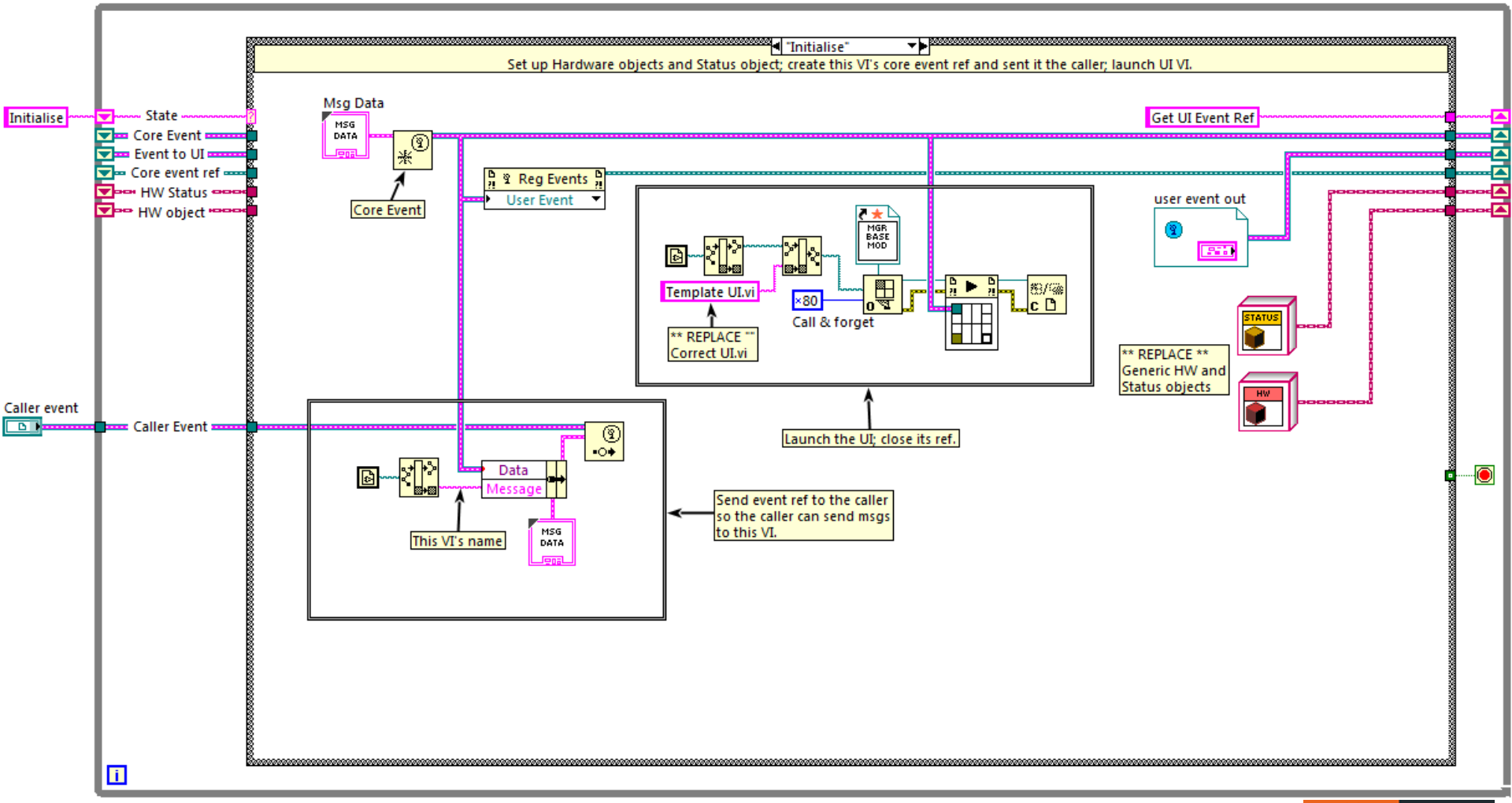
Control and DAQ Hardware

- PXI chassis with:
  - Controller (8105) running Windows XP (for development) and LabVIEW
  - PXI-5152 Digitizer (2 off) 2 channel, 1 GS/s to read diamond detector channels and laser photodiode
  - PXI-6653 Timing Interface for trigger distribution
  - Serial interface to laser beam movers
  - USB interface to laser power meter
  - Network connection to FESA hardware

Laserwire Software

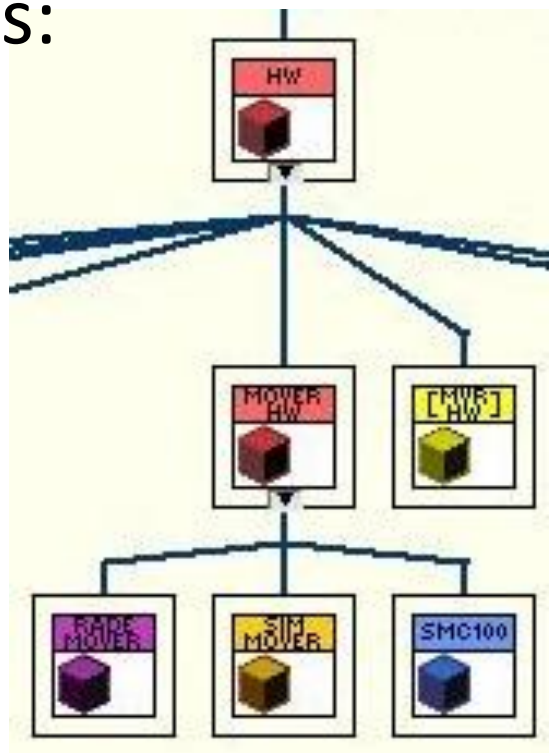
- All control and DAQ software in LabVIEW 2014
- Actor-based architecture
  - Messaging based on user events
  - Zero coupling between most actors » extensive code re-use
  - Easy testing of individual actors
- Classes to represent (different types) of real and simulated hardware
- Statechart to access the Digitizer

Actor Template

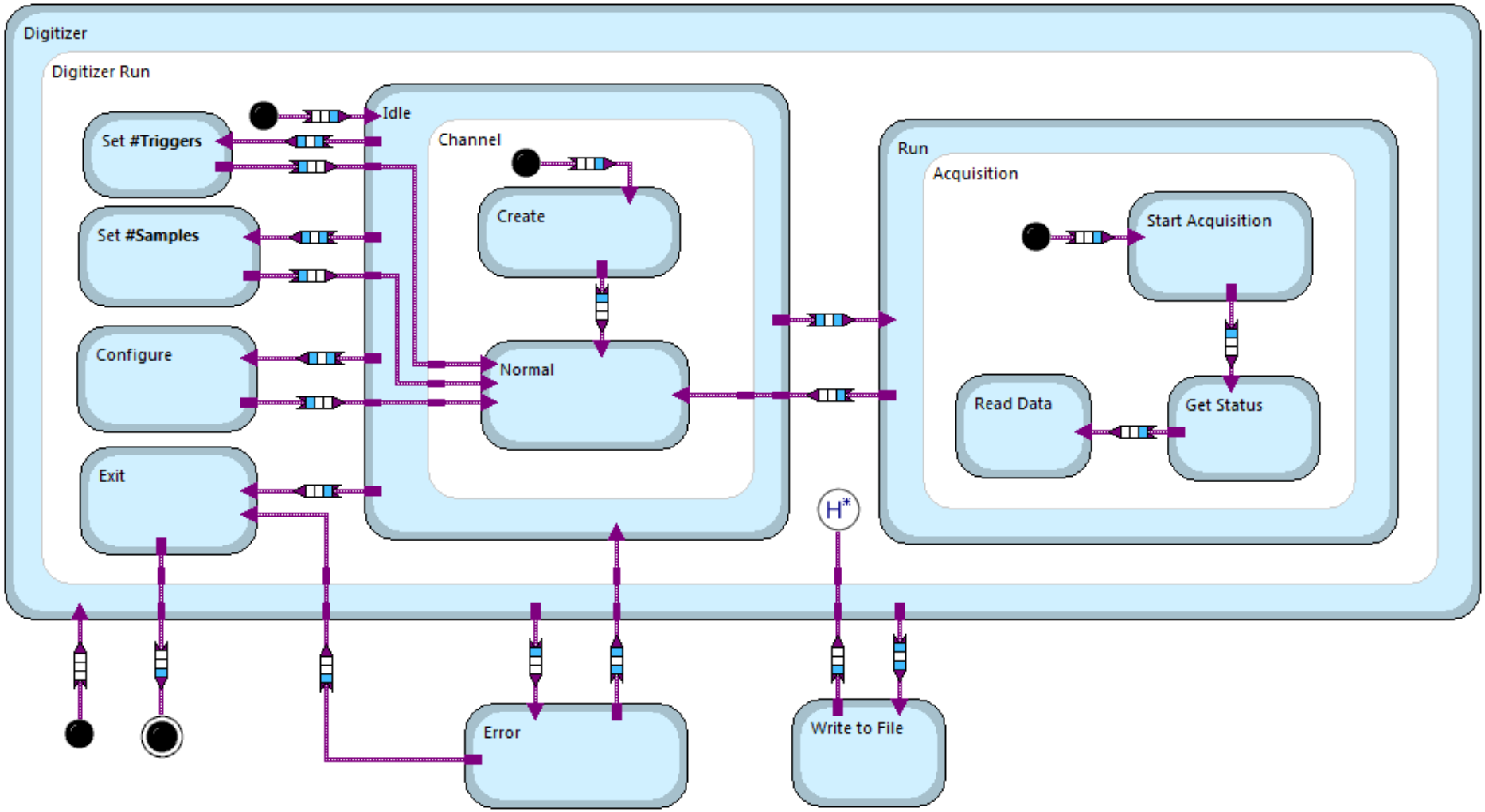


Example of Hardware Class

- A mover can be one of three types: SMC100, RADE or Simulated
- Aggregated into *All Movers.class* (array of *mover.class*)
- Advantage of classes:
  - Top-level code remains the same
  - Easy to add a new child-class
  - Add a *Sim* class to test when no access to HW

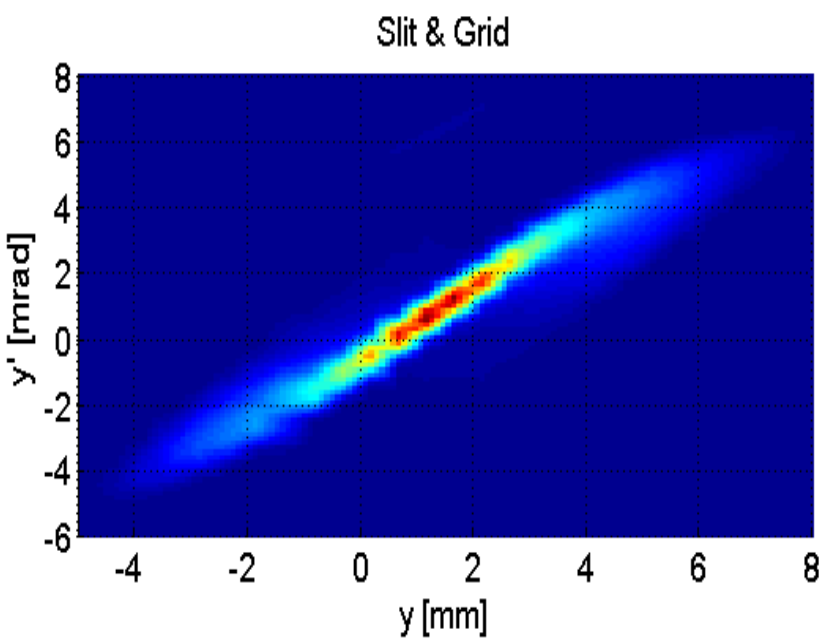


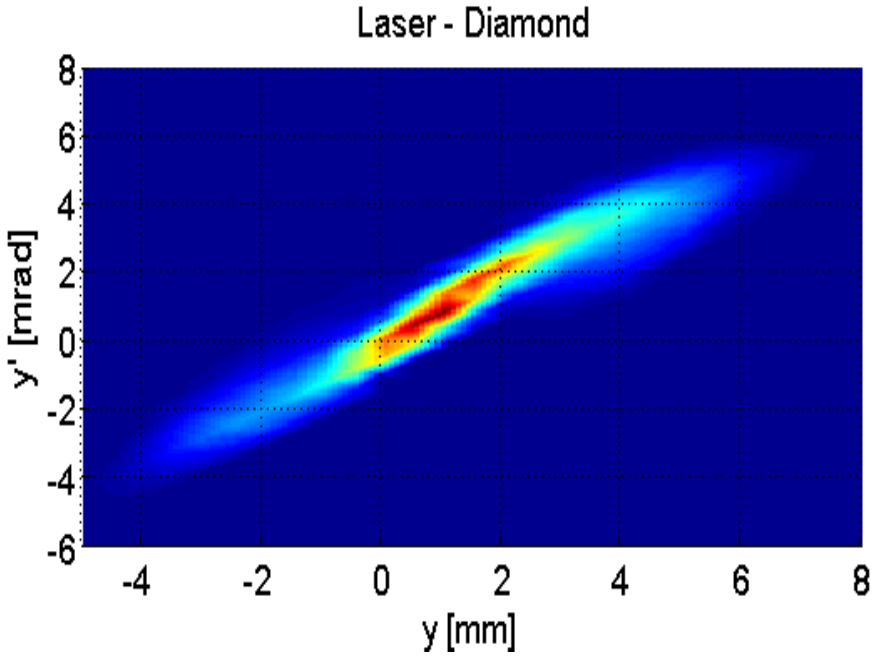
Digitizer Statechart



Results for 12 MeV Laserwire

- Comparison with SEM grid very good
- Expert Laserwire system runs well



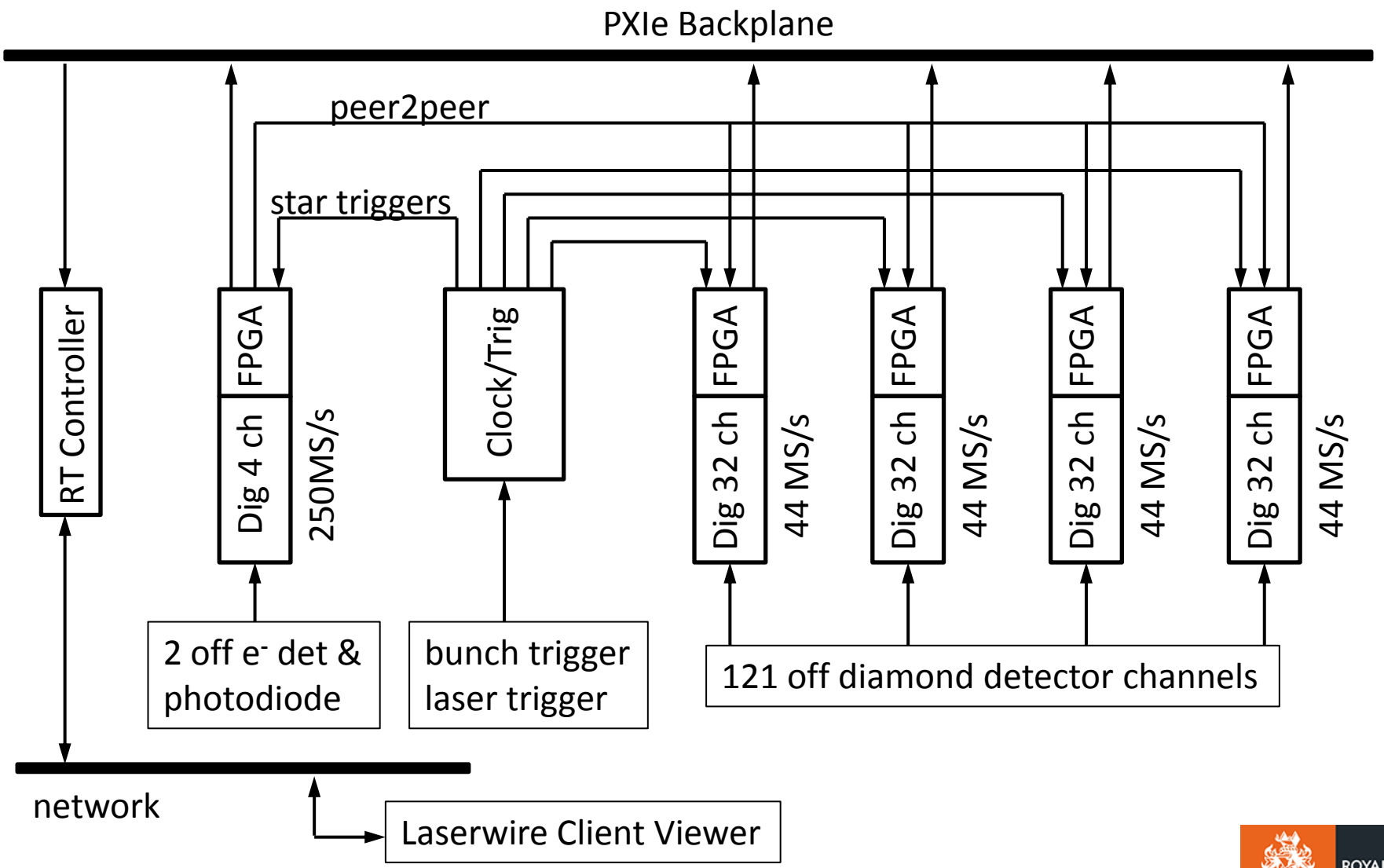


ROYAL HOLLOWAY UNIVERSITY OF LONDON

Proposed 160 MeV Laserwire

- 2D scans in two locations » 121 channels
- Four 32-channel digitizers sampled at 44 MS/s
- FPGA cards for background and pulse analysis
- Four channels sampled at 250 MS/s for electrons and laser pulse – FPGA analysed data streamed to FPGA cards to normalise pulse data
- Integrated pulse streamed to RT Host
- Viewer/logger client to display accumulated phasespace points and emittance value

160 MeV Laserwire PXIe System



Conclusion

- Demonstration of an ion-beam laserwire using diamond detector and fibre-delivery laser
- Excellent agreement between laserwire and wire/grid emittance values for 12 and 50 MeV
- 160 MeV with FPGA-based analysis is challenging but achievable
- Publications in *Physics Review Special Topics (Accelerators and Beams)** and *Nuclear Instrumentation and Methods A#*

* Phys. Rev. ST Accel. Beams 18, 122801 (2015) T Hofmann et al

Publication imminent