Data acquisition, analysis and user base with Ultra-Slow Muon

Kenji M. Kojima (KEK/IMSS & J-PARC)

In order to do μSR...
(a post at M15CR back in 1996)

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- beam is ON,
- sample is READY,
- cryostat is cold, magnets are running,
- DAQ and spectrometer is working,
- analysis program is debugged,

- and Experimentalists are awake.

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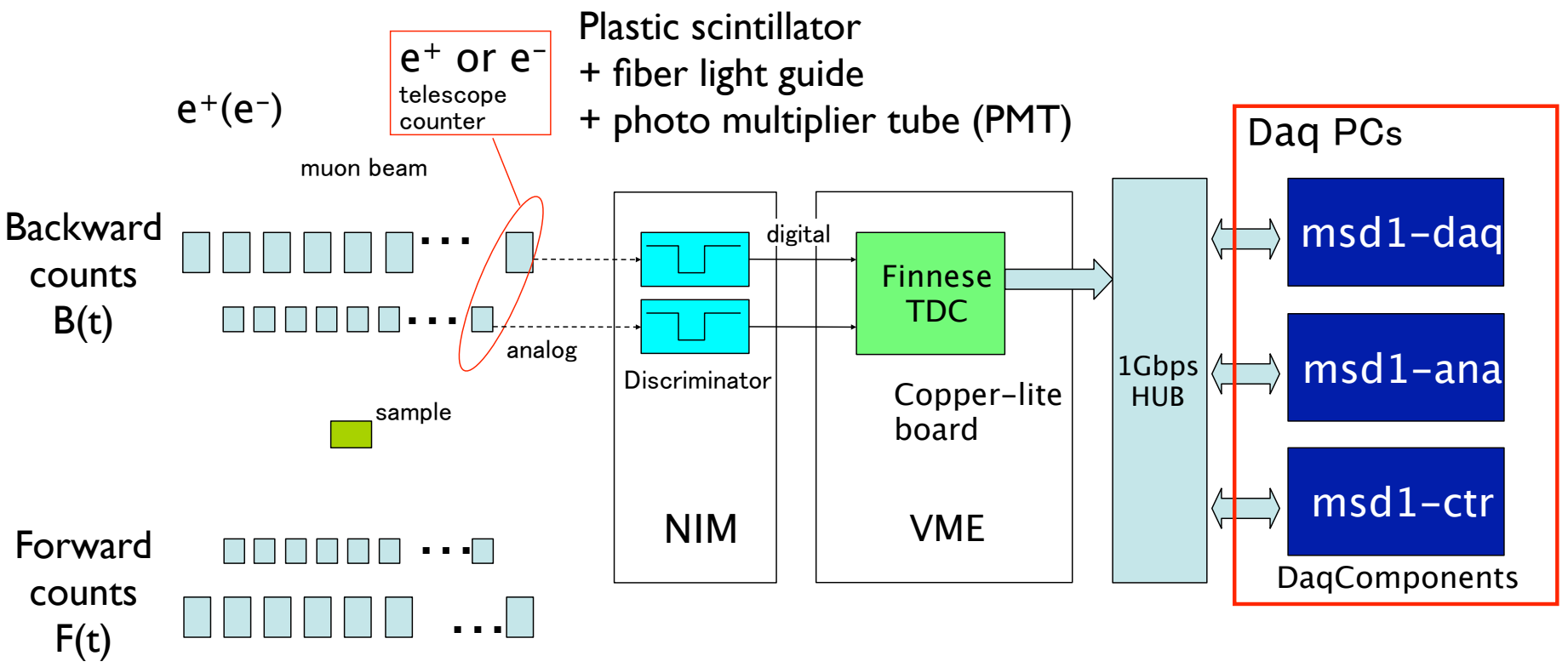
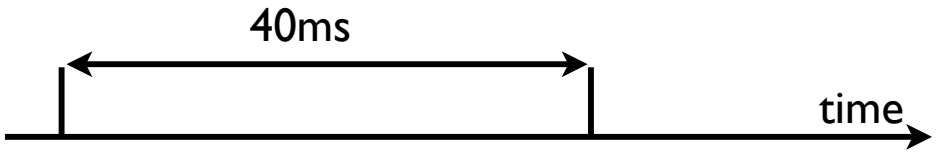
pulsed USM: μSR spectrometer





Advantage :

Disadvantage :

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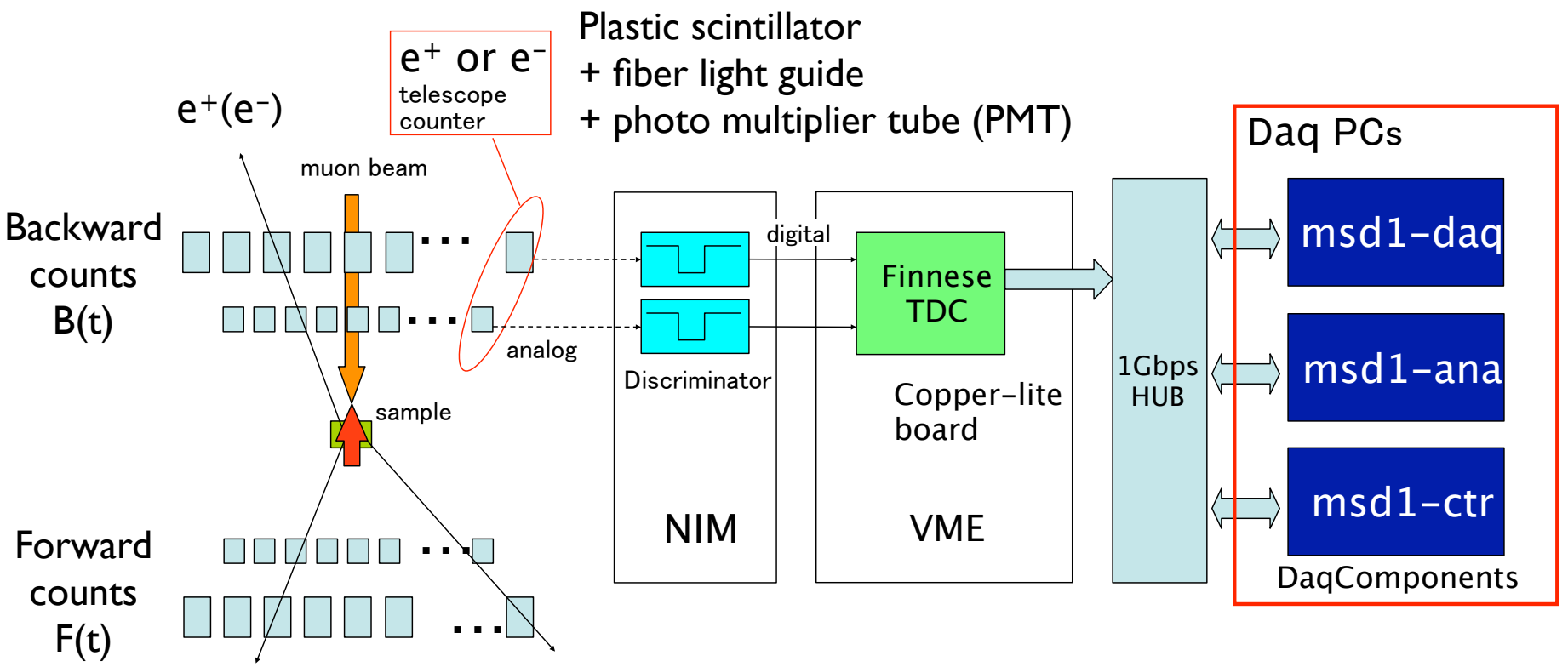

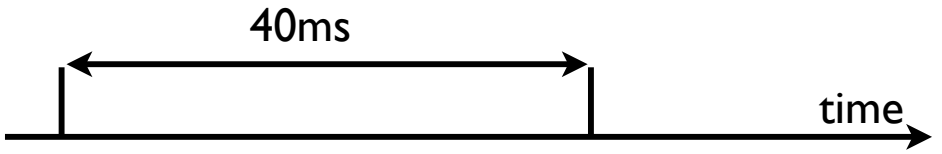

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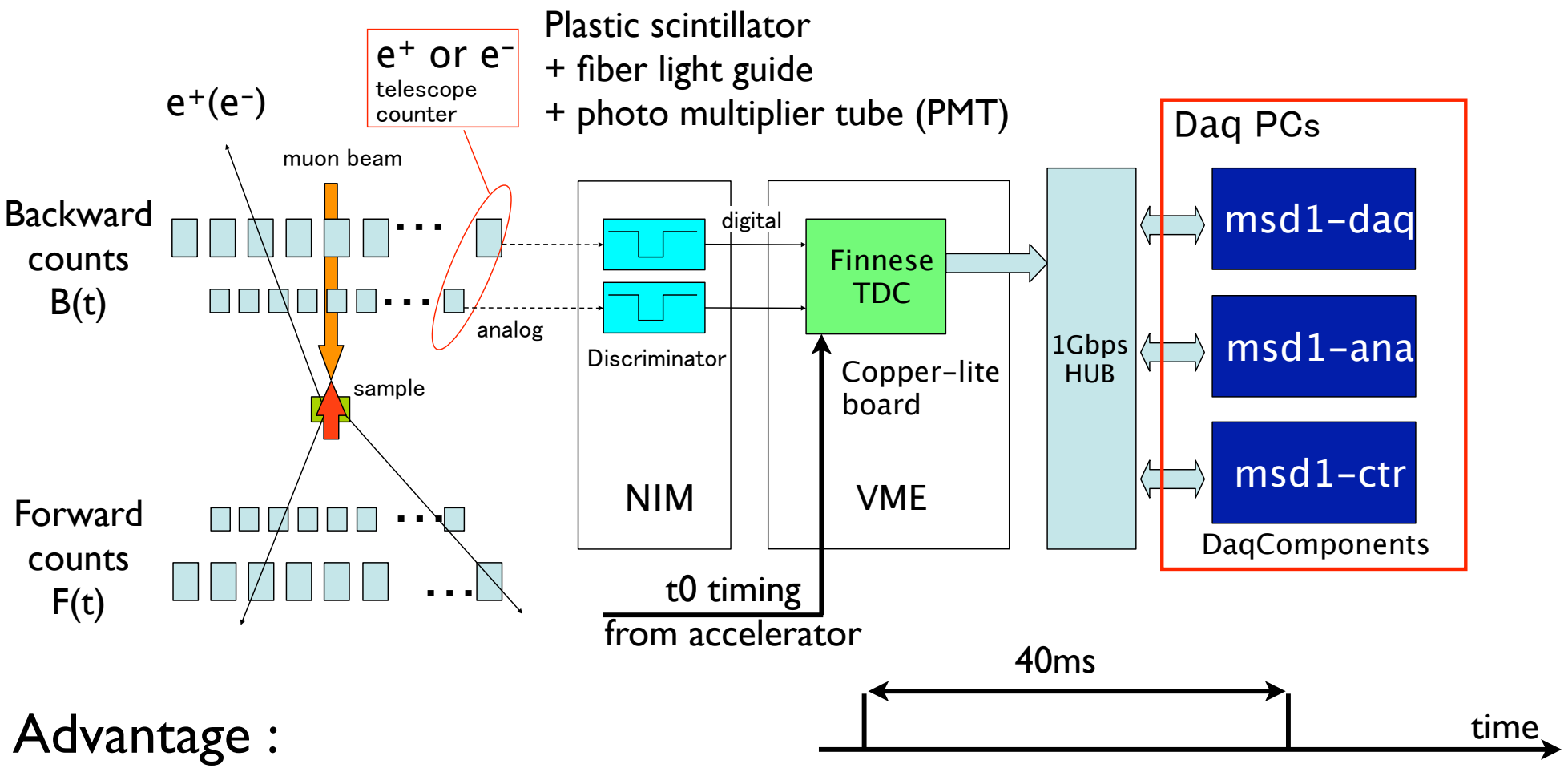

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- no need for TM counter

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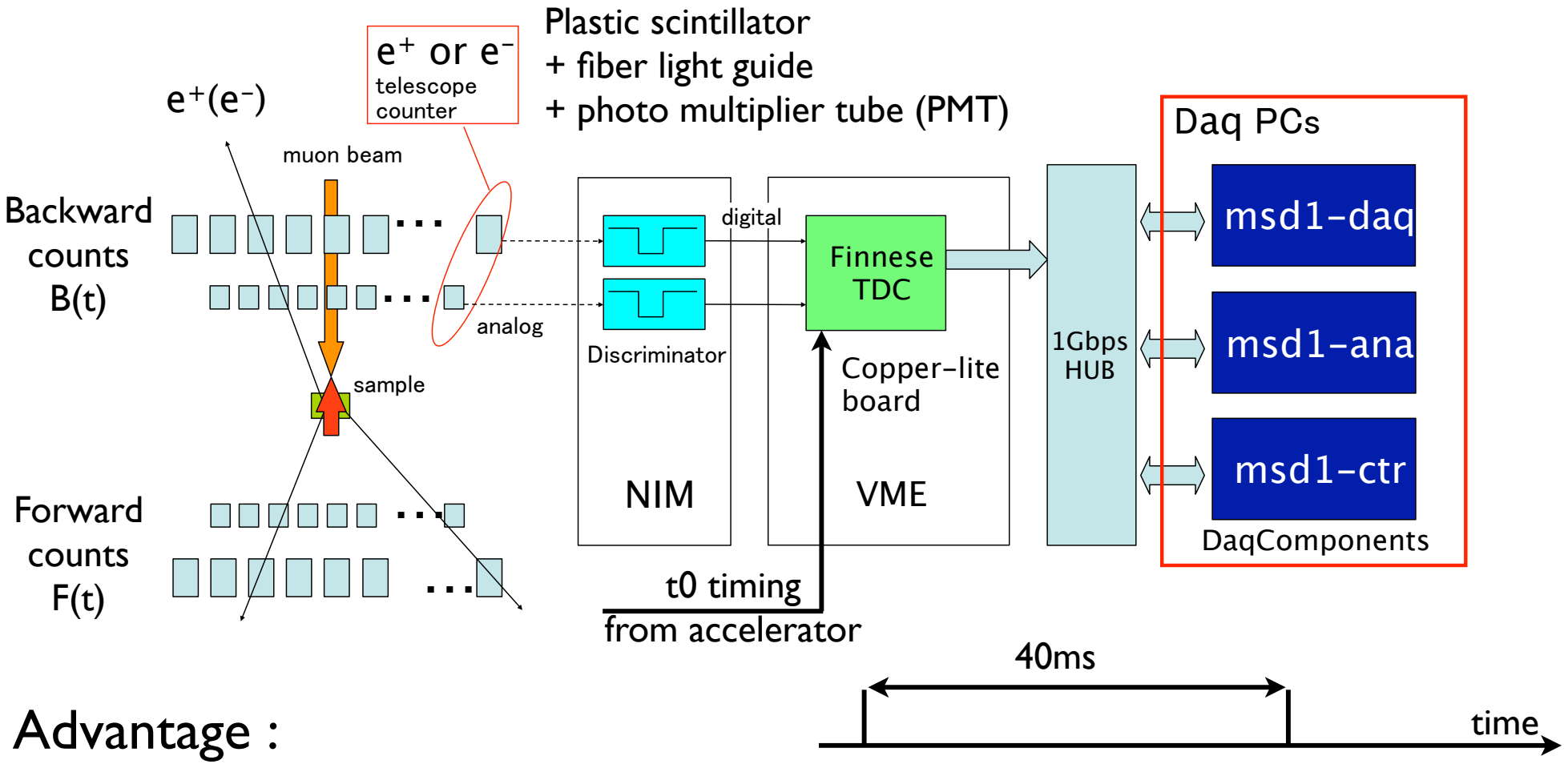

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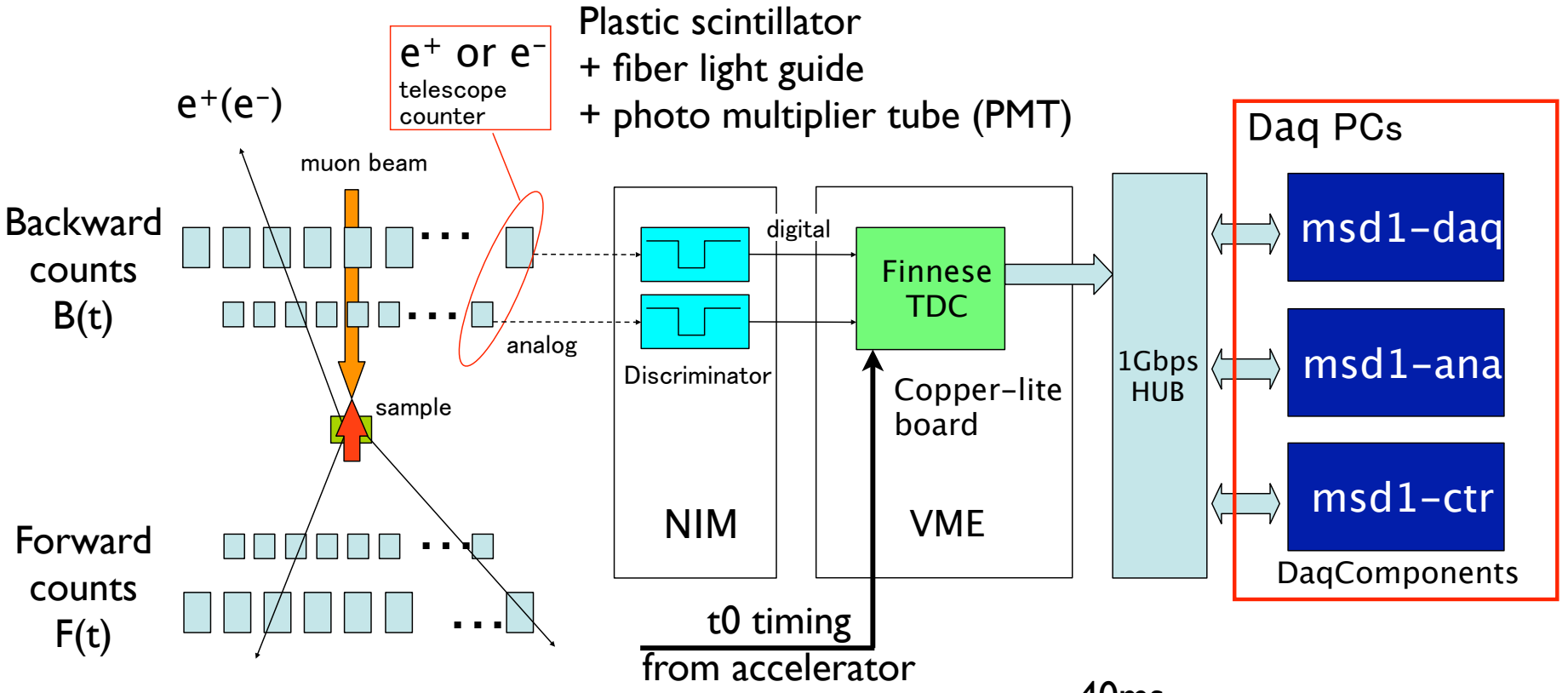

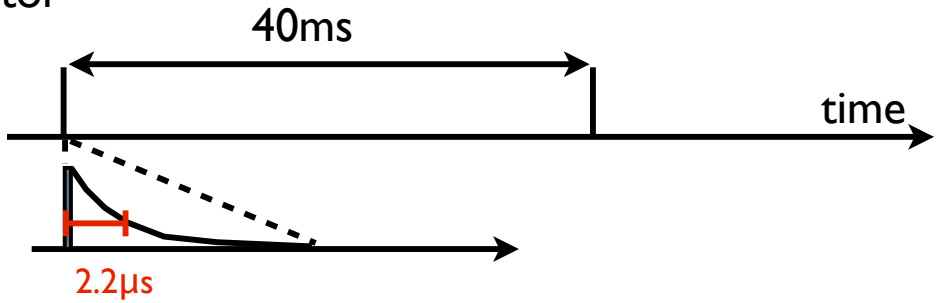

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J-PARC: D-line: 180k muon/pulse/300kW
→100Gcps for 4π
For distortion free: < 5e+/pulse/counter
→3000~10^4 counters for 25% solid angle

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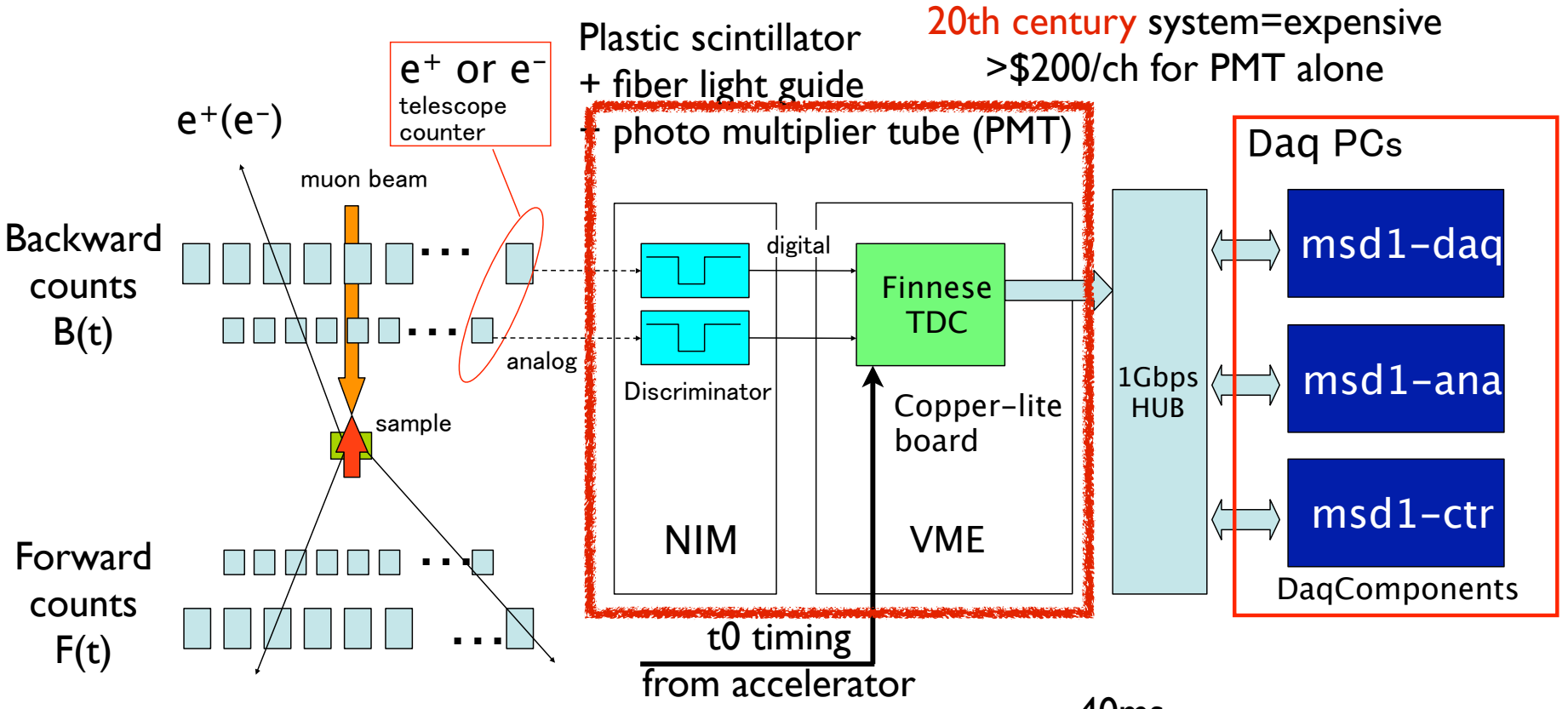

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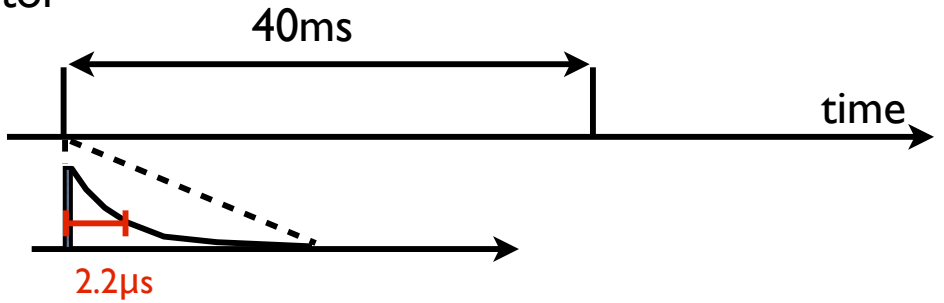

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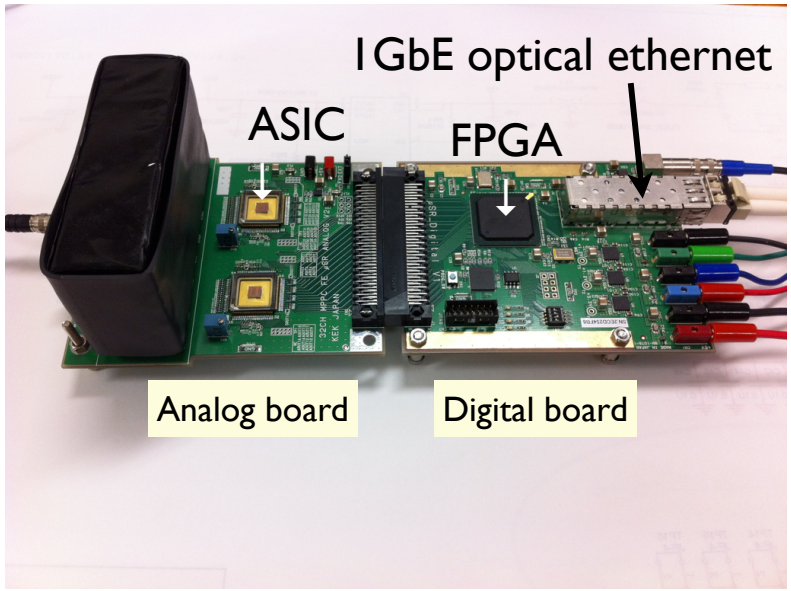
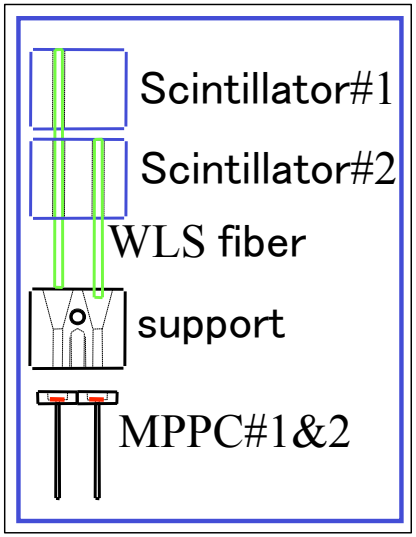
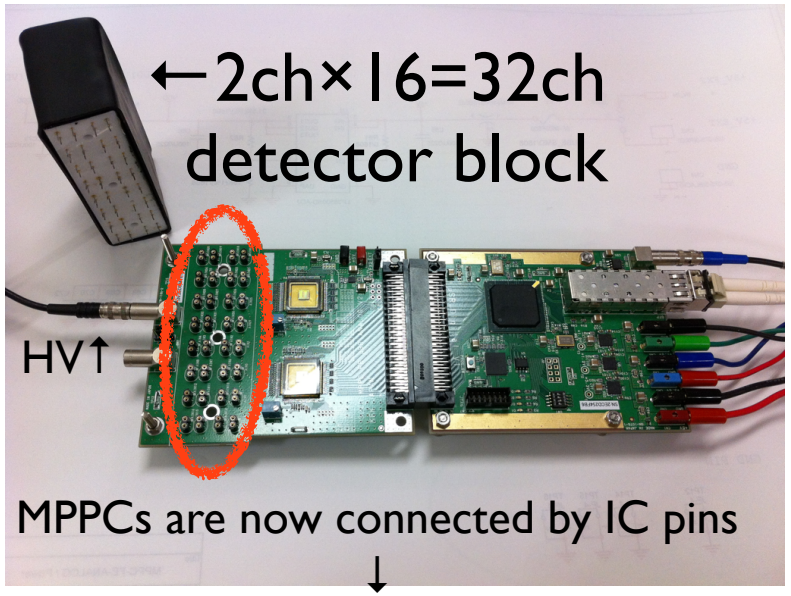
21st century solution: APD/ASIC/FPGA/ethernet-based detector



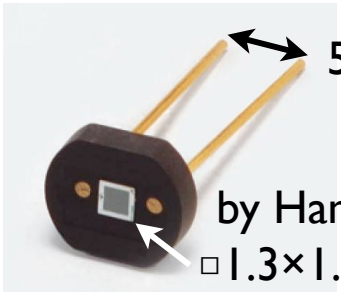




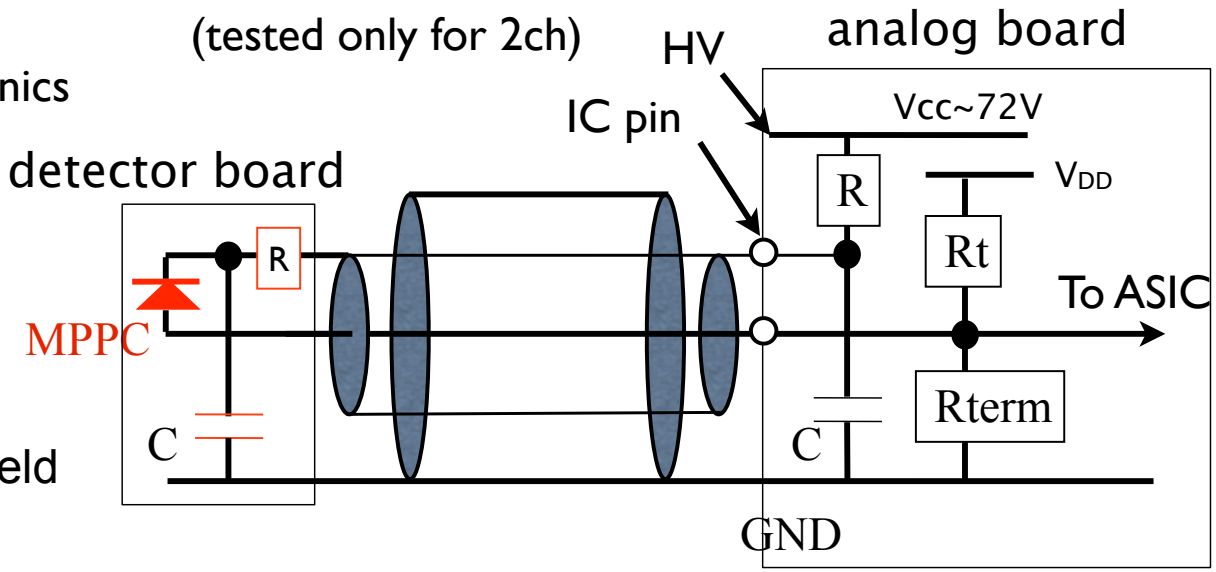
↓

multi-coax connectors
(or MIL 34pin flat connector?)

MPPC(Multi Pixel Photon Counter)



~2m extension was OK
(tested only for 2ch)



- ✓Inexpensive （~$30/piece）
- ✓high gain （~10^6）
- ✓low bias voltage （~70V）
- ✓works under ~Tesla magnetic field
  x temperature sensitive: 50mV/K

Technological elements: (1) Avalanche Photo Diode

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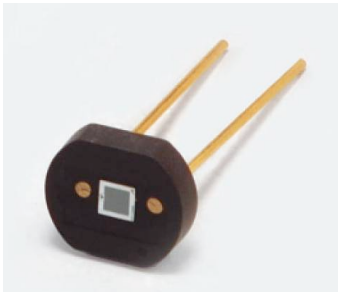

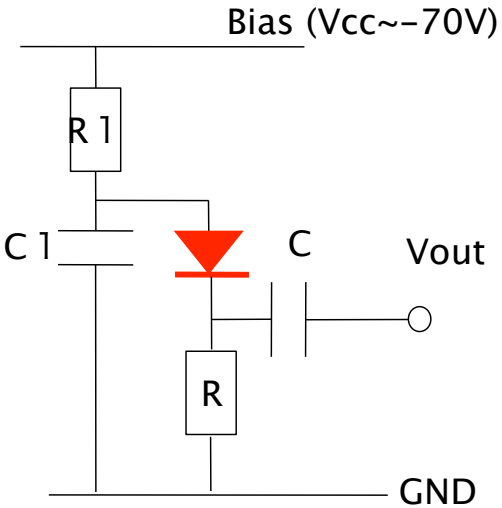

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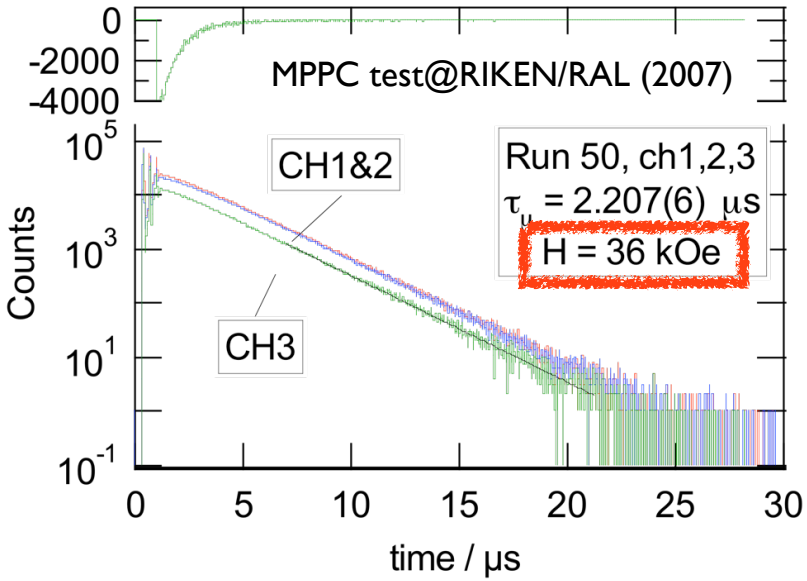

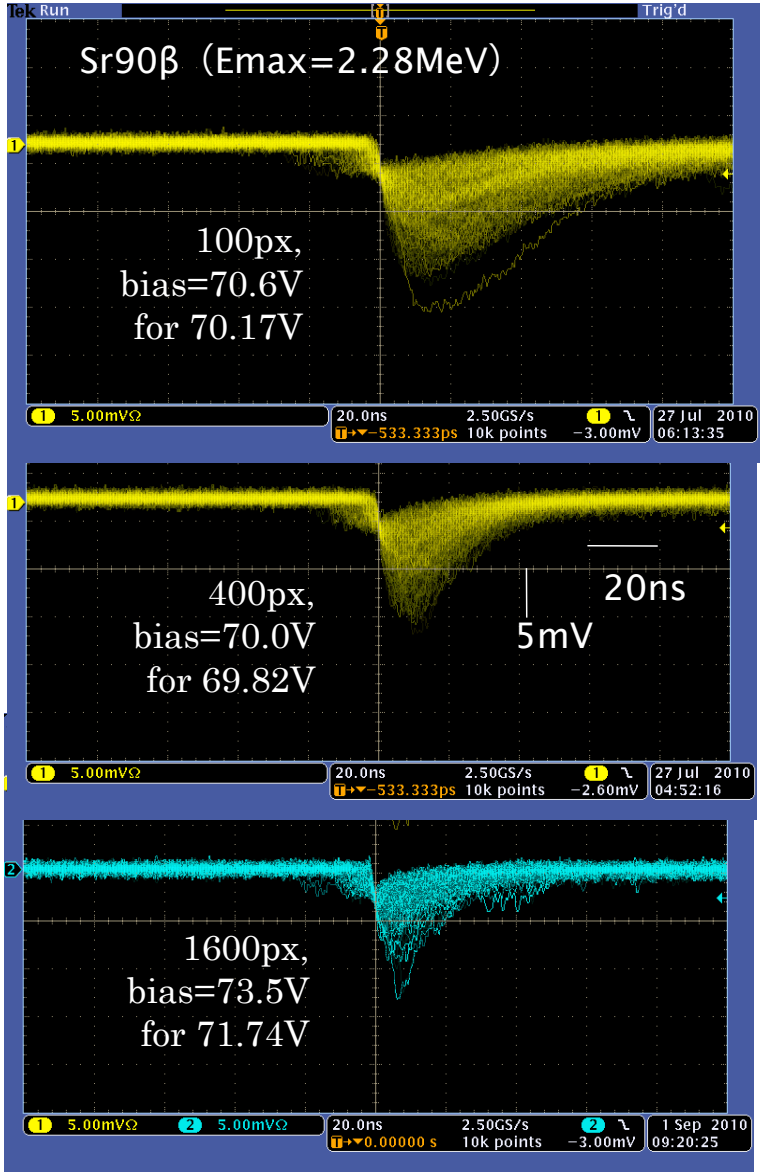

10mm×12mm×10mm Scintillator
Φ1mm WLS fiber

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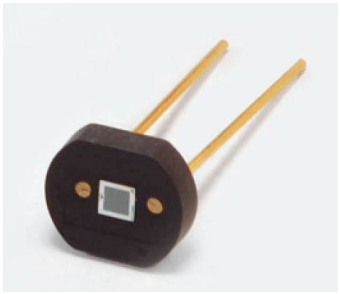

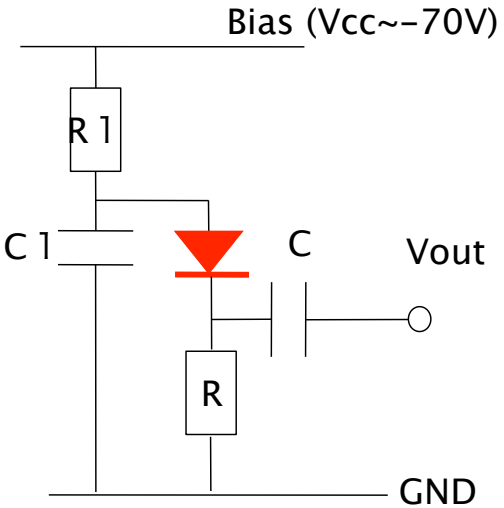

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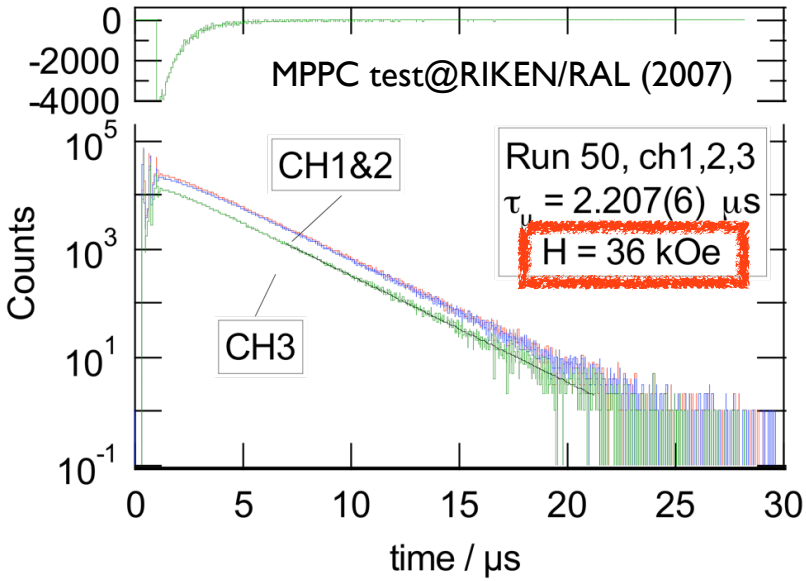

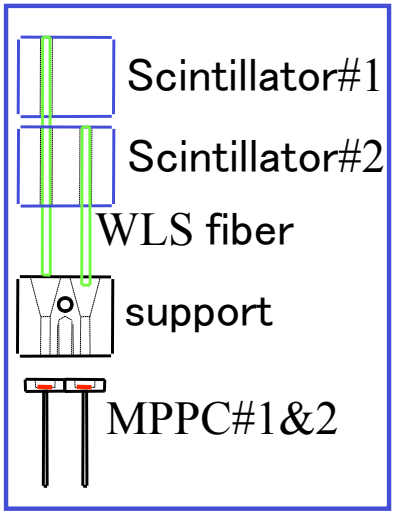

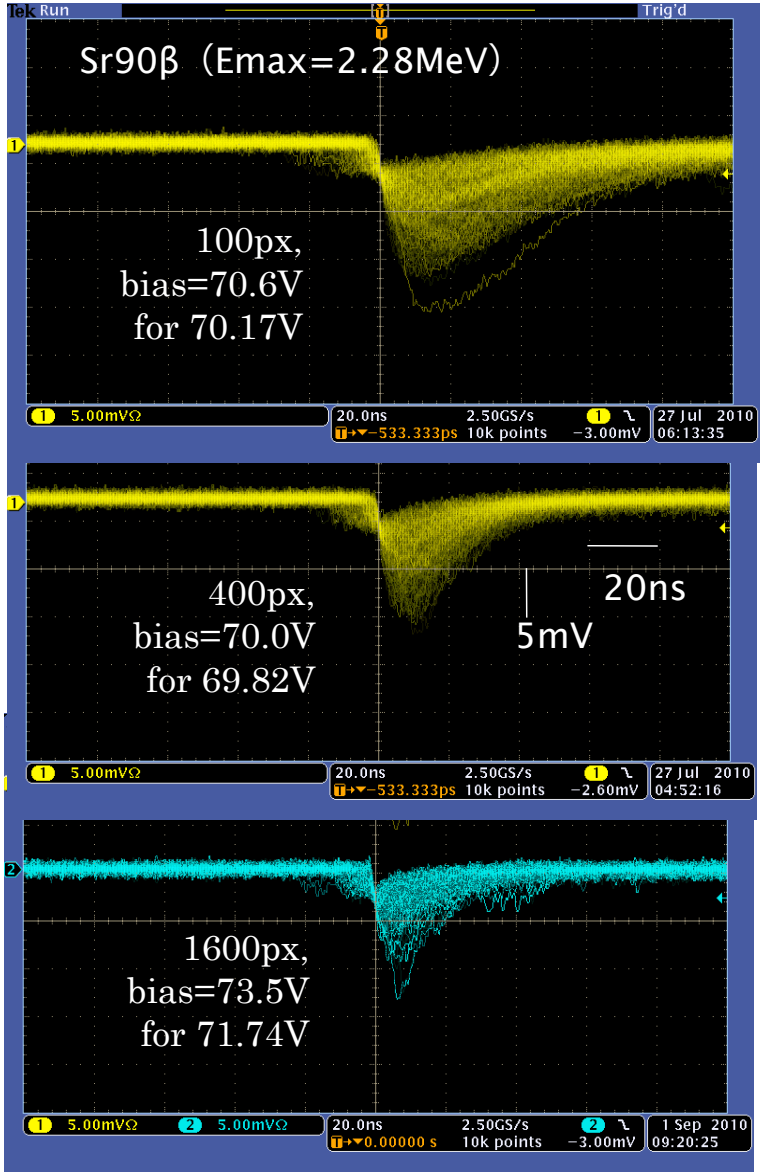

10mm×12mm×10mm Scintillator
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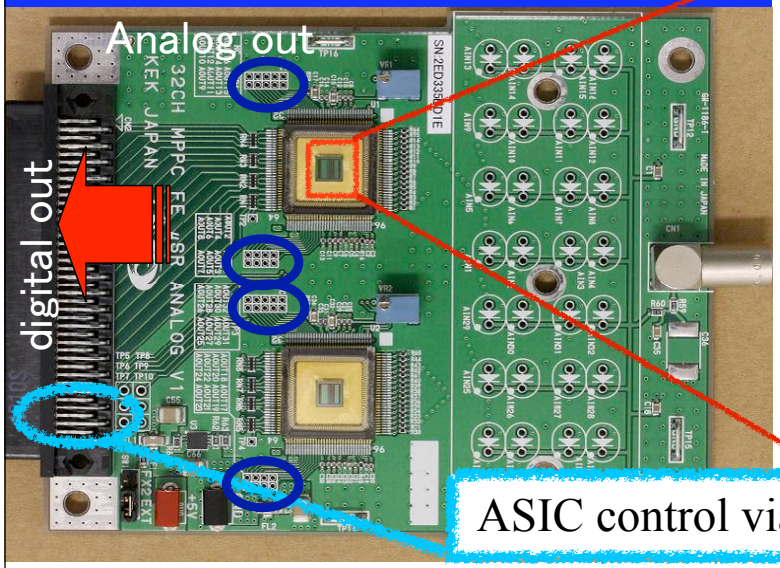
Technological elements: (2) Front-end circuit & ASIC

ASIC (Application Specific IC)



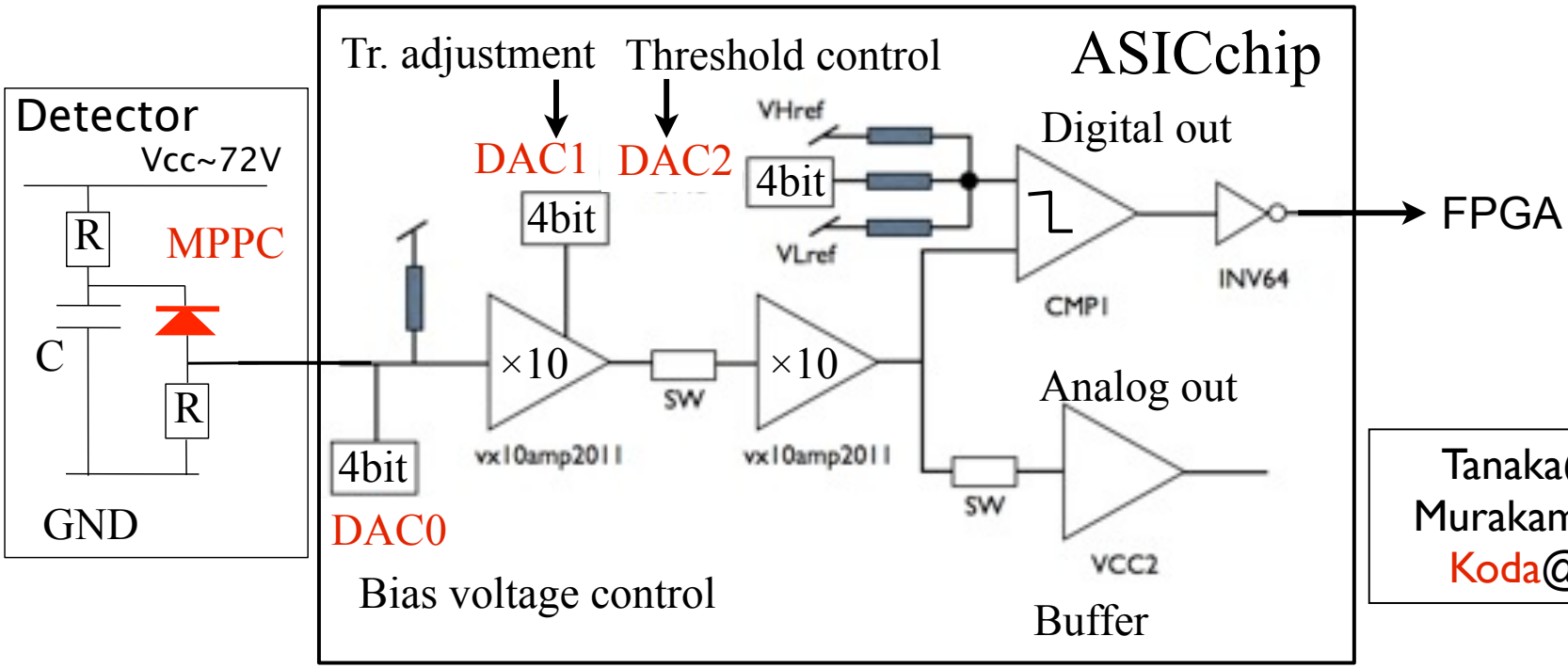
ASIC control via serial: 16bit×16ch=256bit

4bit digital control × 3

- DAC0: Bias voltage
- DAC1: Transistor adjustment
- DAC2: Discriminator threshold

Control bits × 4

- DAC0 enable
- Gain ×10/×100
- Digital out ON/OFF,
- Analog out ON/OFF

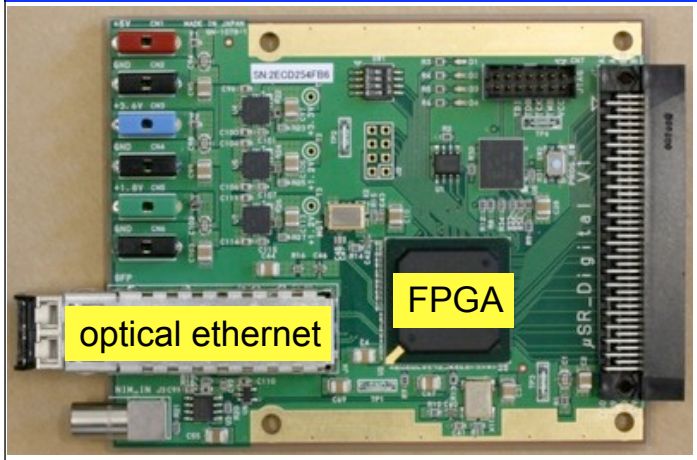


Tanaka@IPNS
Murakami@IPNS
Koda@muon

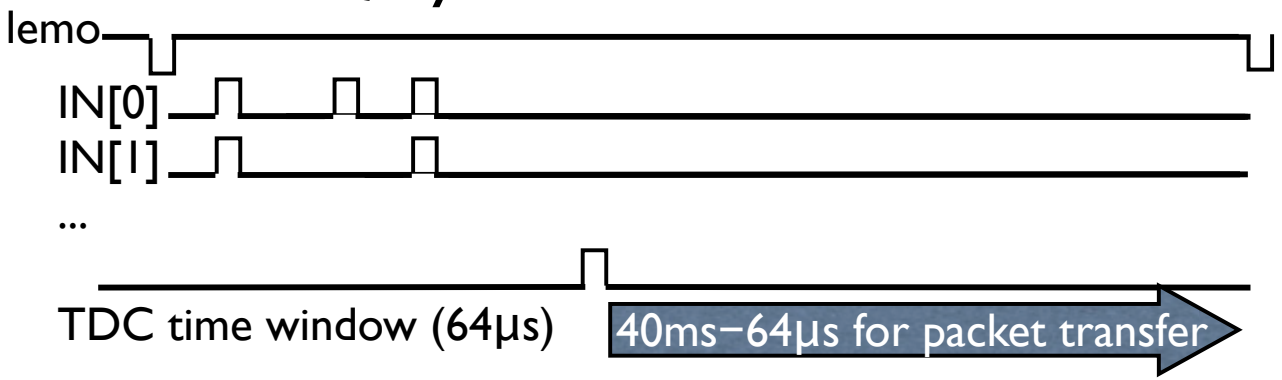
Technological elements: (3) Read-out module & FPGA

FPGA (Field Programable Gate Array)

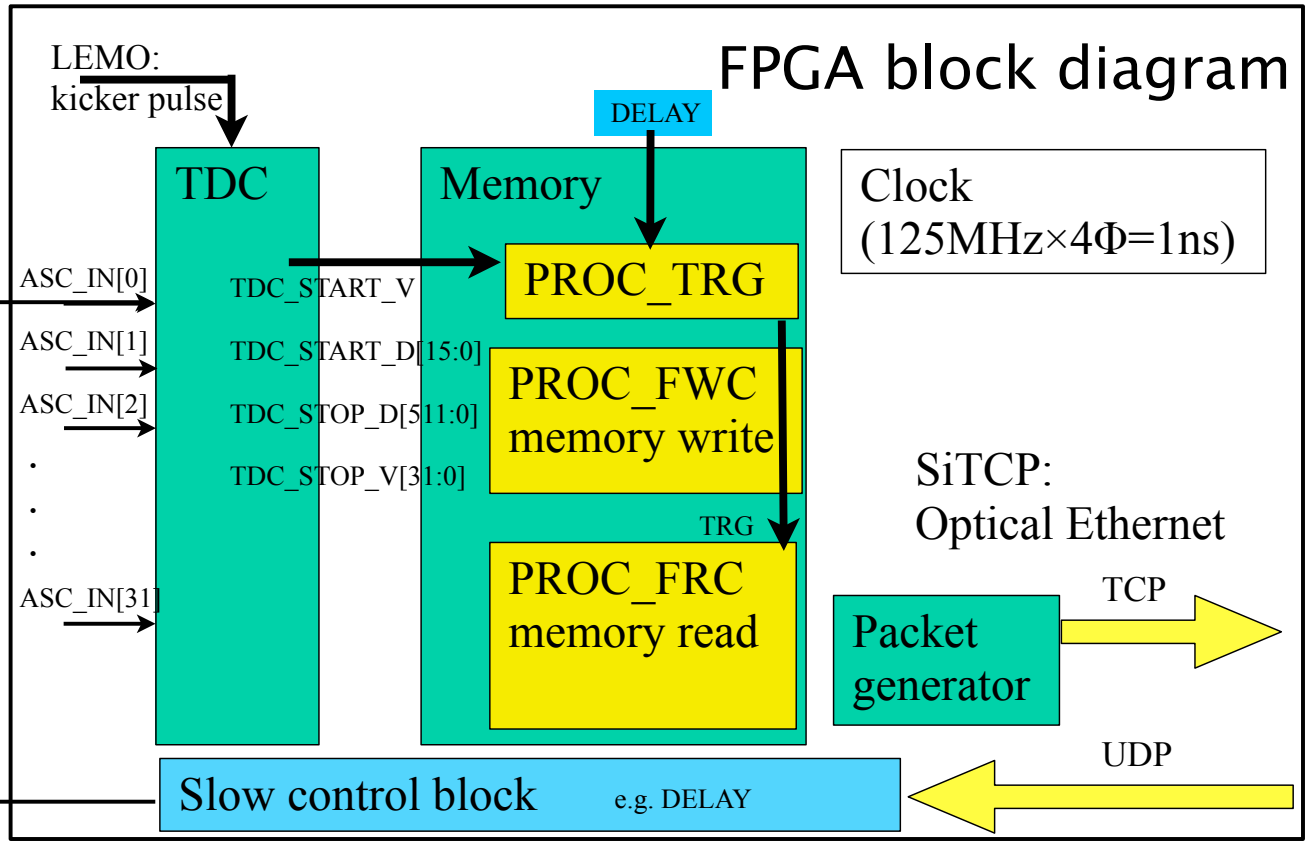
Uchida@IPNS, Kojima@muon



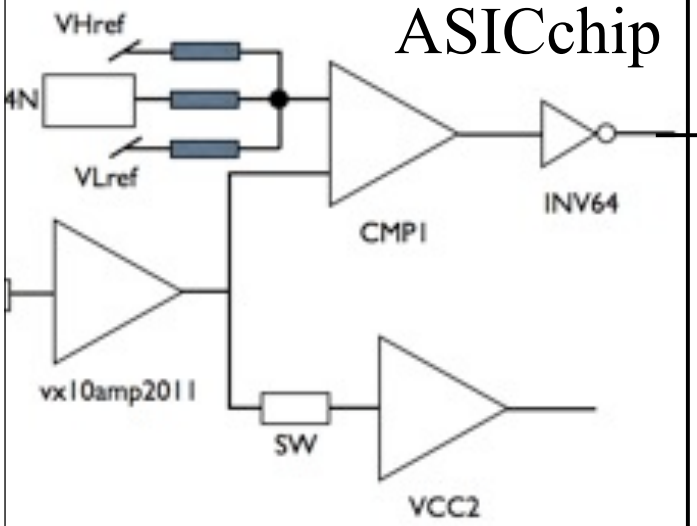
DAQ cycle



FPGA block diagram



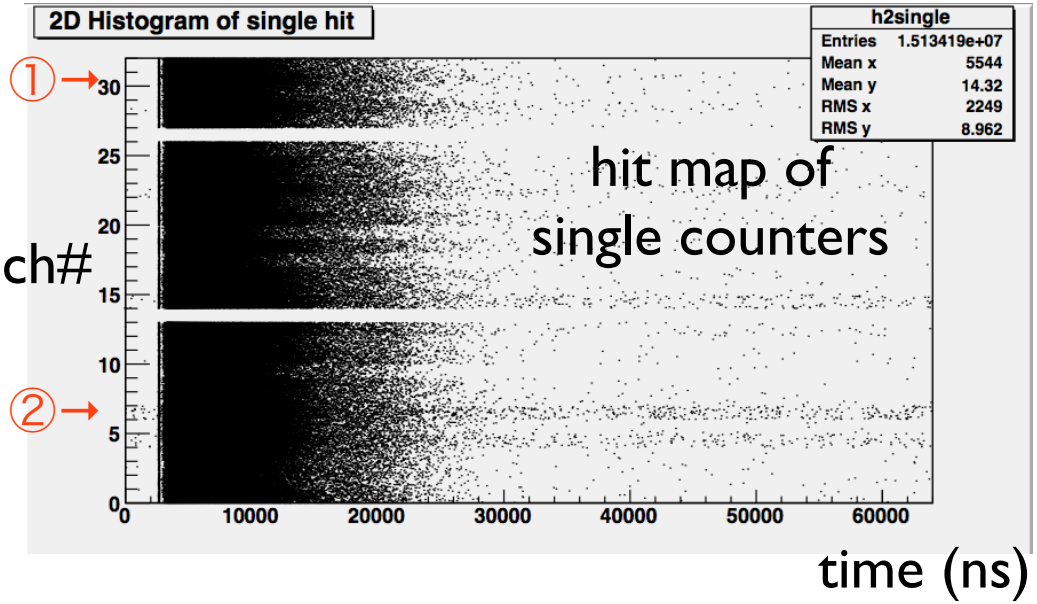
ASICchip

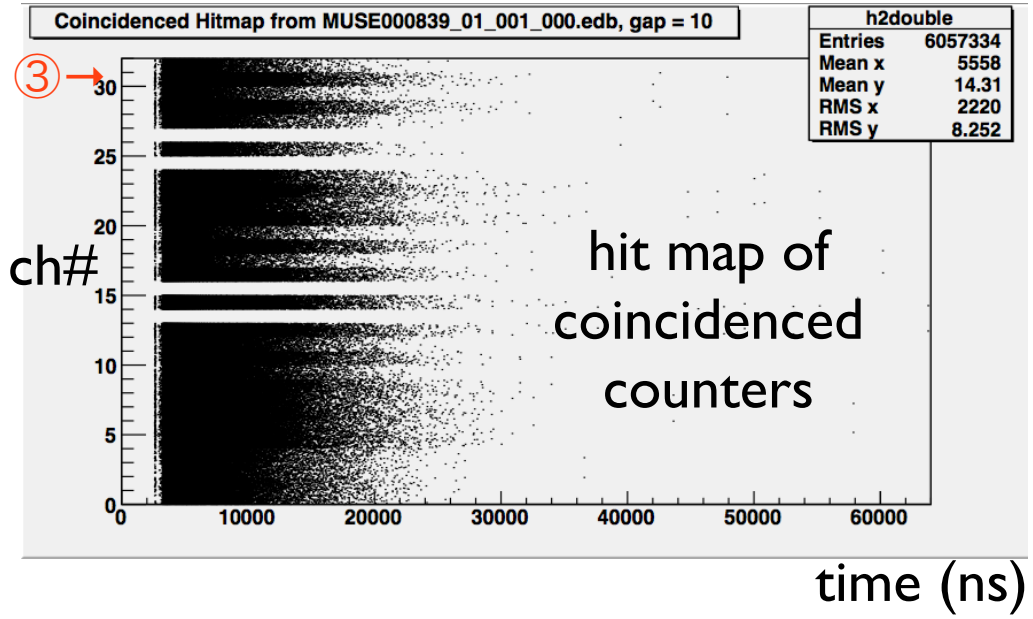


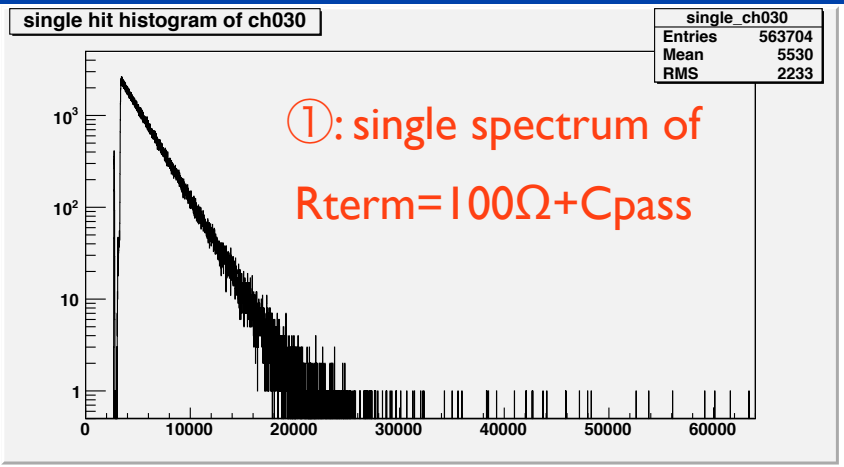
ASIC digital control

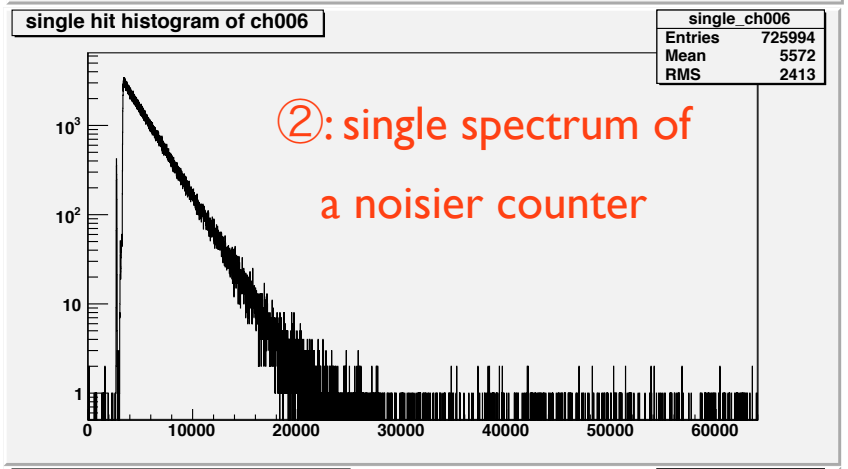
Result of 32ch full spec detector @ RAL: Feb.29~Mar.02, 2012

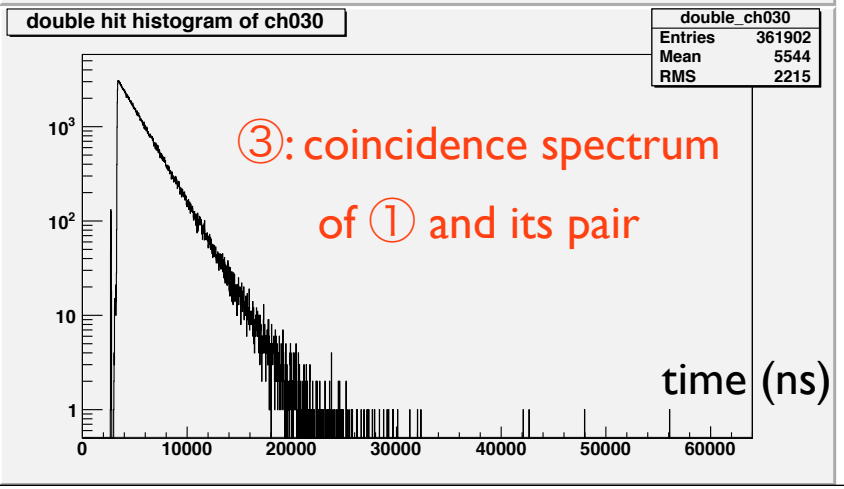
single count rate: ~1e+/pulse



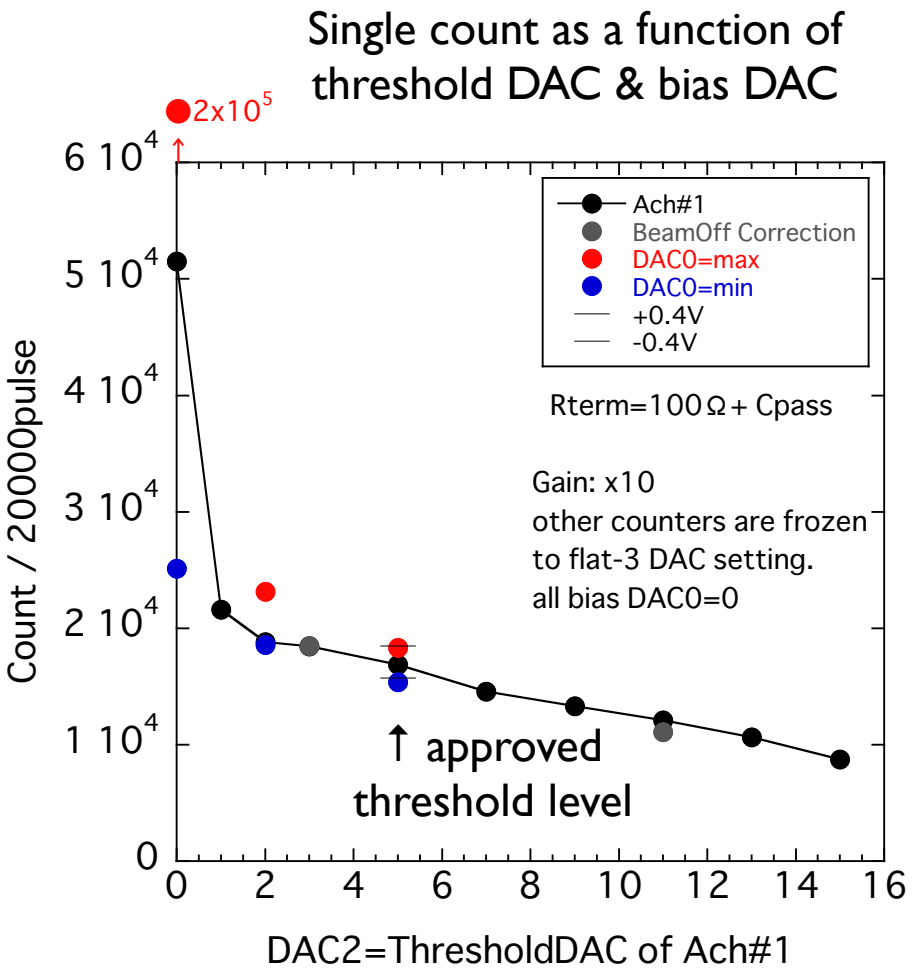








Count rate: DAC control and magnetic-field dependence (?)



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- bias DAC0 spans ~±0.4V equivalent which is ~1 digit in threshold DAC
- gain control:
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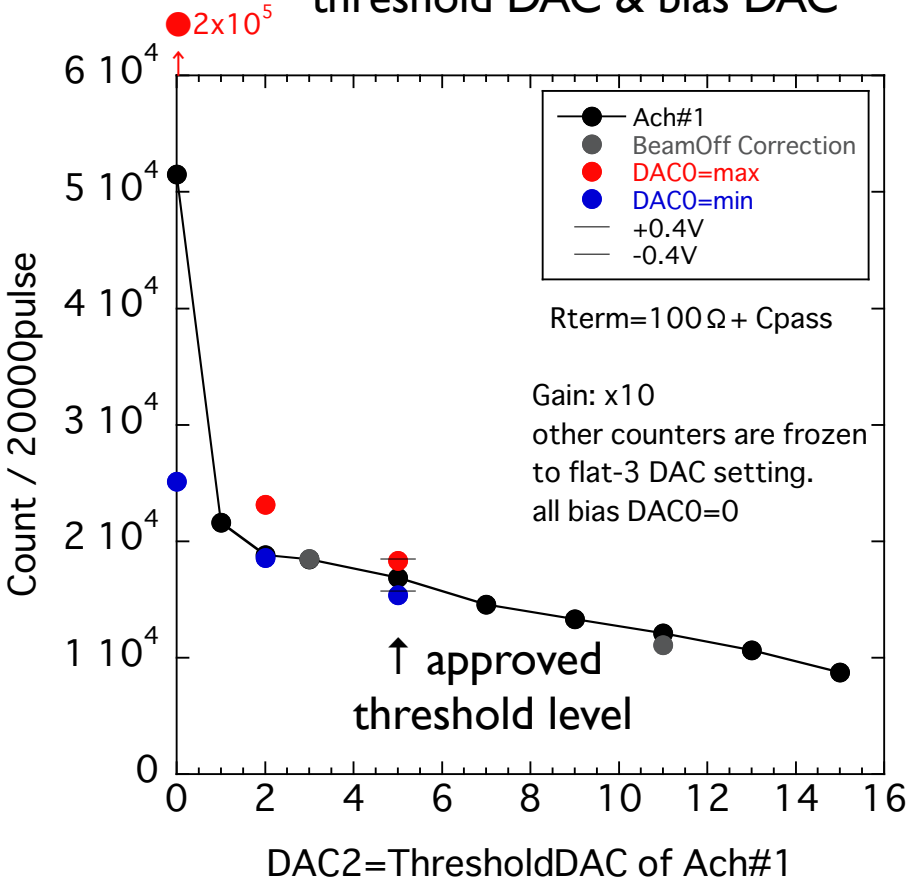
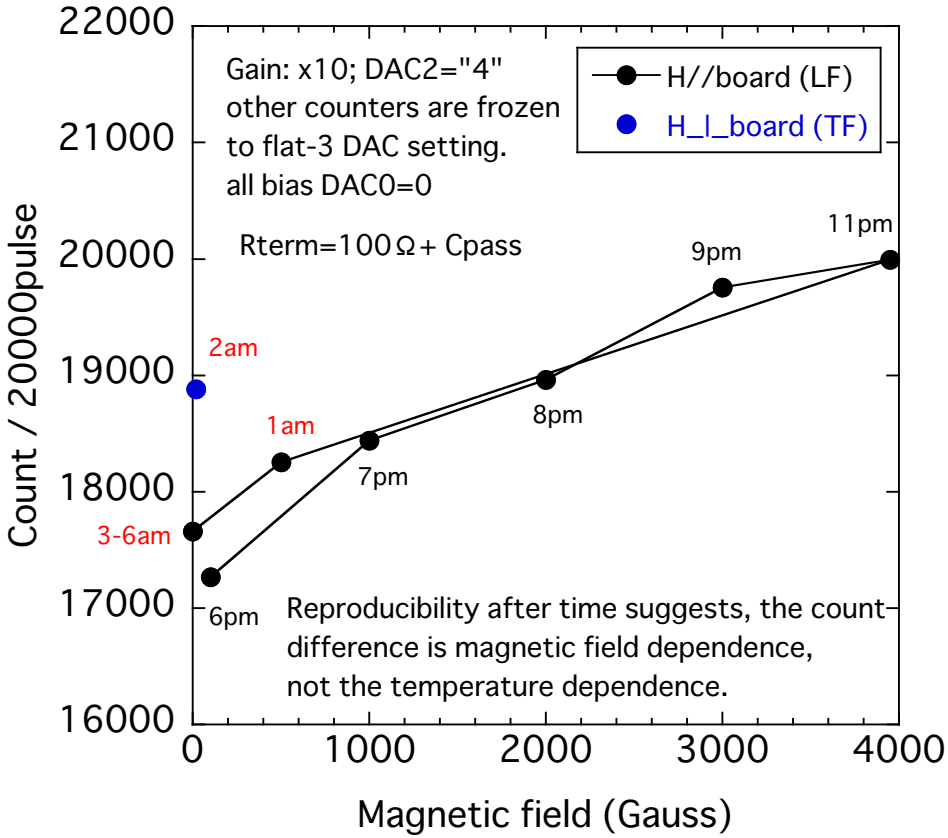
Single count as a function of threshold DAC & bias DAC



Single count rate as a function of magnetic field (LF//board, TF_|_board)



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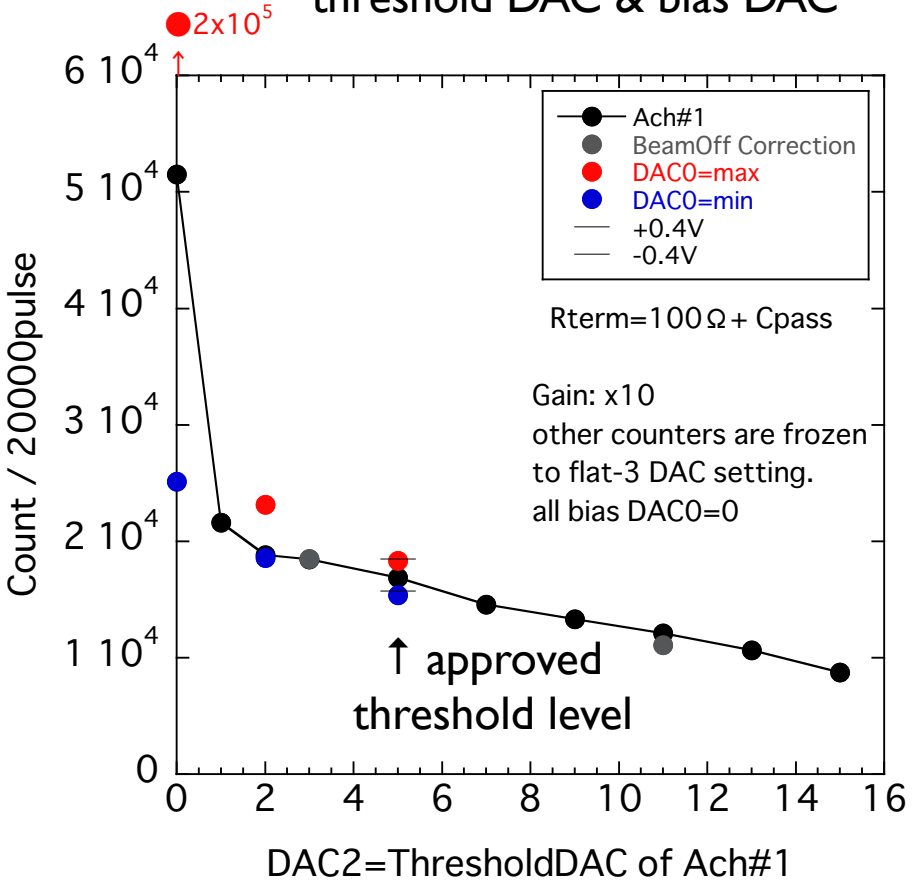

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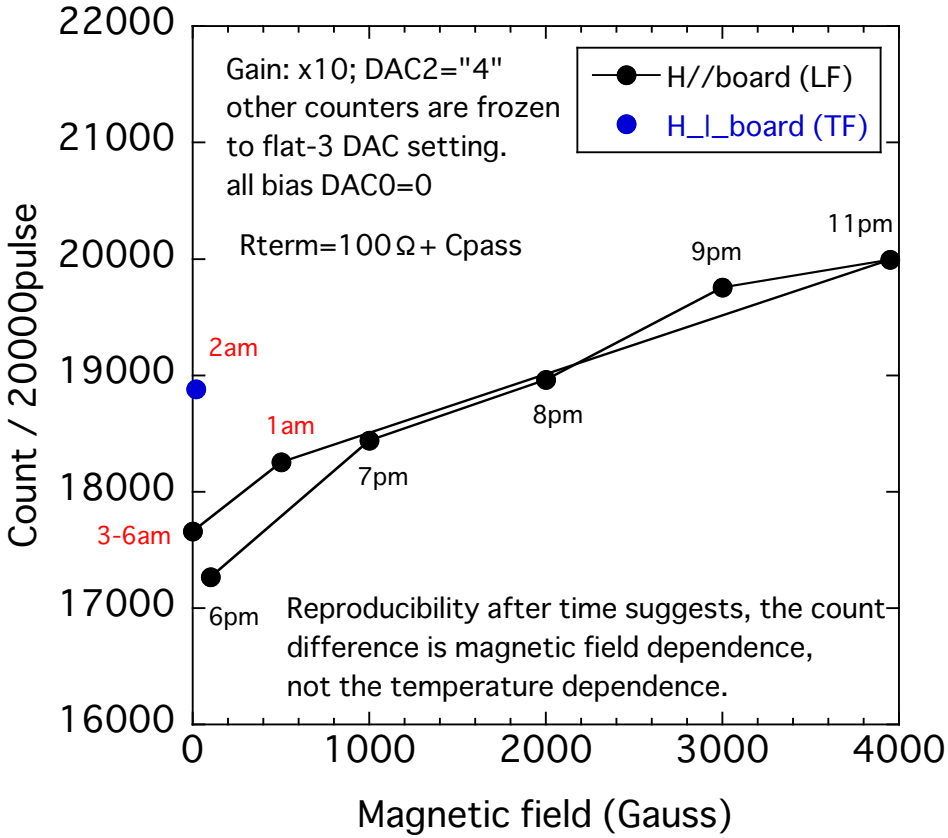
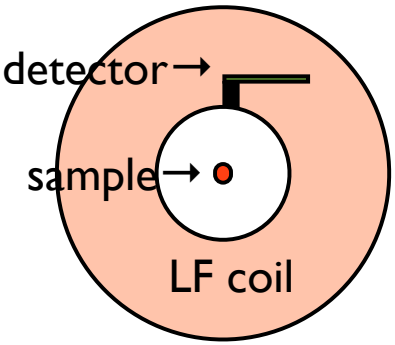


view from downstream of ARGUS



Preliminaly: 10% increase in 4kG field.
Beam normalization check underway.

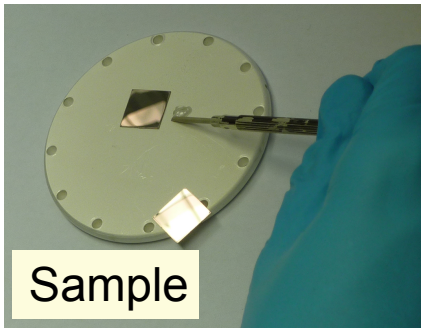
Cost Estimate

- Scale: 10^3 channels=32ch×32 units

	per 32ch unit	sub total
Scintillator+MPPC+support	$100?×32=$3.2k?	$100k?（×32 units）
Analog board	$1k or less	$32k or less（×32 units）
Digital board	$0.6k	$19.2（×32 units）
Optical ethernet switch	$26k for 16×32ch （16×1GbE→10GbE）	$52k（×2 units）
PC	$5k for 1×10GbE	$10k（×2 units）
total		~$200k

probably, 1/3~1/5 cost of PMT-NIM-VME based (20th century) detector system

Ultra-slow muon for usual users...



black box

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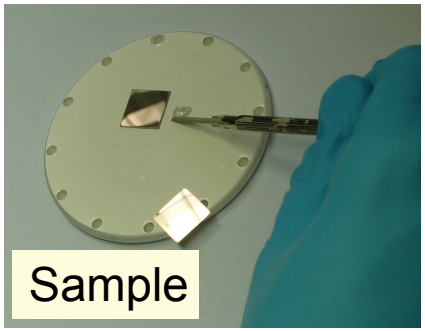

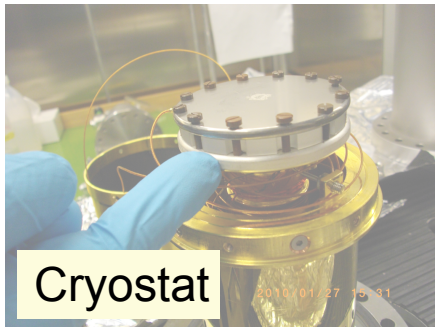

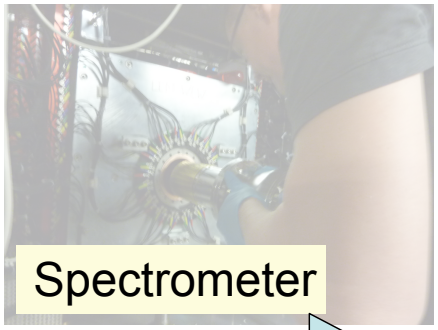

less familiar...

BL magnets
Detectors
Electronics
DAQ-PC
run-control HW

black box

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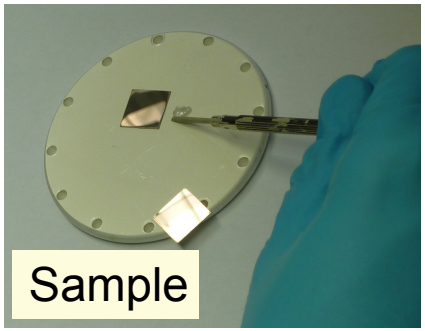

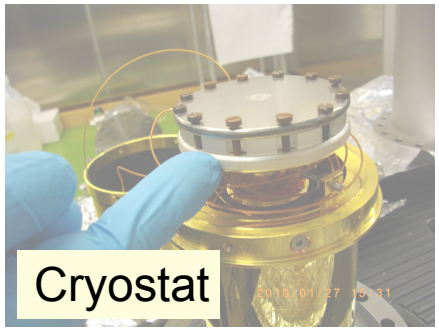

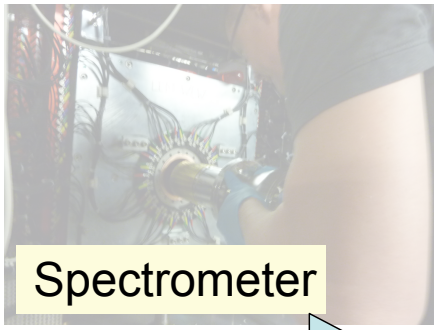

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Two important I/Os to users

- User interface of run control
- Data-file & analysis program

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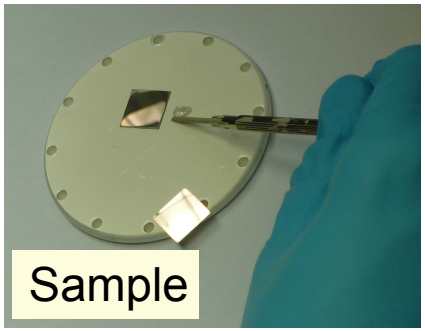
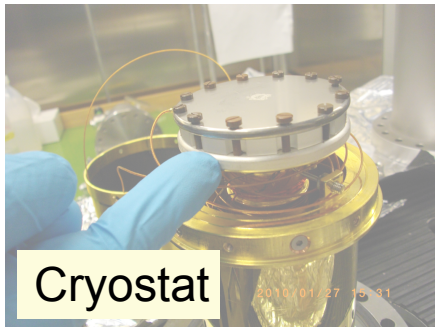
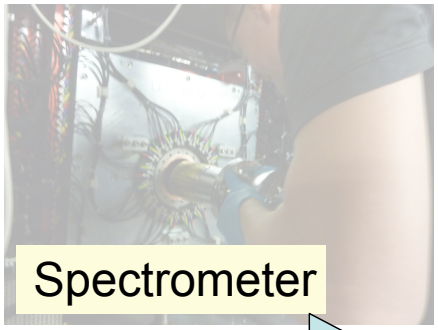




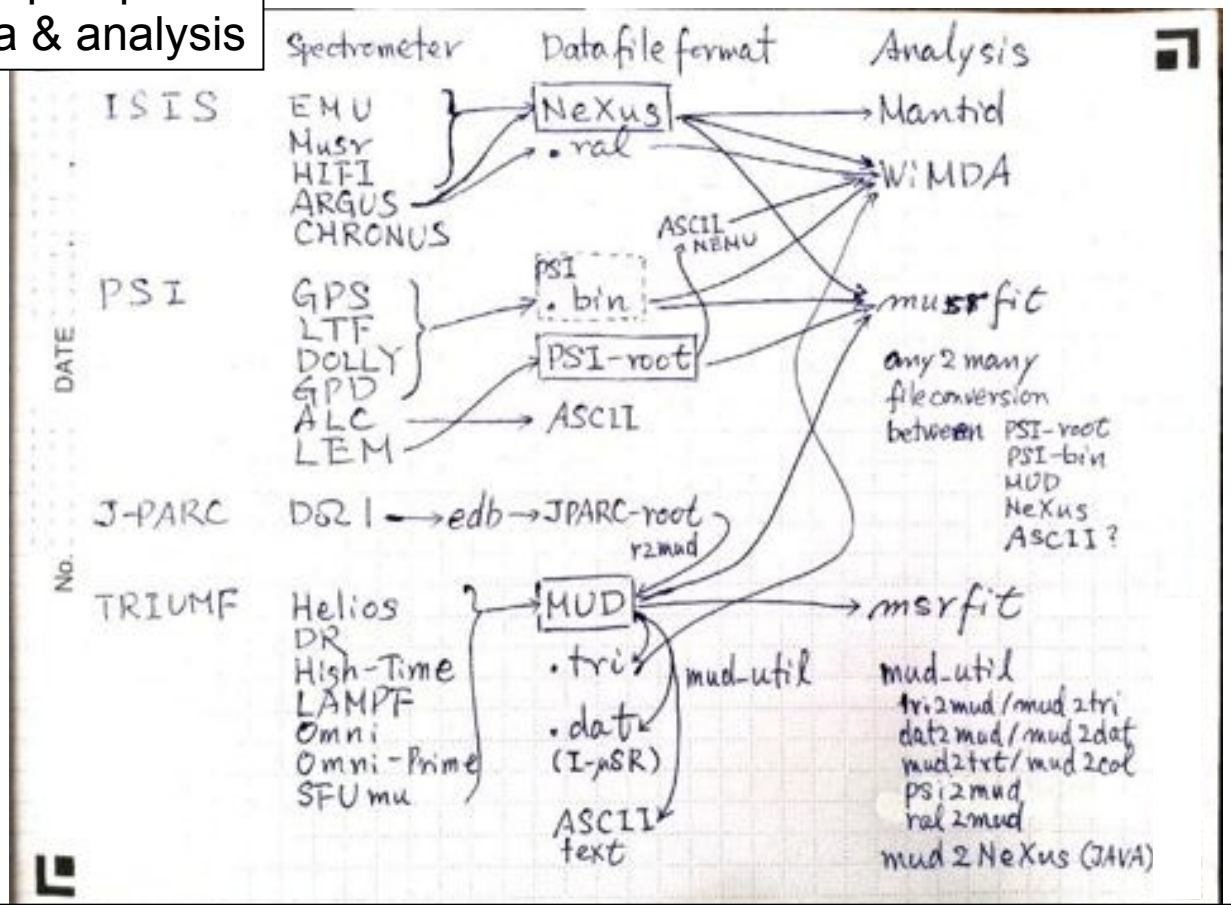


less familiar...

BL magnets
Detectors
Electronics
DAQ-PC
run-control HW

black box

map of μSR data & analysis



Two important I/Os to users

- User interface of run control
- Data-file & analysis program

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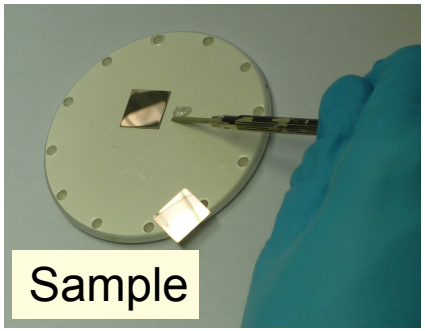

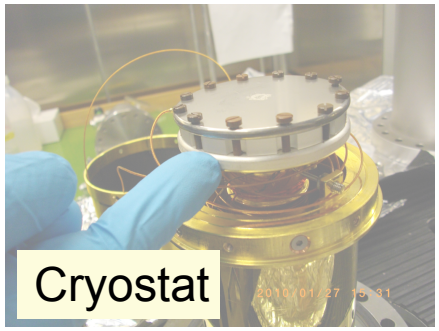

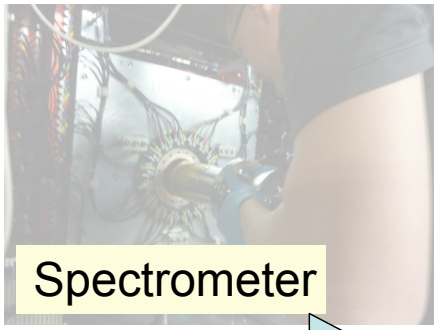

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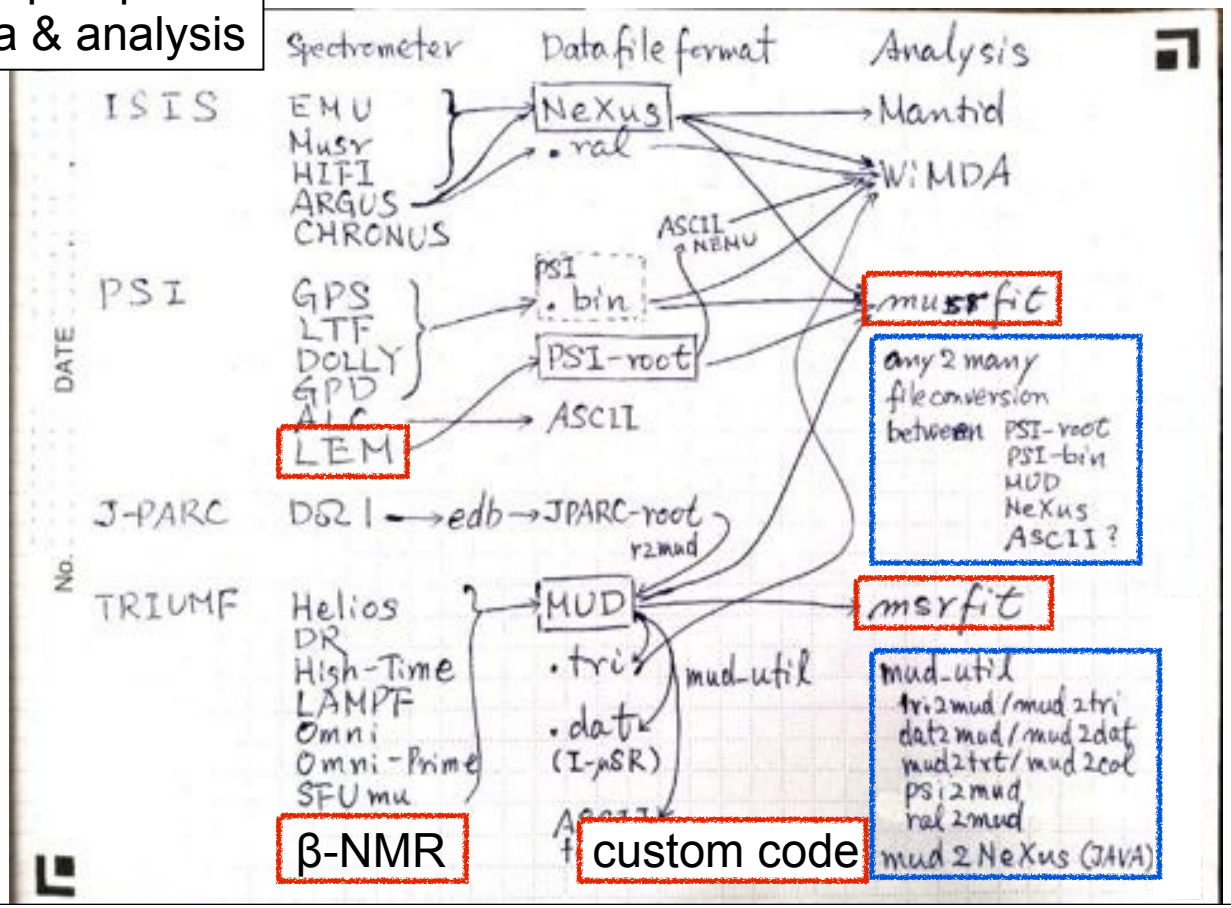

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Run control and data-file format of USM/J-PARC

	run control	data-file format	analysis code
LEM/PSI	MIDAS	LEM-root	musrfit
β -NMR/ TRIUMF	MIDAS	... →MUD	custom made C C++ code (long life of Li requires)
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Boundary condition for run control:
J-PARC neutron standard= ISIS-style script

Data-file format
RIKEN/RAL users is familiar with NeXus or .ral→WiMDA
Conversion code between file format is important

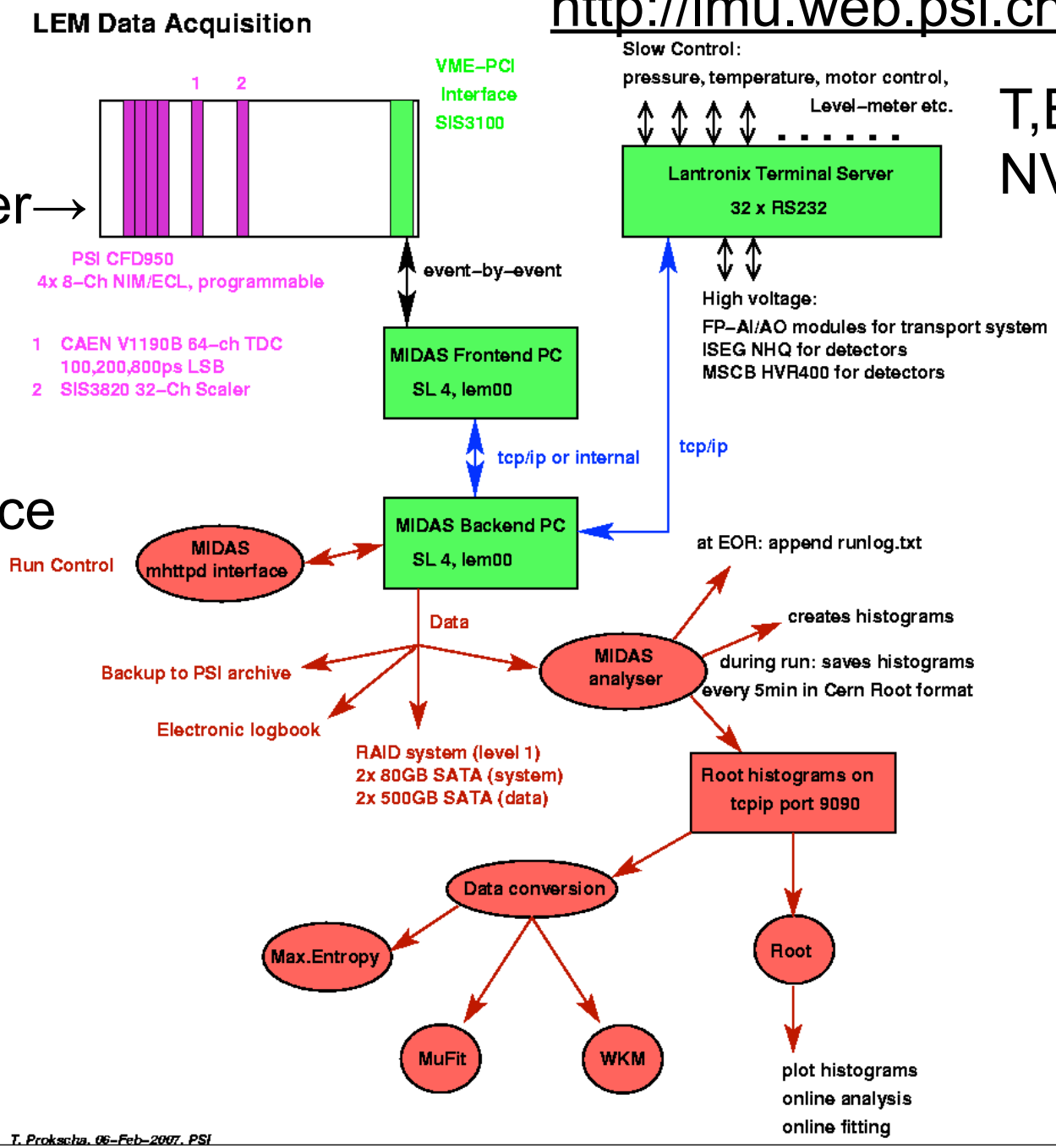
MIDAS system at PSI

http://lmu.web.psi.ch/lem/lemdaq/

from LEM spectrometer→

T,B,P, NV,...hardware

User Interface

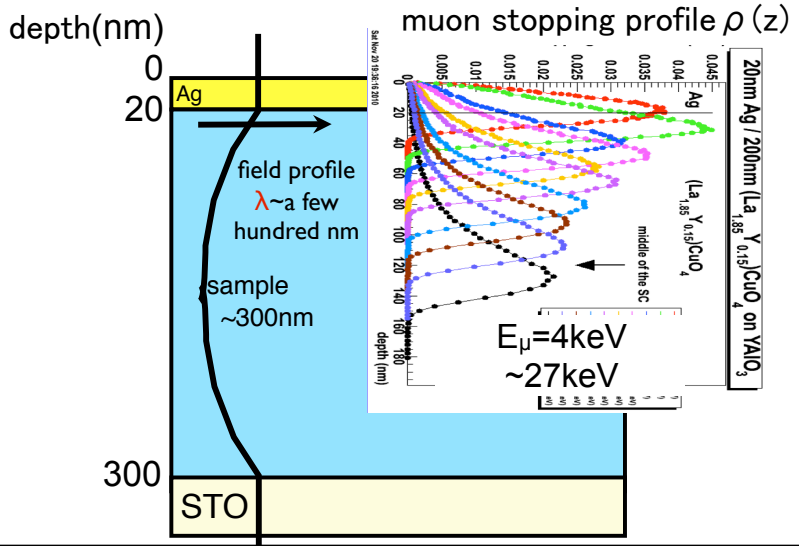


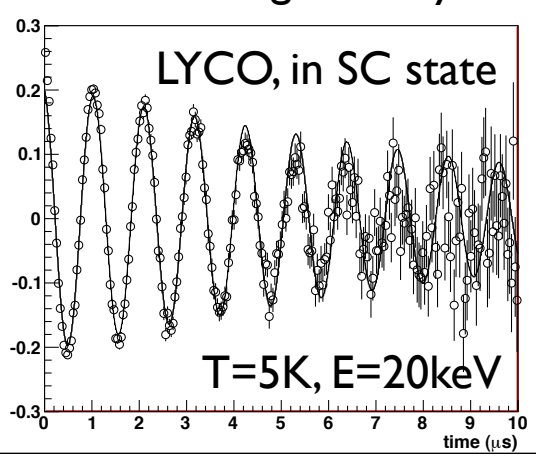
msrfit vs. musrfit

As far as I understand...

- msrfit (Jess Brewer@UBC/TRIUMF) exists since 80s (I grew up with).
  - command-line base
  - table fitting
  - mysterious SIGNAL line (=fit function definition) and SPECTUM line
  - Suzanne Flaschin's how to: http://einrichtungen.ph.tum.de/E15b/documents/fit/fit.html

- musrfit (Andreas Suter & Bastian M. Wojek@PSI) is actively maintained
  - musredit (customized editor+gui) exist
  - more readable FUNCTIONS line
  - Users manual: http://lmu.web.psi.ch/facilities/software/musrfit/user/MUSR/MusrFit.html
  - For LEM usage, depth-profile convolution is incorporated.





in musrfit
depth profile convolution

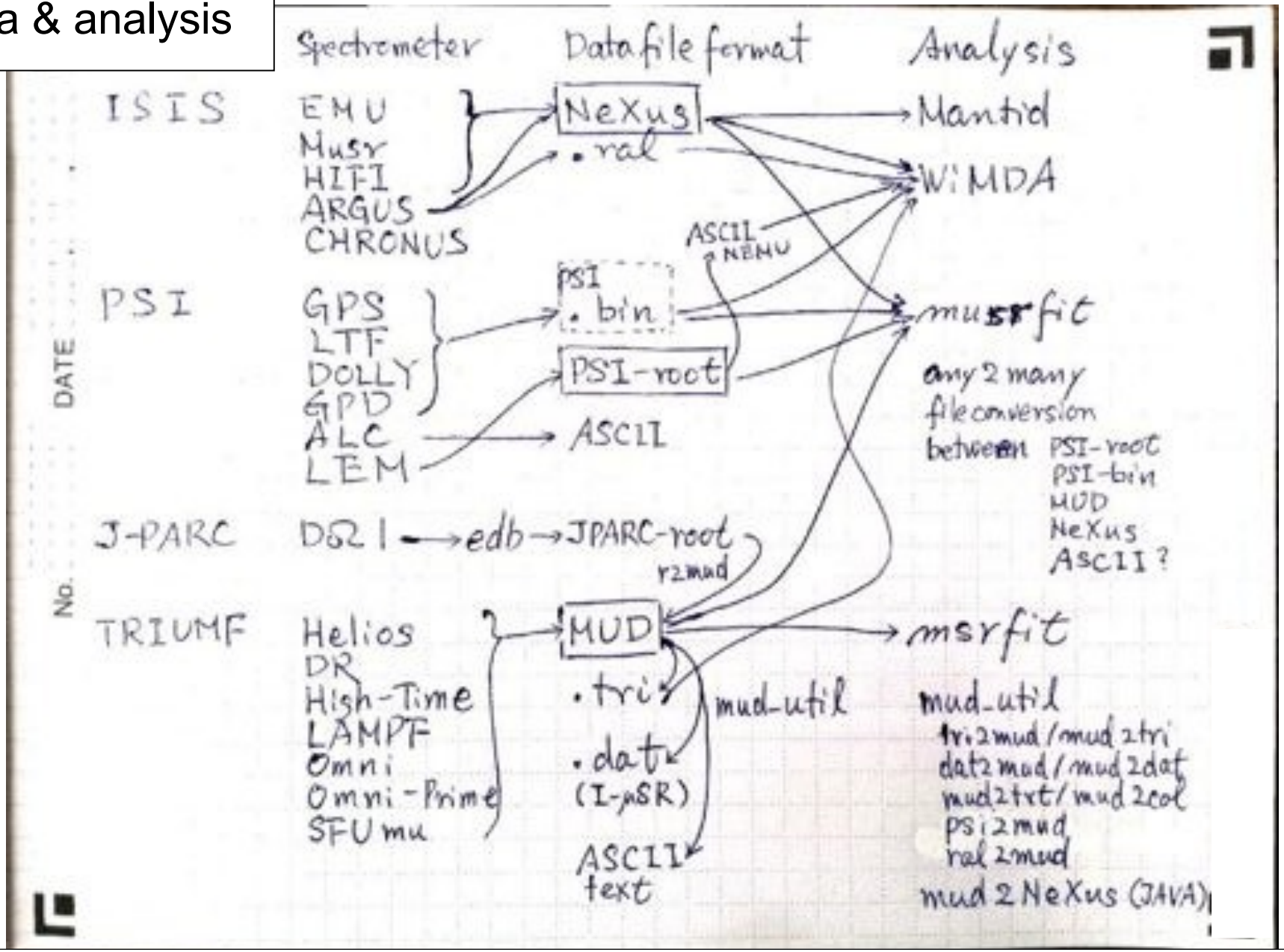
$$P_\mu(t)=\int \rho(z)P_\mu(t,z;\lambda)\,dz$$

↓

penetration depth λ

Path from J-PARC-root to musrfit: just add keys as in PSI-root

map of μSR data & analysis



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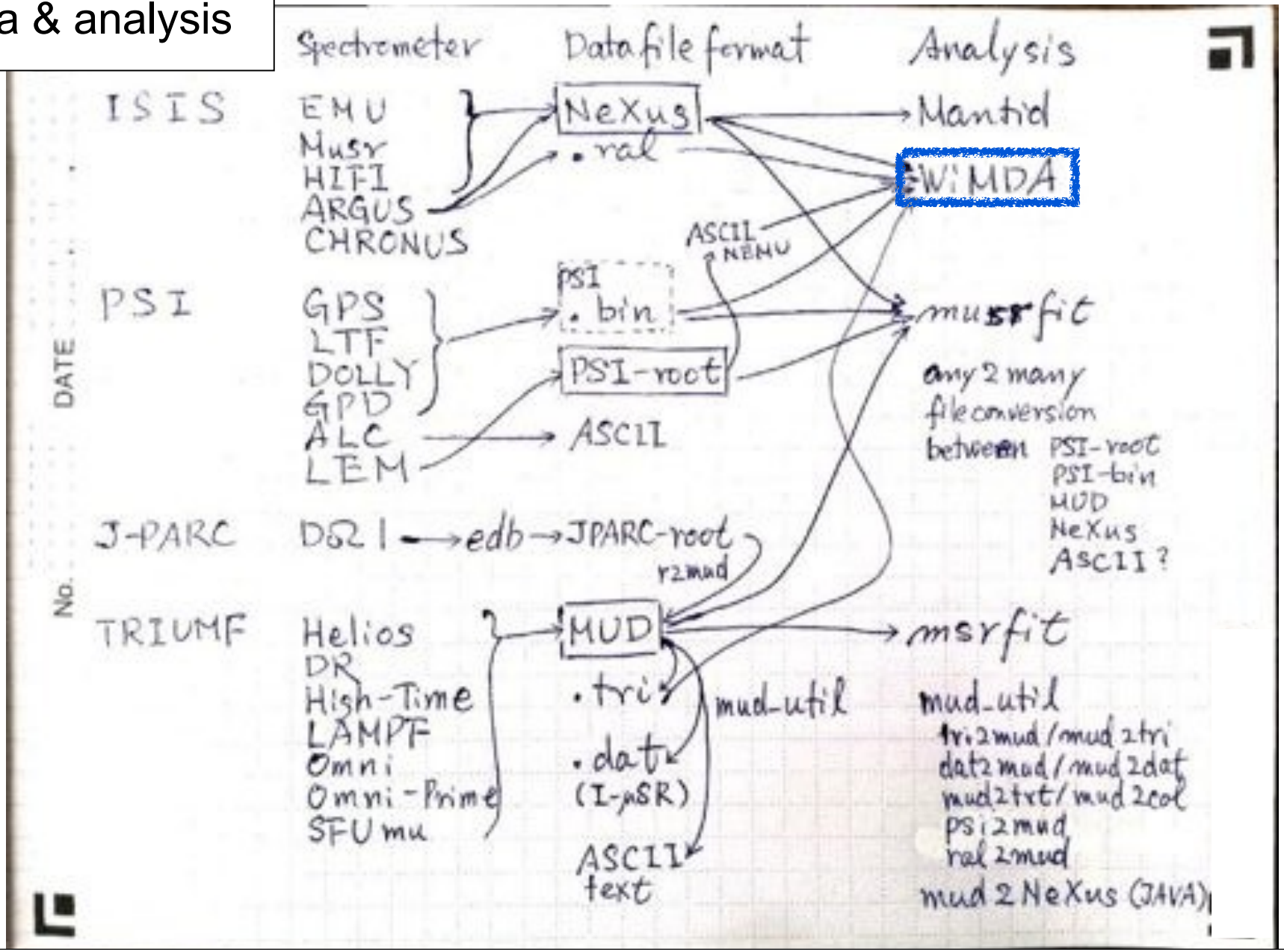

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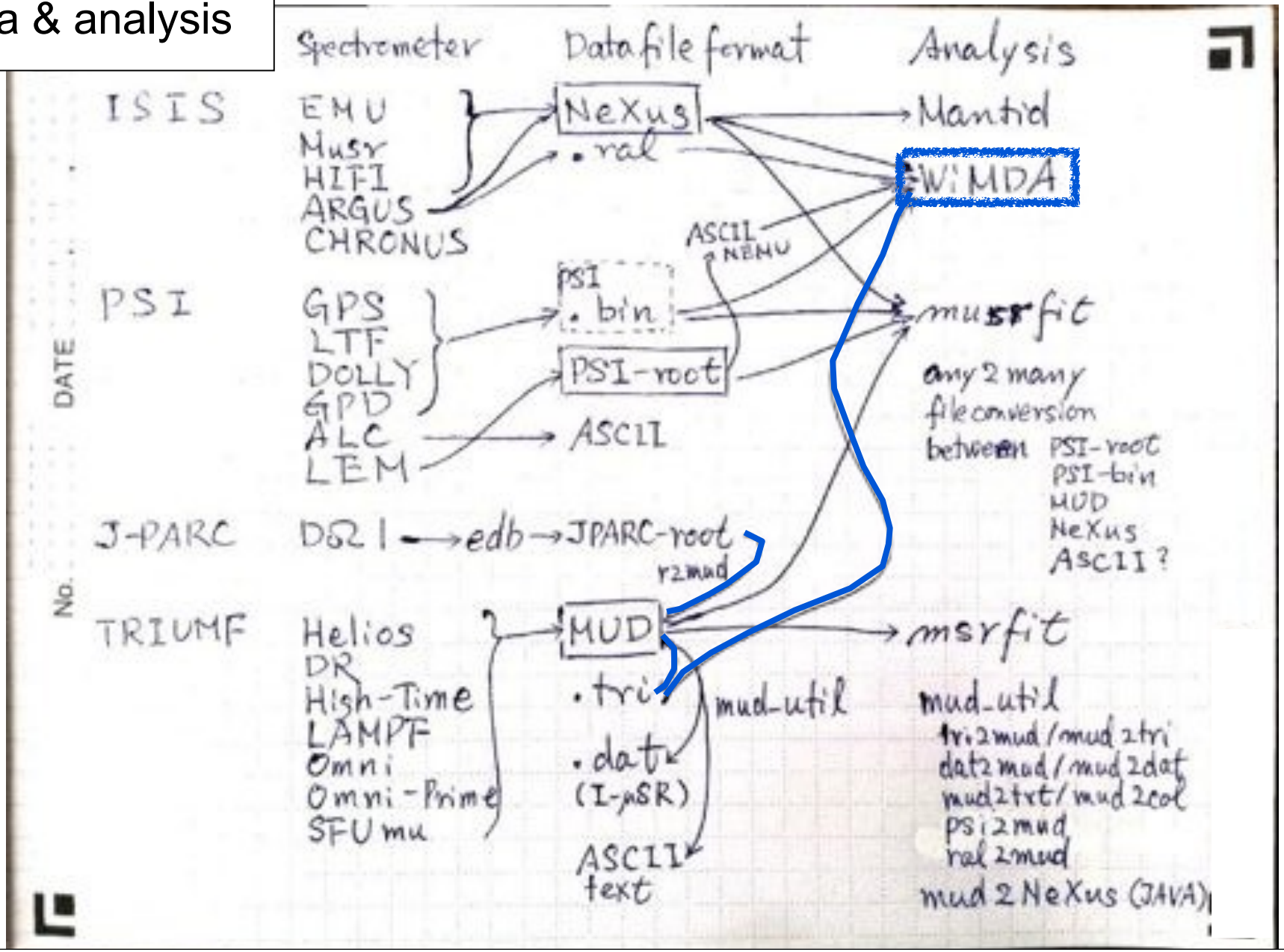

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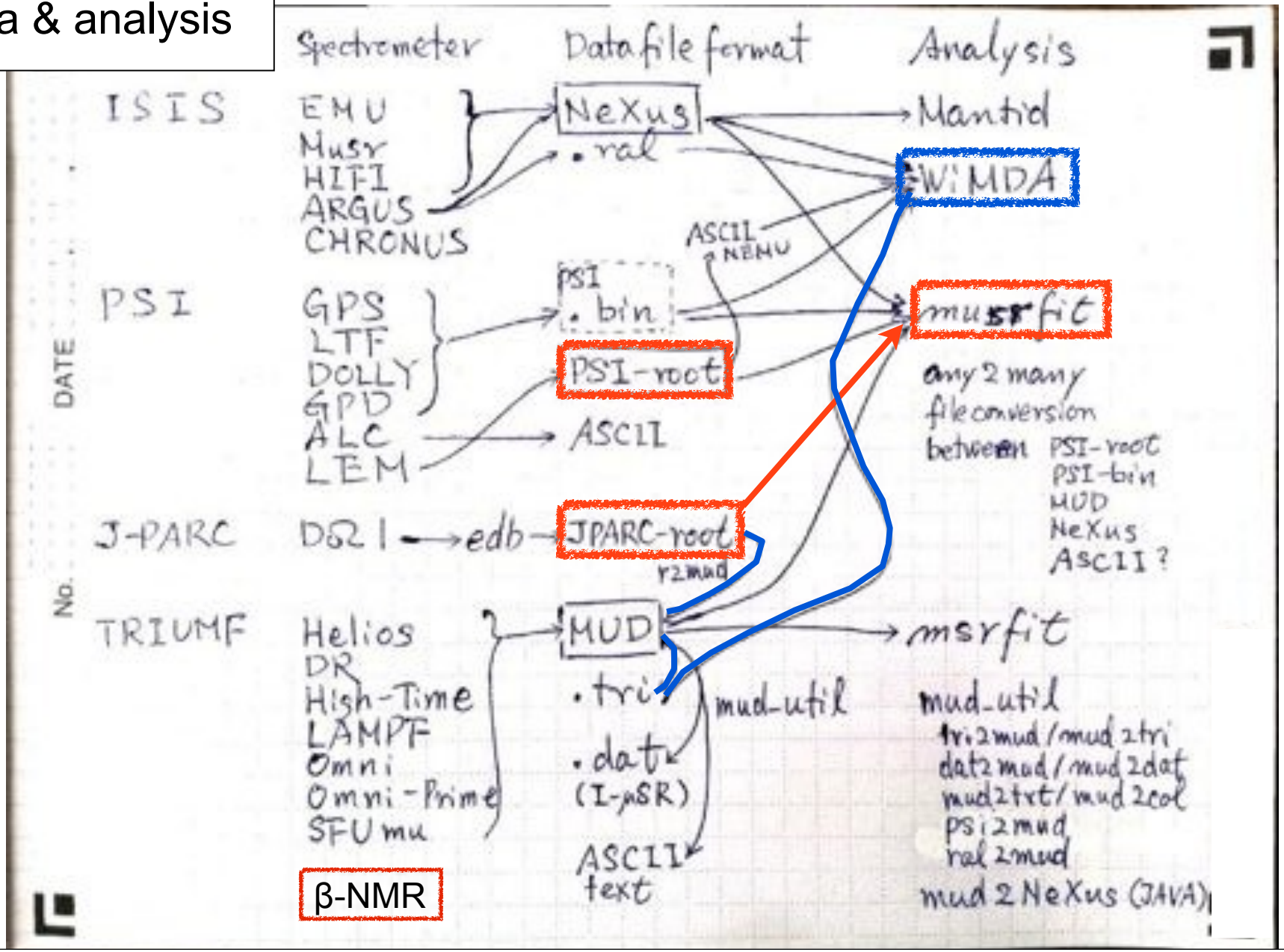

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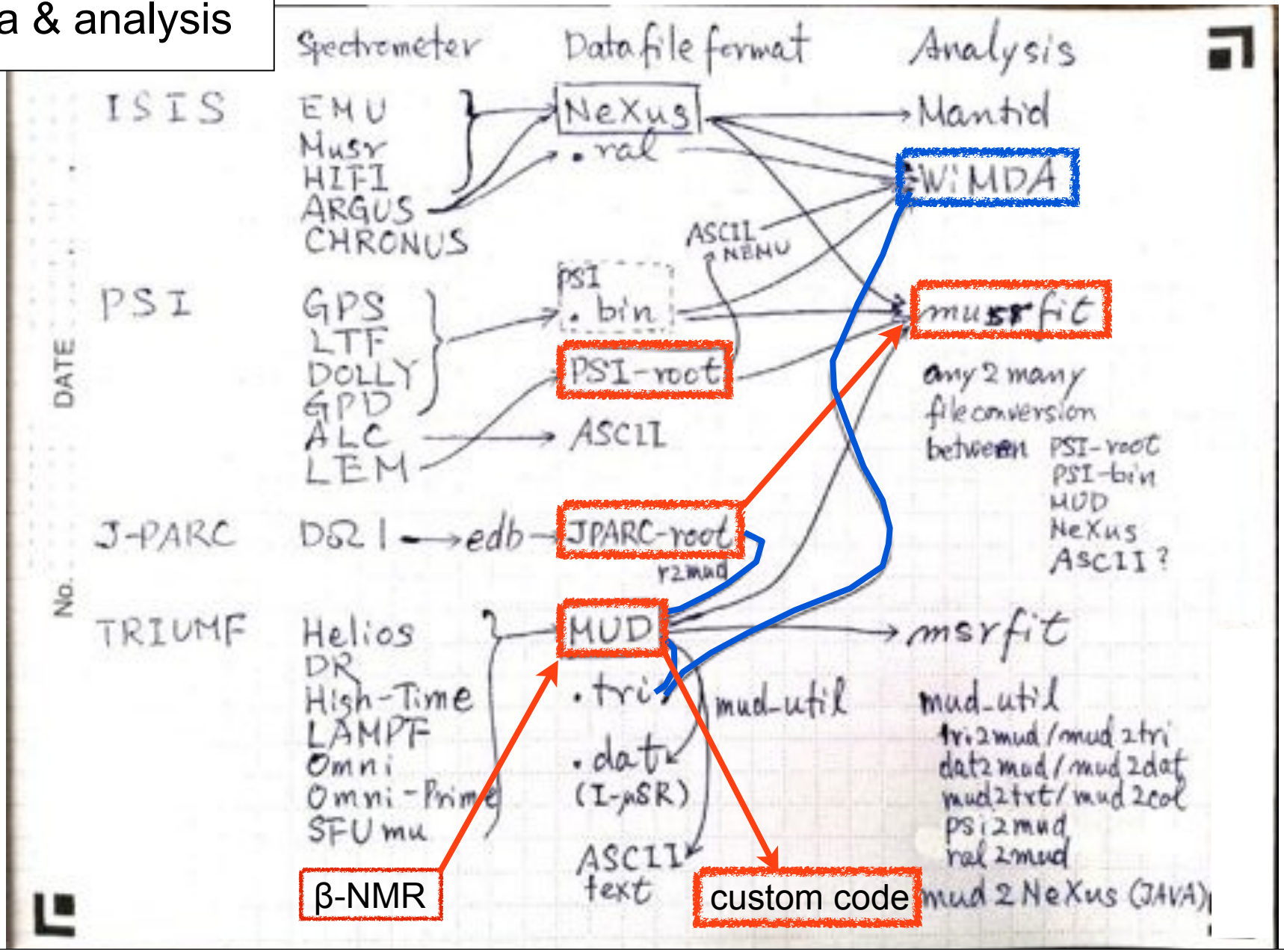

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Pulsed μSR requires multi-segmented detector
- 21st century solution is MPPC/ASIC/FPGA/ethernet-based detector
- R&D is in the final step, and mass production is starting.

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  - Common interface at J-PARC/MLF is based on ISIS neutron system
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My principle:
Don't try to build everything by myself. Use *existing* facility.
→collaboration with LEM (PSI) & β-NMR (TRIUMF)!