Micromegas vertex tracker for the Clas12 Experiment
(or “Cabbages and Kings”)

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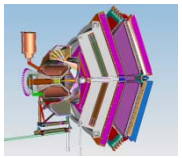
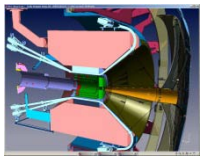
Overview

- **Detector**
  - → Clas12 — Strange classification

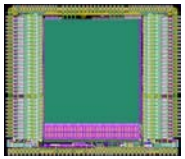


  - → Micromegas tracker — Voltaire



- **Read-out electronics**
  - → Signal cables — Miracle

  - → Dream ASIC — Dream



  - → Frontend Unit (FEU) — Fire

  - → Backend Unit (BEU) — Weed

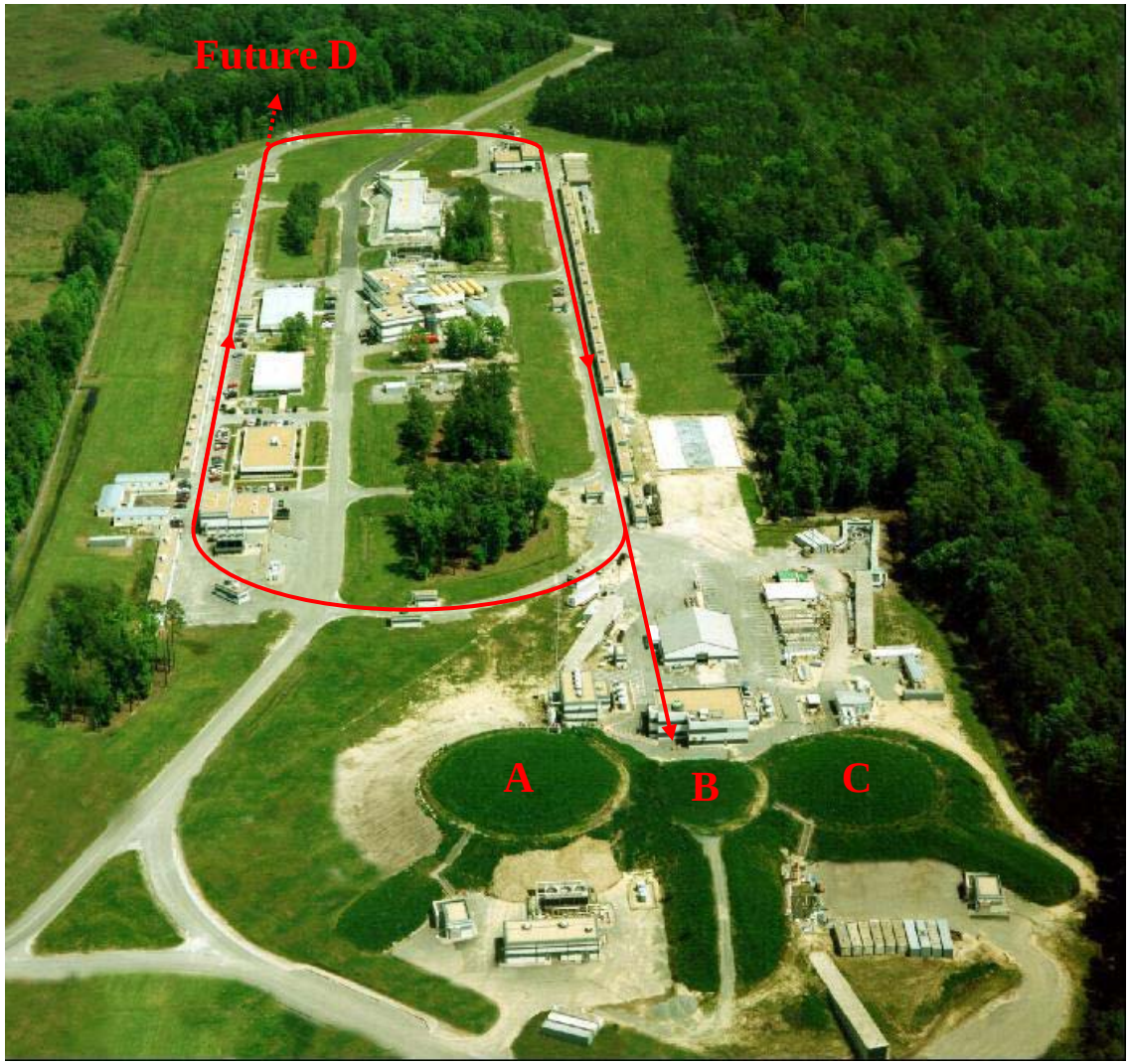
- **Current status**
  - → Conclusive remarks

The Clas12 experiment: Where

- Thomas Jefferson National Accelerator Facility (JLab)
  → Newport News, Virginia, USA

  Continuous
  Electron
  Beam
  Accelerator
  Facility

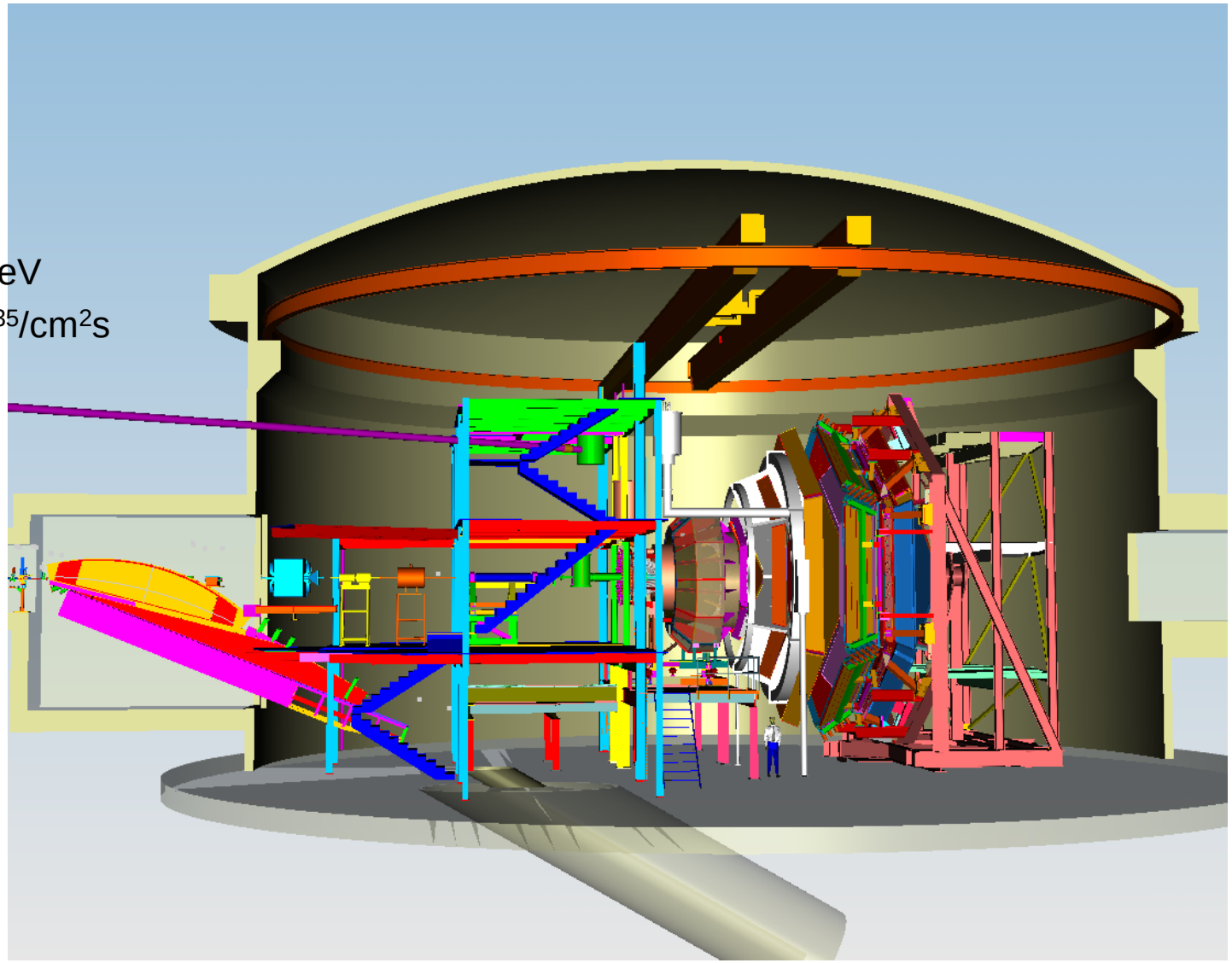
- Upgrade
  → 6 GeV → 12 GeV
  → 2014-2015



The Clas12 experiment: What

- Clas upgrade
  - → Hall B
  - → 6 GeV → 12 GeV
  - → Luminosity: $10^{35}/cm^2s$
  - → 2013-2015

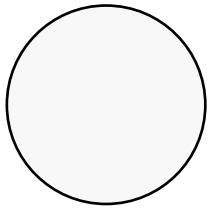
CEBAF
Large
Acceptance
Spectrometer

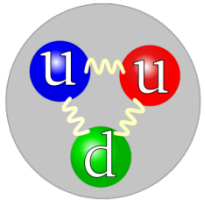


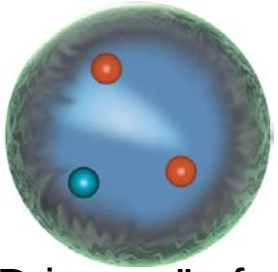
The Clas12 experiment: Why

- Study of structure of nucleons and nuclei

Proton in 1920 **Proton in 1968** **Proton in 1986**



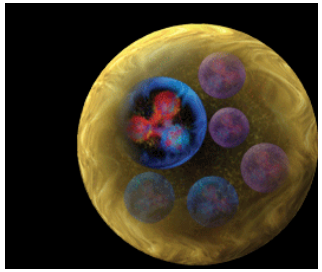




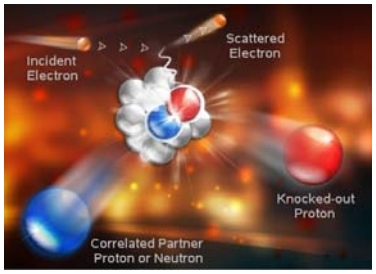
→ generalized parton distributions (GPDs): kind of a “3D image” of nucleons

- Correlation between spatial and impulse distributions

- Fixed target experiment



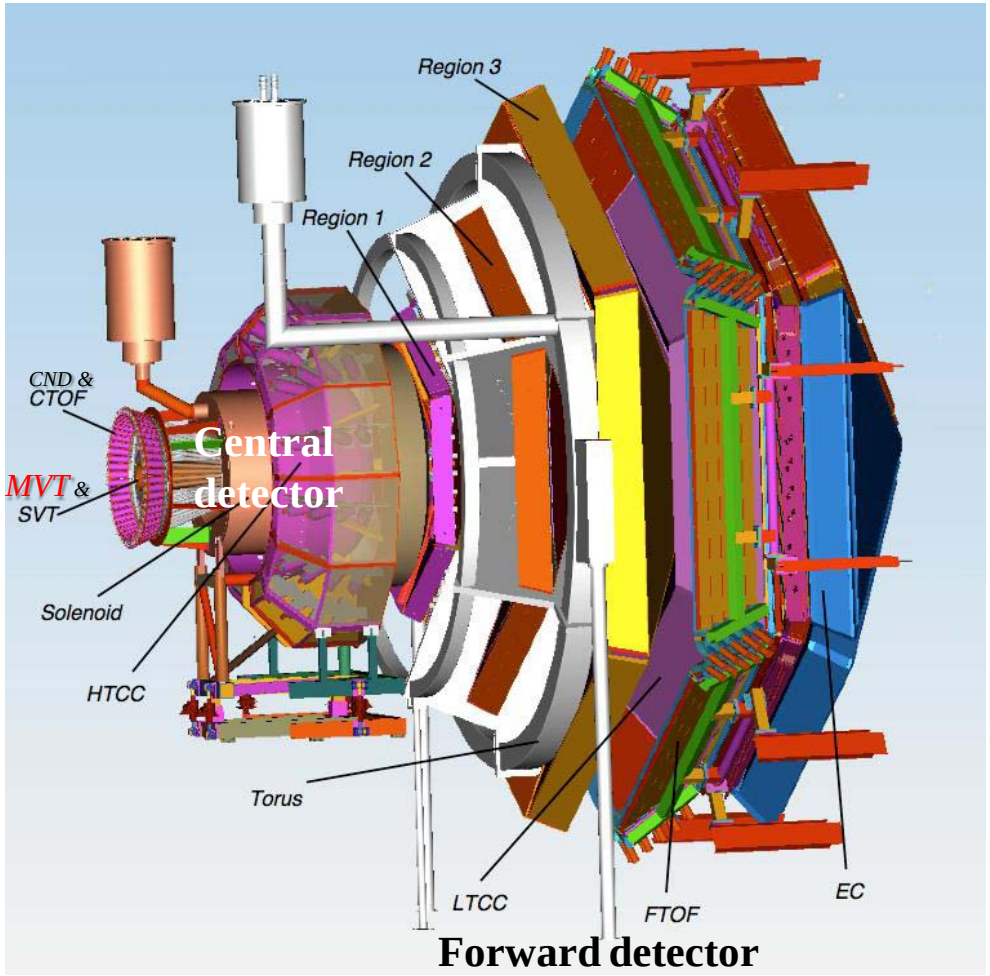
→ Example process: deeply virtual Compton scattering (DVCS)



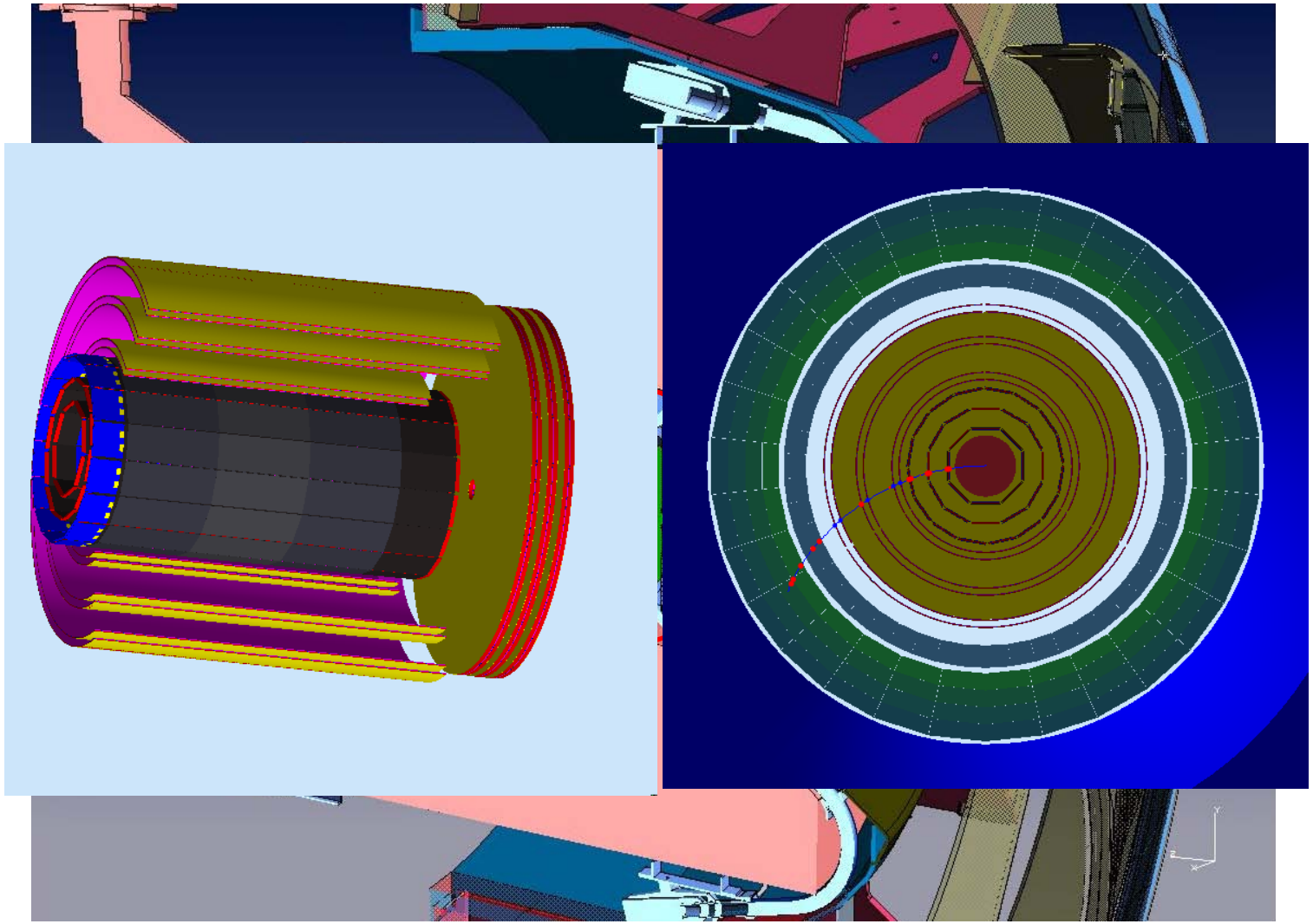
The Clas12 experiment: How

- Central detector:
  - → 5T solenoid
  - → Central neutron detector
  - → Central time-of-flight
  - → Micromegas barrel & forward trackers
  - → Barrel silicon tracker

- Forward detector:
  - → 6T torus
  - → High threshold Cherenkov counters
  - → Drift chambers (3 regions)
  - → Low threshold Cherenkov counters
  - → Forward time-of-flight
  - → Preshower calorimeter
  - → E.M. calorimeter
  - → Inner calorimeter

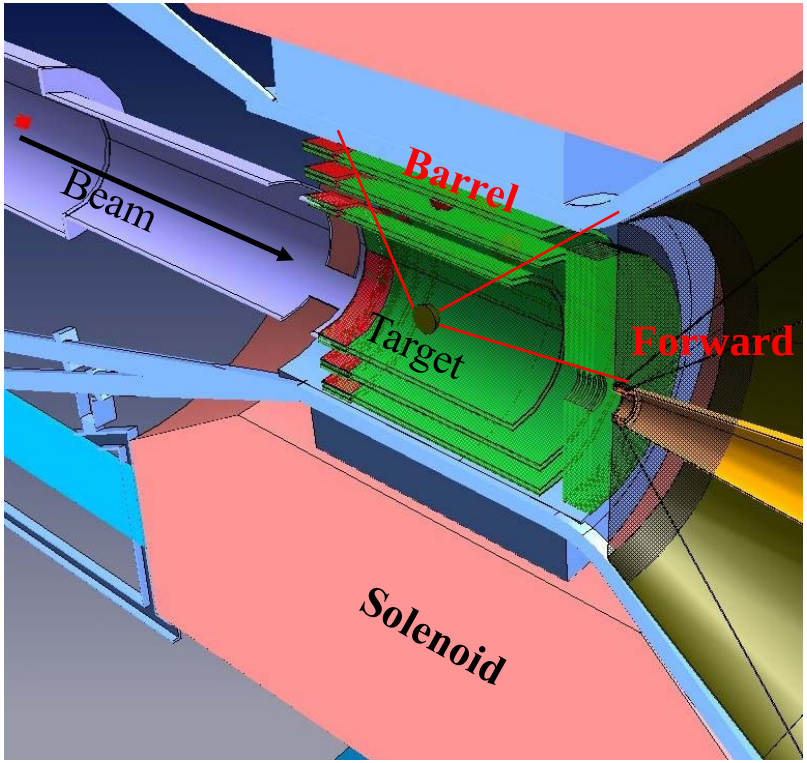


Micromegas Vertex Tracker



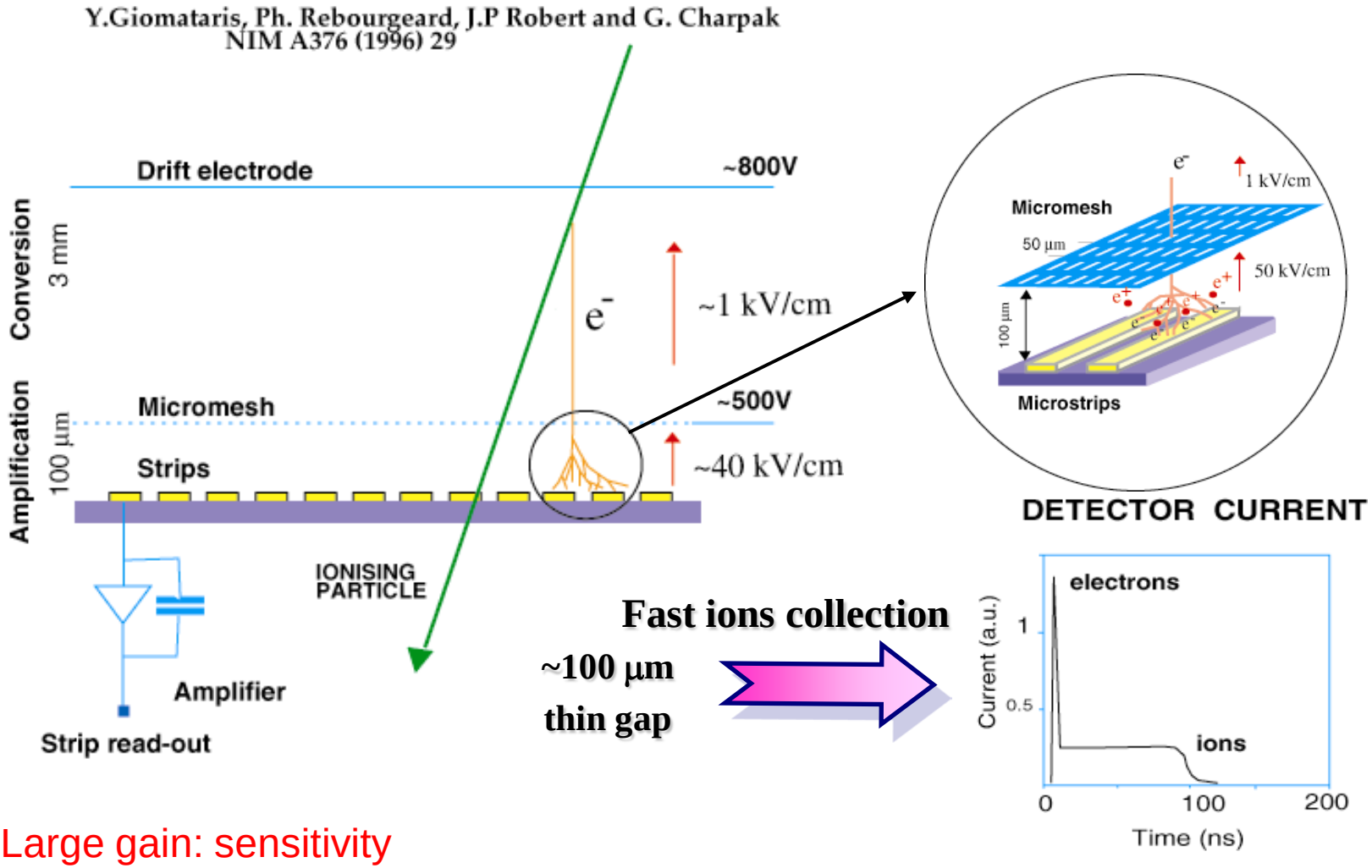
Micromegas Vertex Tracker

- Barrel MVT
  - → 6 cylindrical layers
    - Alternated X and Y coordinates
    - 2.7 m^2
  - → Coverage: 145°-35°
  - → Precision: ~220µ in X and ~100µ in Y
    - ~19 000 strips
- Forward MVT
  - → 6 disks
    - Alternated X and Y coordinates
    - 1.3 m^2
  - → Coverage 35°-5°
  - → Precision: ~100µ
    - ~6 000 strips



- → 5T Magnetic field
- → Low allowed material budget
- → No space for electronics
- → Minimal dead zones
- → 20 MHz background

Micro Mesh Gaseous Structure



Large gain: sensitivity

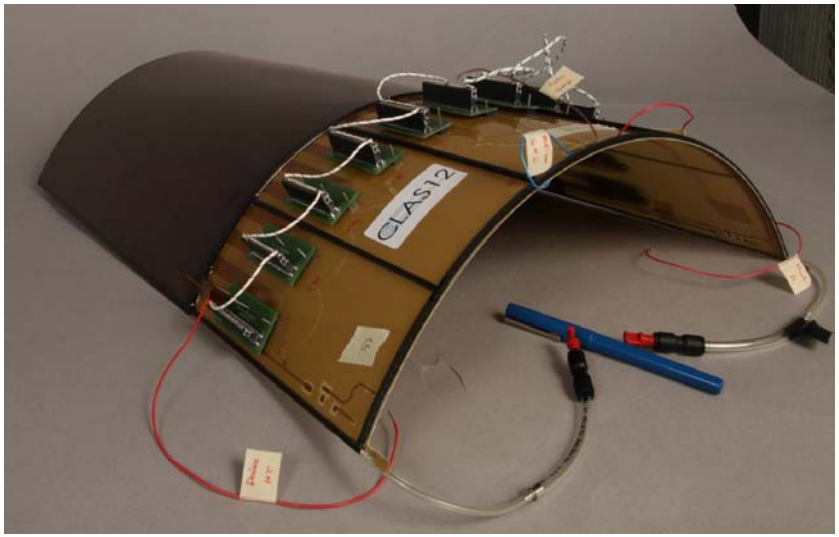
Fast signals: high rate

Gaseous: low material

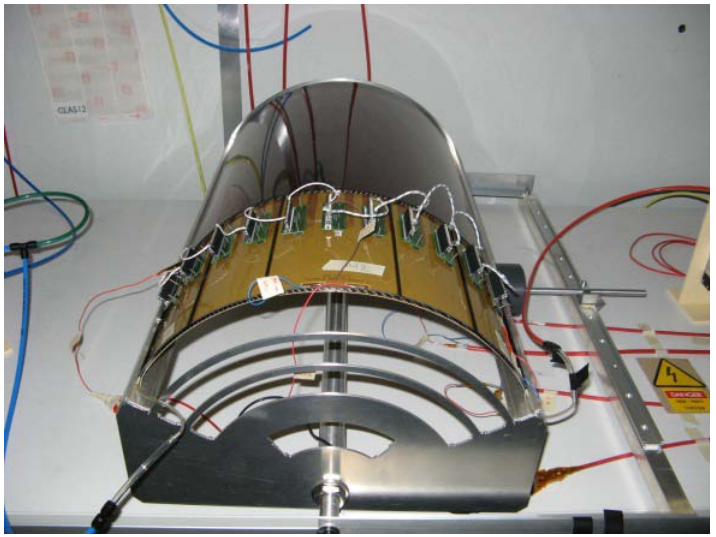
Printed circuit board technology: cheap

Curved self-sustained Micromegas tiles

Cylindrical station formed with 3 tiles



High voltage and gas leakage tests



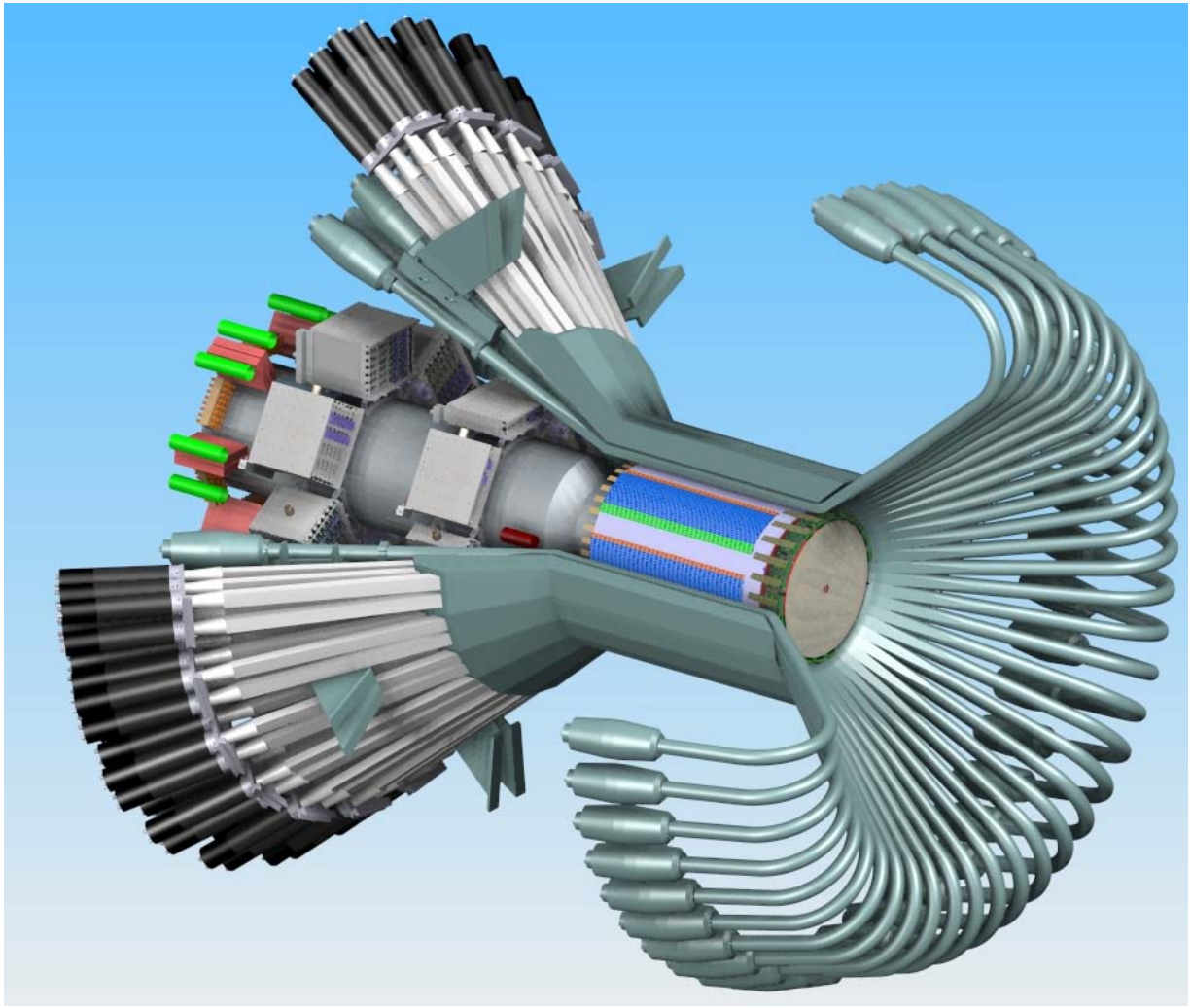
- Large active area: ~500 mm x ~500 mm
- 200µ thick PCB
- Number of strips: ~800

  → 5µ copper

Readout electronics: requirements

- Number of channels: ~25 000
  - → Barrel: 18 curved tiles: ~19 000
  - → Forward 6 disk: ~6 000
- Physics background: 20 MHz
  - → Up to 60 kHz hit rate
- Trigger rate: 20 kHz
  - → pipeline: 16 µs
- Timing resolution: ~10 ns
- Charge measurements dynamics: 10-bit
- Large detector capacitances: 100-150 pF
  - → Signal to Noise ~ 40
- Hostile on-detector area
  - → No place for electronics
  - → Limited off-detector area
    - 0.8T residual magnetic field

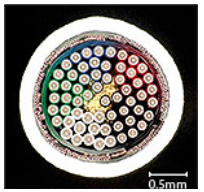
Readout electronics: off-detector

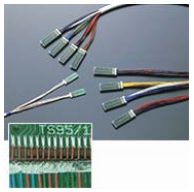


Micro-coaxial cables

- Extremely compact micro-coaxial cable assemblies

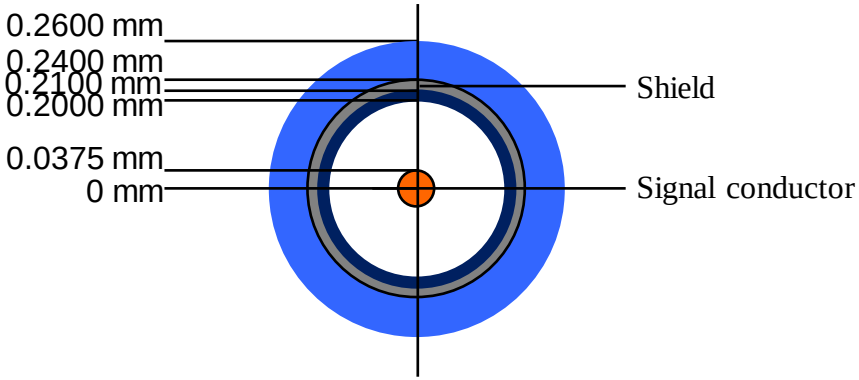
- Round cables
  → Up to 300 coaxes in a 6-7 mm diameter



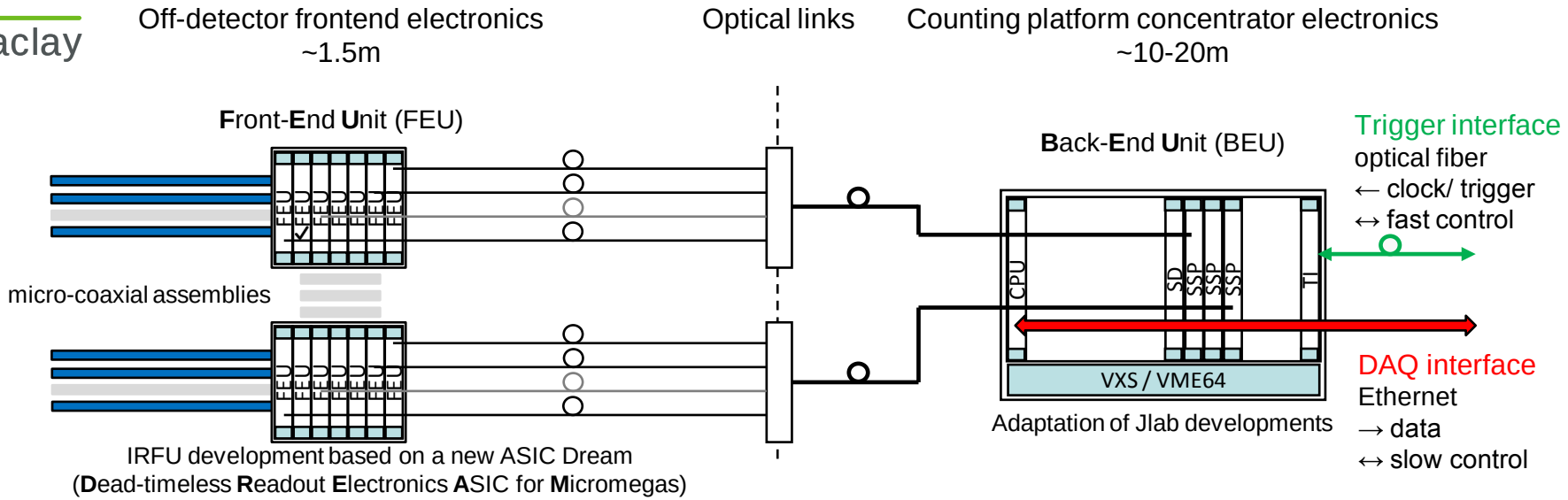


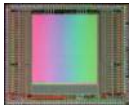
- Flat woven cables
  → 32 coaxes in 24 mm x 1 mm
  → Weight of 20-coax assembly : 8 g/m
    - 2 kg for 96 cables of forward region

- Standard: linear capacitances down to 40 pF/m
  → Clas12 production: 40 pF/m



Read-out implementation

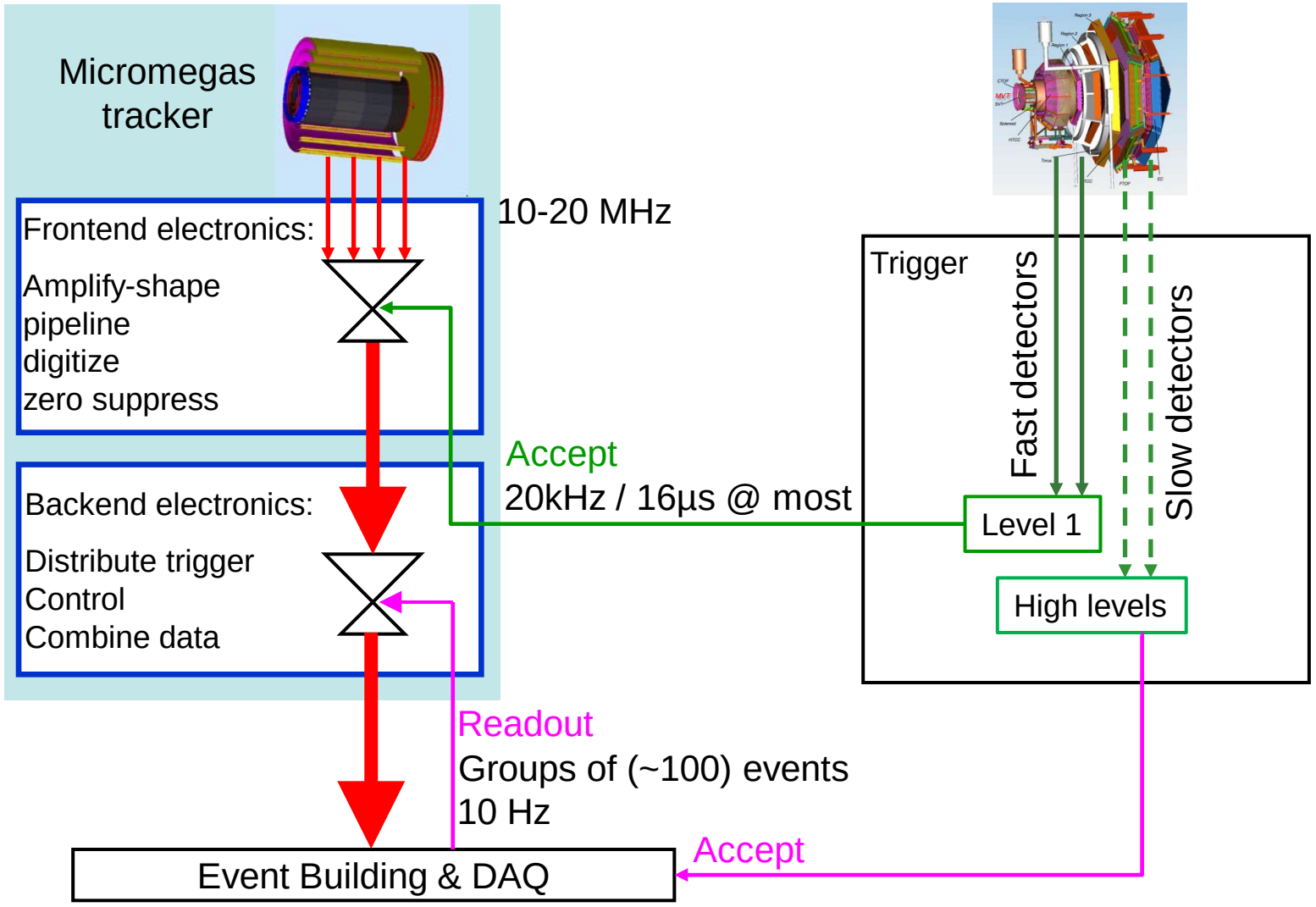




```
01000011 - C
01101100 – l
01100001 - a
01110011 - s
00110001 - 1
00110010 - 2
```

- In numbers
  - → ~500 64-channel micro-coaxial assemblies pF
  - → ~60 512-channel FEUs
    - 500 Dream chips
  - → 60 optical links @ 2.5 Gbit/s
  - → 1 or 2 BEU(s)
- Challenges
  - → Large input capacitance100-200 pF
  - → Trigger rate 20 kHz
    - Pipeline 16 µs
  - → Limited off-detector space
  - → Residual magnetic field ~1T

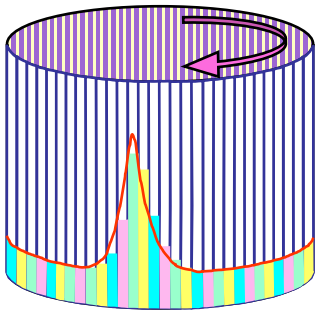
Read-out principles



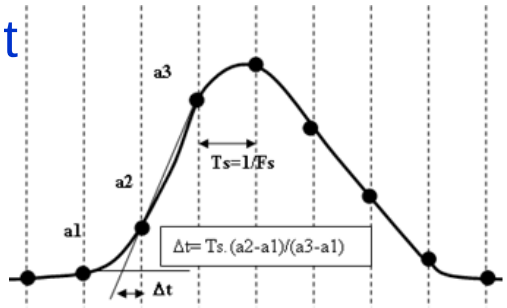
Real time synchronous & asynchronous system

Readout principles

- Signals are continuously pre-amplified, shaped, sampled at 20-30 MHz and kept in a circular analog memory
  → Deep enough to sustain 16 µs trigger latency



- At each trigger 4 - 6 corresponding samples are readout and digitized
  → Readout does not disturb sampling



Courtesy: E. Delagnes

- Retained samples are digitally processed
  → Common noise subtraction
  → Zero suppression
  → Measure charge and time

Better immunity to common noise sources

Timing precision better than sampling period

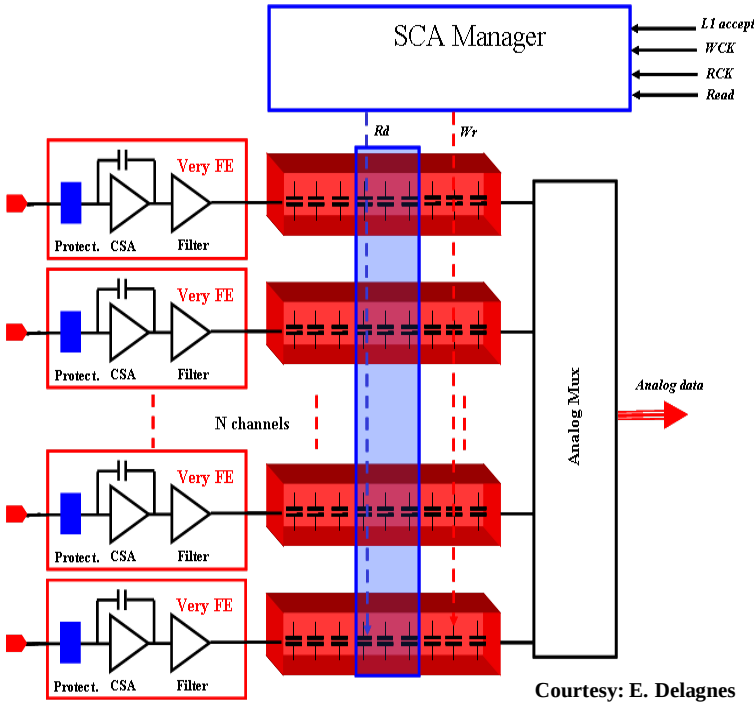
Oscilloscope-like operation

Data volume reduction by a factor of 70

DREAM

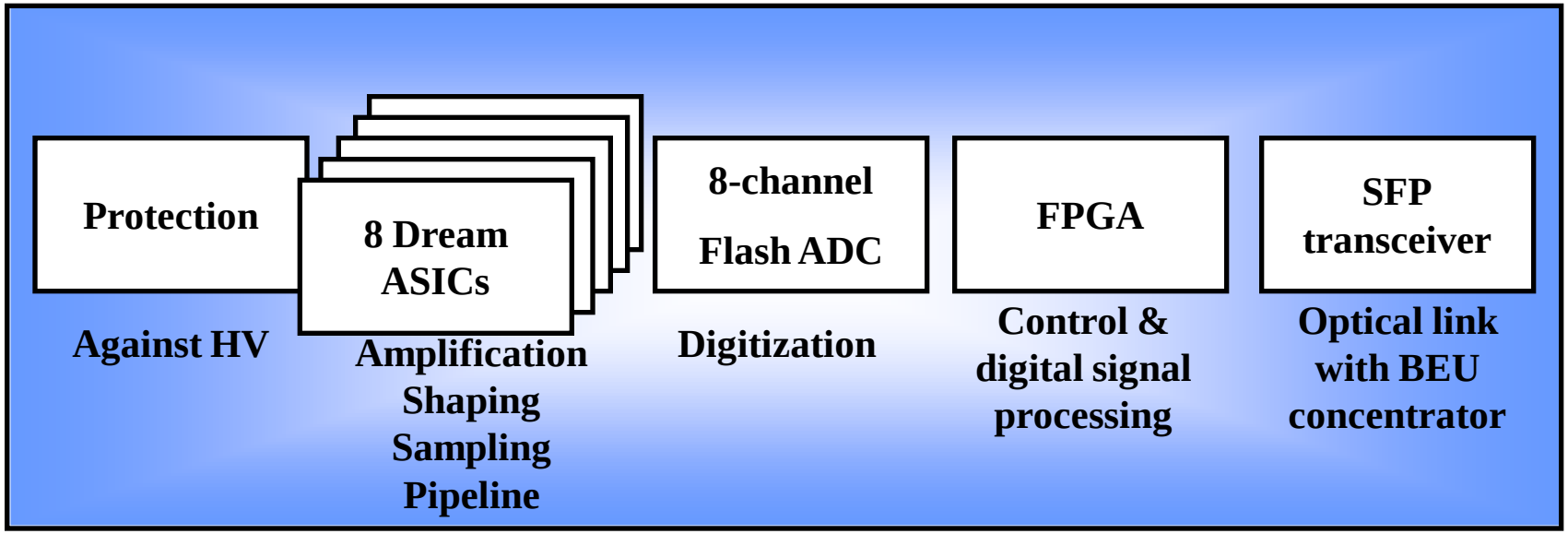
Dead-timeless **R**ead-out **E**lectronics **A**SIC for **M**icromegas

- Characteristics
  - → 64 channels
  - → 4 gain ranges: 60 fC, 120 fC, 240 fC, 1 pC
  - → 16 programmable peaking times: from 50 ns à 1 µs
  - → Sampling rate: 1- 50 MHz
  - → 512-cell deep analog memory per channel
    - Trigger pipeline of 16 µs
  - → Readout rate: 20 (40) MHz
  - → 140-pin 0.4 mm package
    - Small 17 mm x 17 mm footprint
- Versatile chip
  - → Adapted for different detector types
  - → Tailored for detectors with high capacitances



Courtesy: E. Delagnes

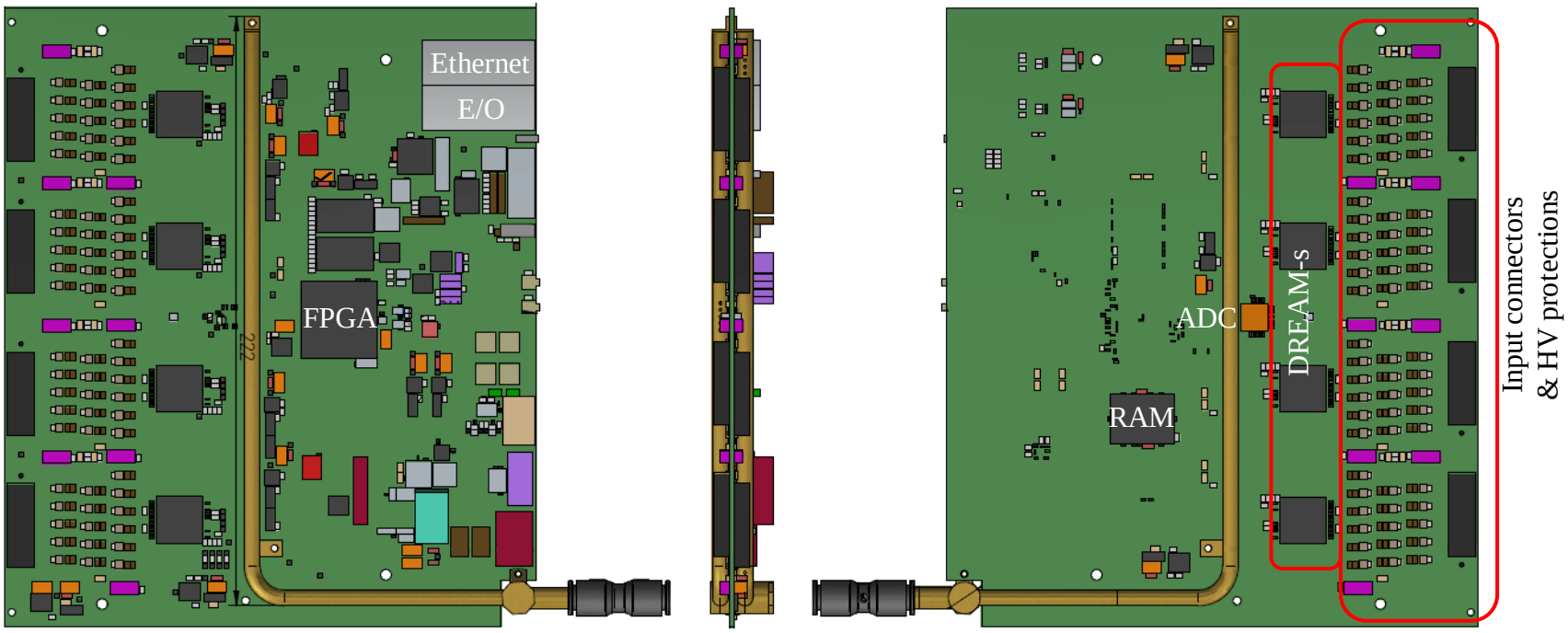
Front-End Unit: FEU



- Mixed digital-analog design under development
  - → 233 mm x 200 mm PCB
  - → 8 Dreams: 4 on each side
  - → Analog Device AD9222 8-channel 40 MHz Flash ADC
  - → Xilinx Virtex-6 FPGA
  - → 2.5 Gbit/s optical link with BEU (Back-End Unit): Trigger / DAQ system
    - or Ethernet for test bench activities

Front-End Unit: FEU

- Automatically generated image from electronics CAD
  - → 233 mm x 200 mm PCB
  - → 512 channels
  - → Pressurized air cooling



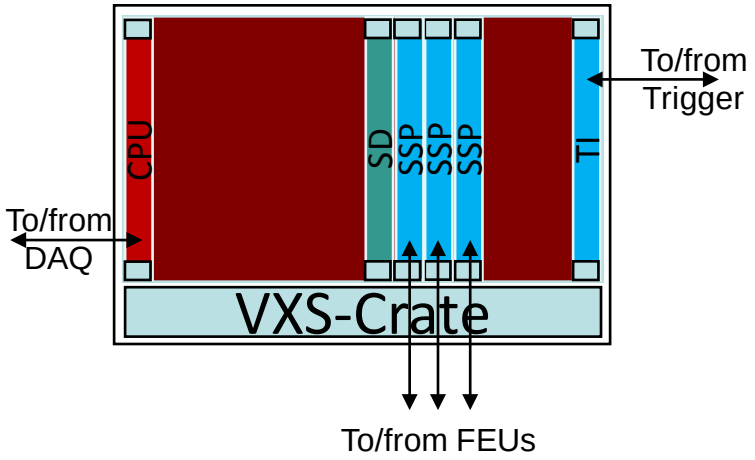
Back-End Unit: BEU

- Single 6U VXS crate

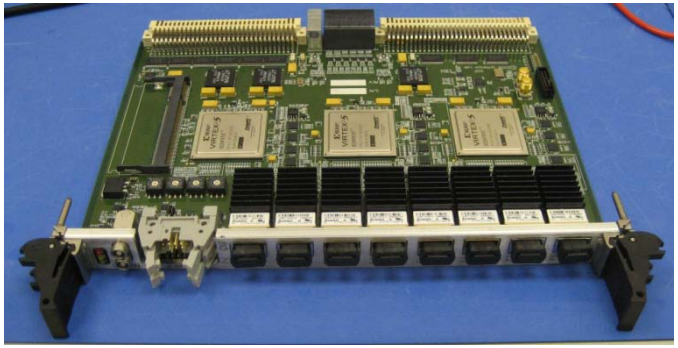
- Trigger Interface
  → Distribution of system clock & trigger signals
  - Synchronous, <1ns accuracy
  - Over VXS and optical links

- DAQ interface
  → Event builder and slow control links
  - Over VME and Ethernet

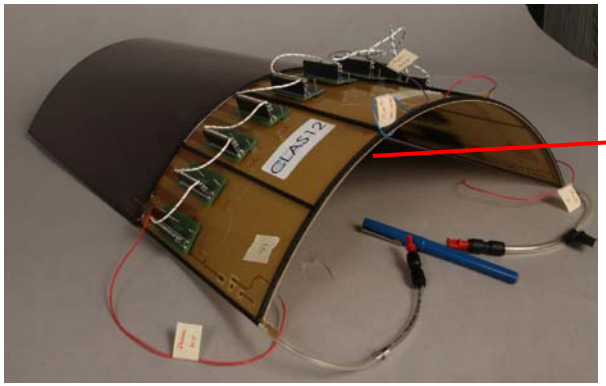
- Adaptation of JLAB developments
  → Firmware and software

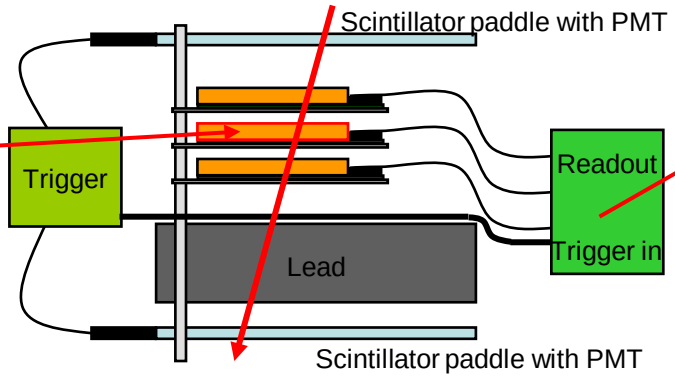


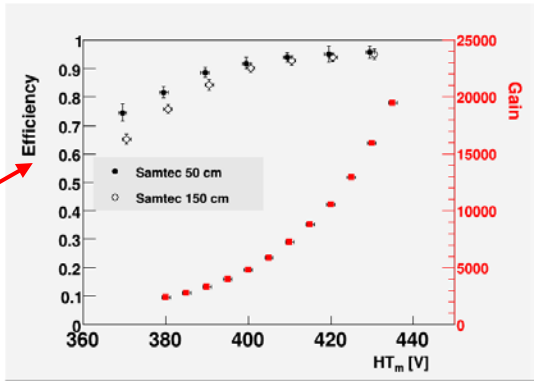
SSP: sub-system processor



Tests with cosmic rays







- Validate & characterize detectors
  - → R&D and production
    - ~30 detectors to produce
- Validate off-detector electronics
  - → Impact of cable length

- Based on current tests S/N of ~35 is expected

Summary

- Challenges
  - → Curved large detectors
  - → 5T magnetic field
  - → High background rate
  - → Off-detector frontend electronics 1.5m away
- Pre-production detector prototypes under tests
  - → Cosmic rays
- New read-out ASIC Dream developed and validated
  - → Ongoing series production run
- Pre-series production of micro-coaxial cable assemblies underway
- Frontend boards under prototyping
- Large scale tests of entire system from 2014
- Commissioning and installation in fall 2014

First tracks expected in 2015

Le mot (pathétique) de la fin

For a society to have a chance to progress

→ parents must have the possibility to study cosmic rays

"Cosmic Rays" by Victor F Hess in 1912

Something more to celebrate in 2013

→ youths always and everywhere must have the possibility to read good books

"Treasure Island " by Robert Louis Stevenson

"A Good Book" by Paul Fischer