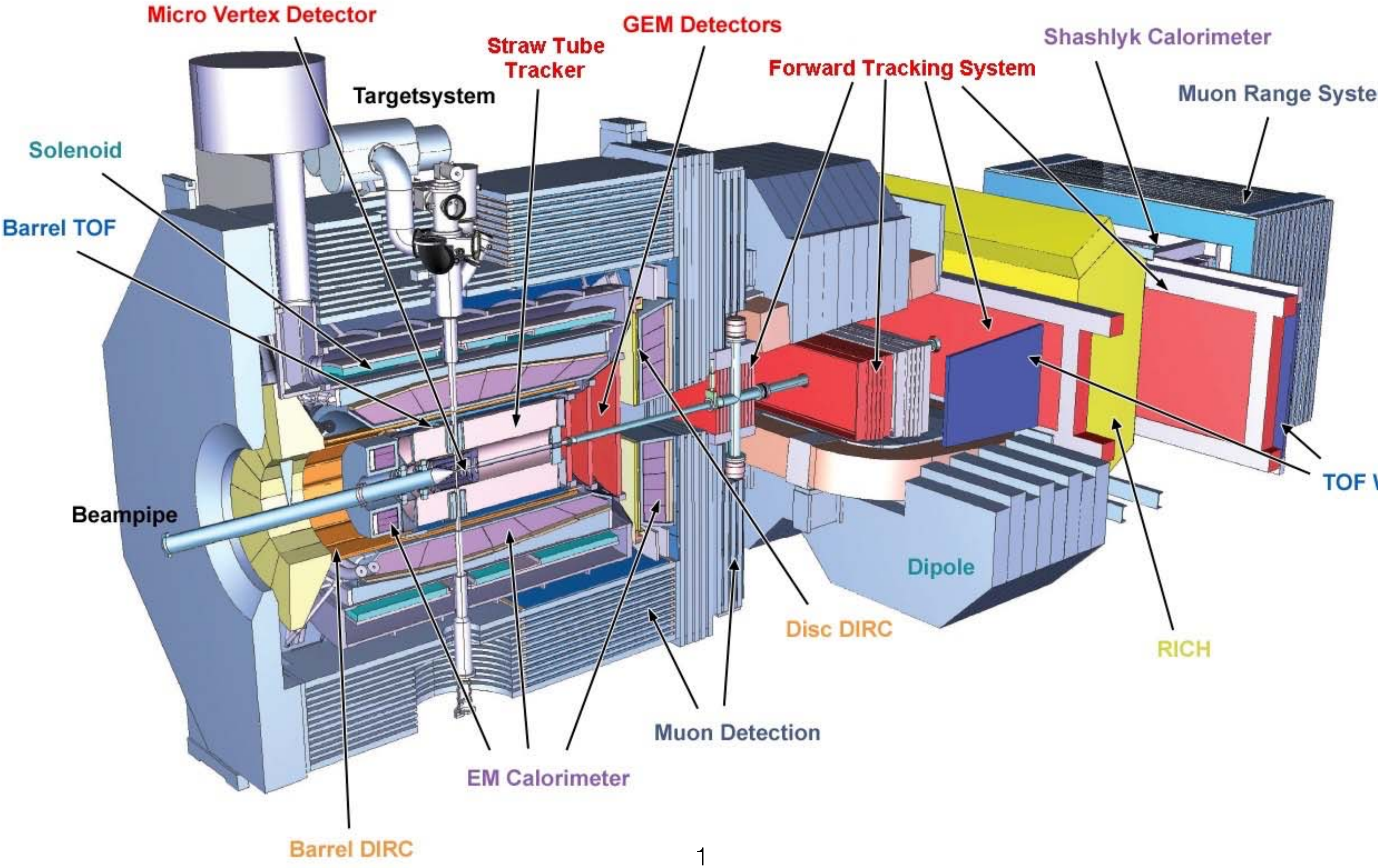
PANDA Detector



PANDA Physics

- HADRON SPECTROSCOPY
  - CHARMONIUM
  - GLUONIC EXCITATIONS
  - OPEN CHARM
  - STRANGE AND CHARMED BARYONS
- NUCLEON STRUCTURE
  - GENERALIZED DISTRIBUTION AMPLITUDES (GDA)
  - DRELL-YAN
  - ELECTROMAGNETIC FORM FACTORS
- HYPERNUCLEAR PHYSICS
- HADRONS IN THE NUCLEAR MEDIUM

FAIR/PANDA/Physics Book i

Physics Performance Report for:

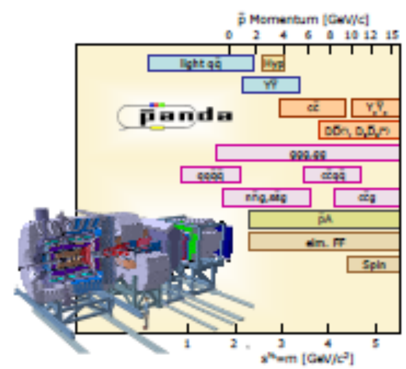
$\overline{\text{P}}$ANDA

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

$\overline{\text{P}}$ANDA Collaboration

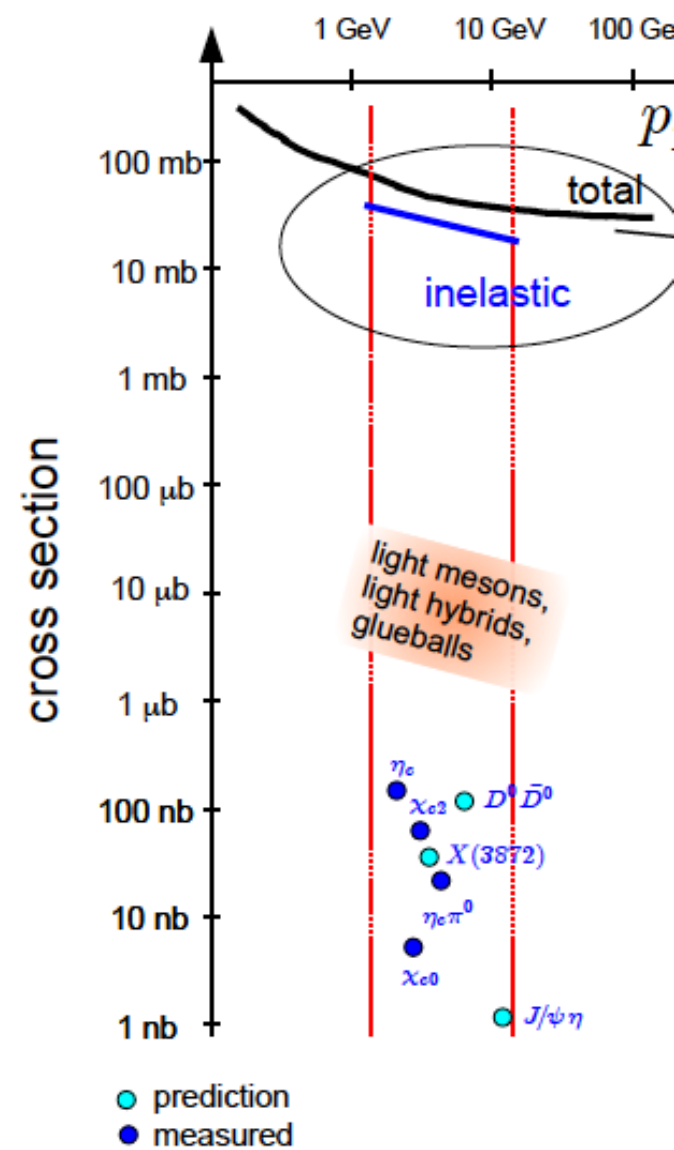
To study fundamental questions of hadron and nuclear physics in interactions of antiprotons with nucleons and nuclei, the universal $\overline{\text{P}}$ANDA detector will be build. Gluonic excitations, the physics of strange and charm quarks and nucleon structure studies will be performed with unprecedented accuracy thereby allowing high-precision tests of the strong interaction. The proposed $\overline{\text{P}}$ANDA detector is a state-of-the-art internal target detector at the HESR at FAIR allowing the detection and identification of neutral and charged particles generated within the relevant angular and energy range.
This report presents a summary of the physics accessible at $\overline{\text{P}}$ANDA and what performance can be expected.



ArXiV:0903.3905

Panda Physics, Data Acquisition and Event Filtering

- Problem: finding the needle in the haystack
- total inelastic cross section
  - 50 mb
- Interesting physics
  - most channels < 100 nb
- $2x10^6$ interactions /s
- Data rate after FEE reduction: 200 GBytes/s
  - 17 PBytes/day
- Goal for online event filtering:
  - reduce “background” by factor of 1000



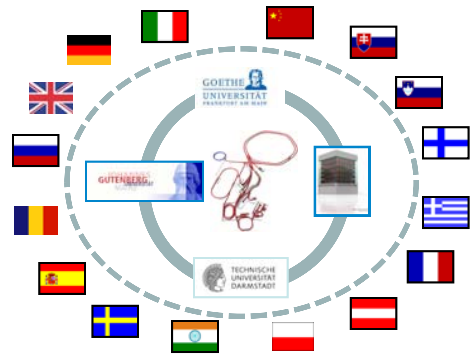
FAIR Tier 0 Data Center

Estimated total for full FAIR

FAIR Tier 0

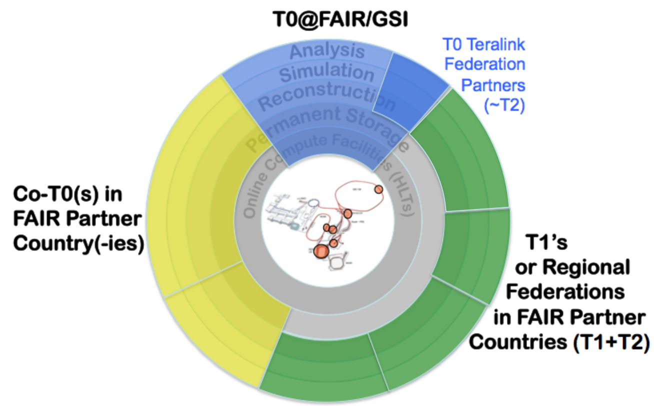
- 300.000 CPU-cores
- 35 PByte/year Online-Storage (HDD)
- 30 Pbyte/year Permanent-Storage (Tape)

Comparable resources in FAIR partner countries

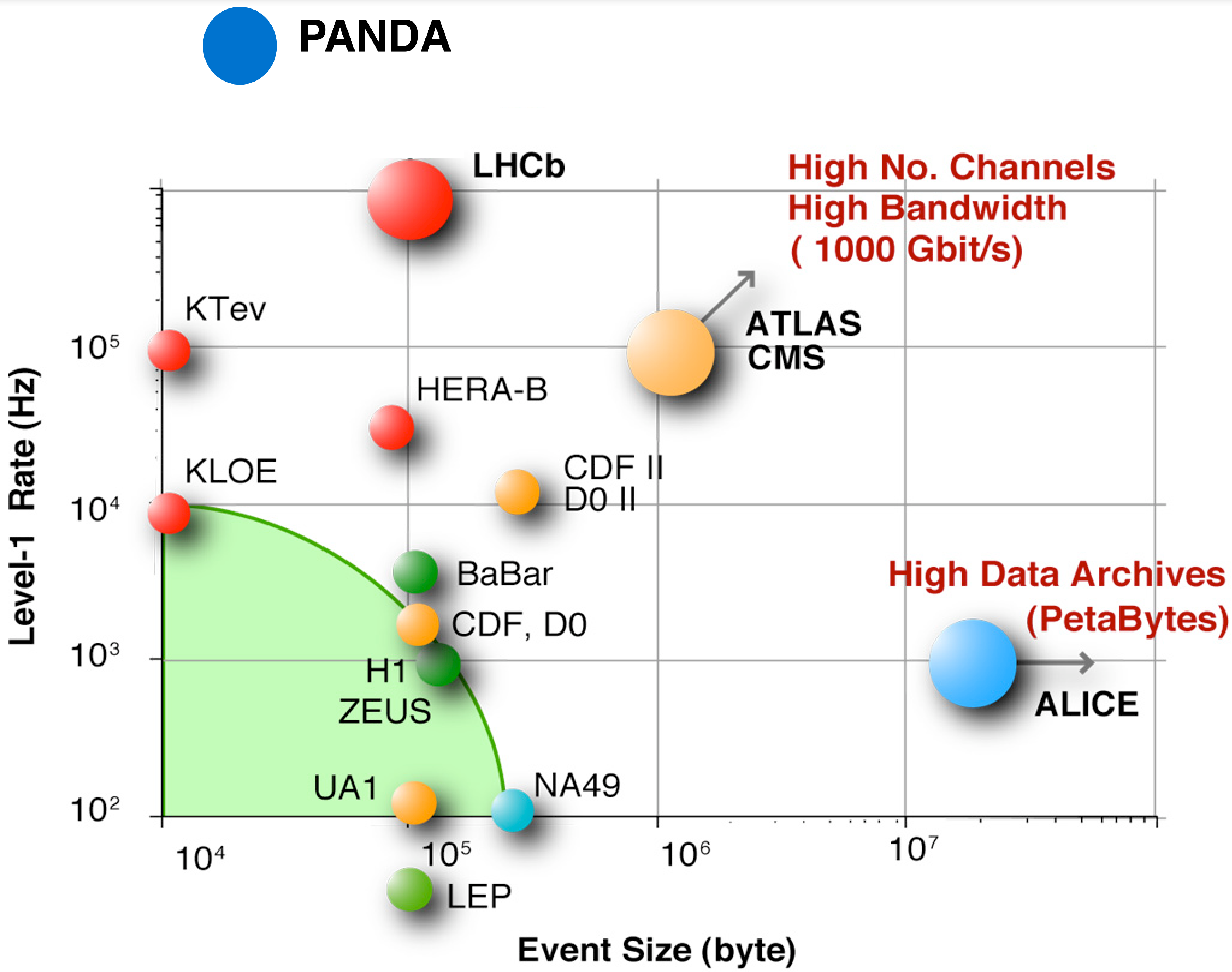


Key Points

- Few big, highly efficient data centers
- Further partner connected via regional federations

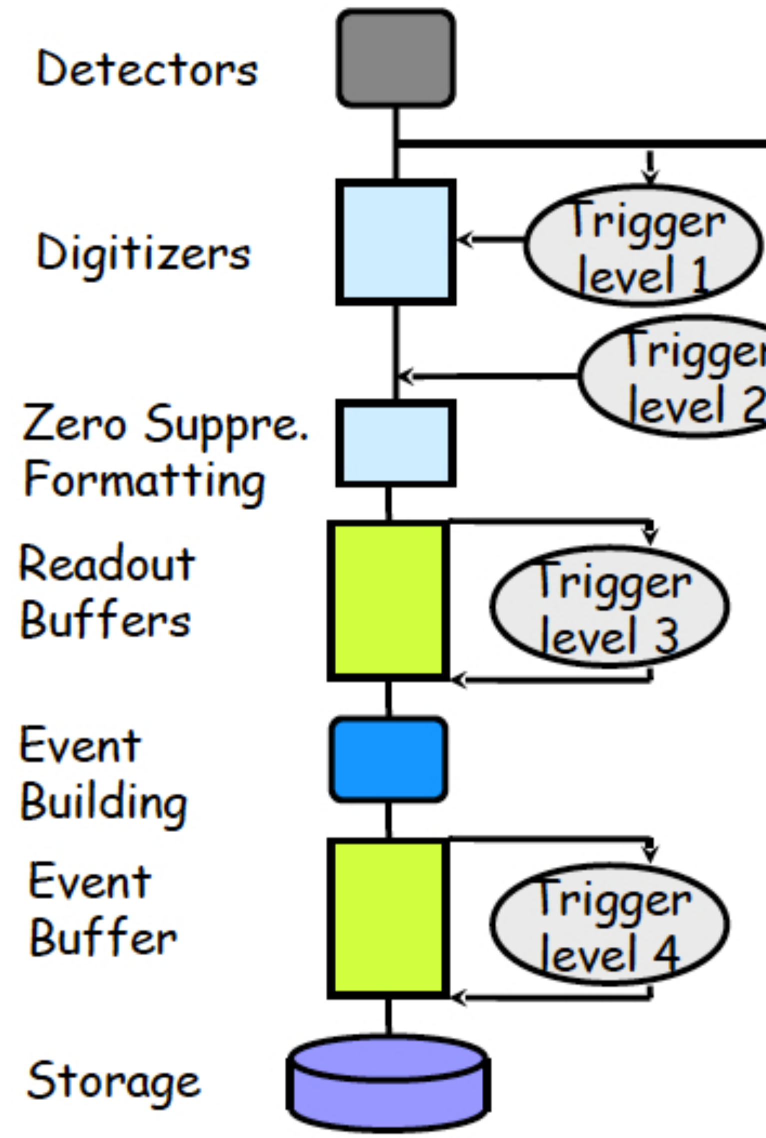


The PANDA DAQ Challenge



Conventional Approach

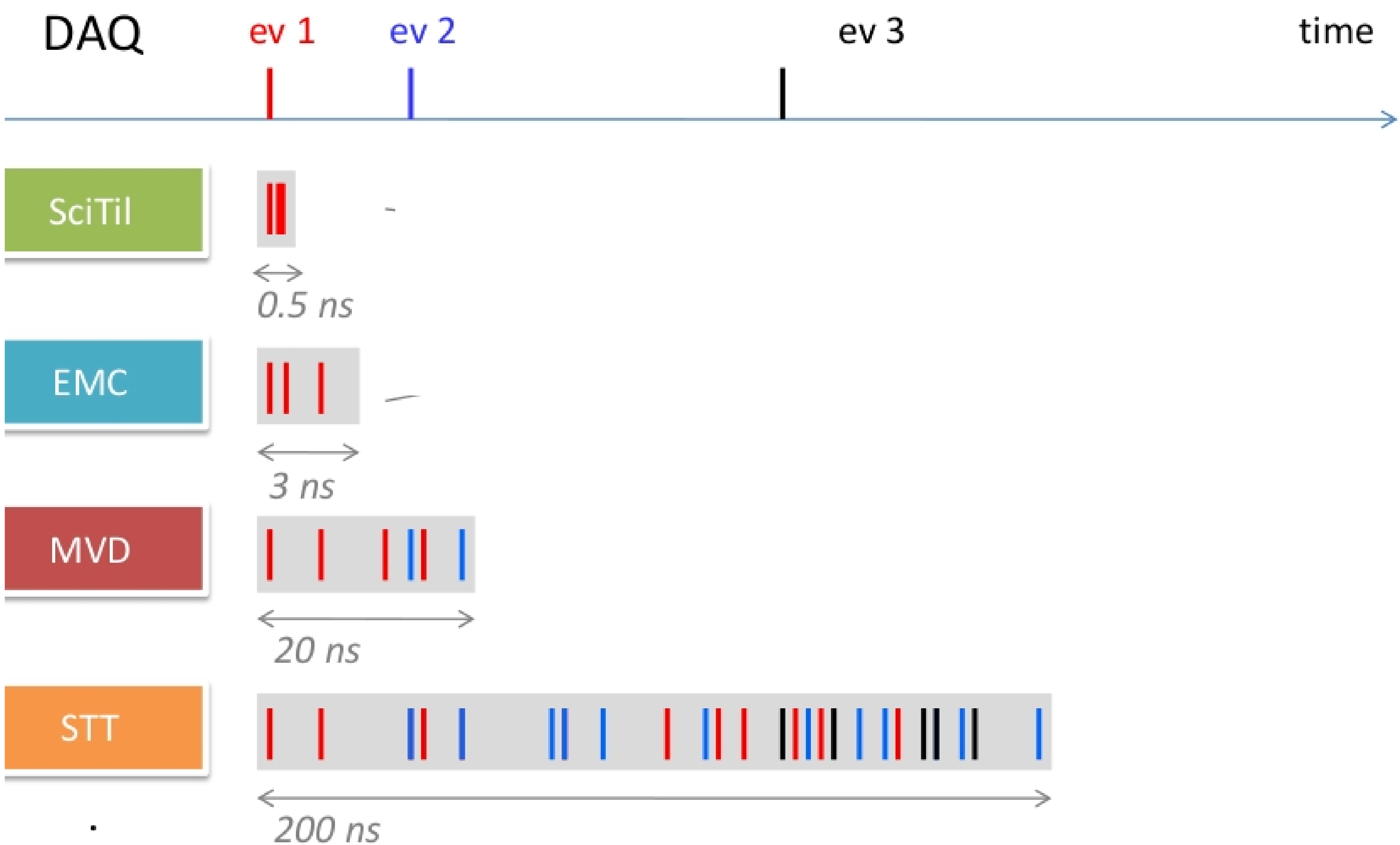
- Multi-level hardware trigger
  - Buffering at each level until trigger decisions are taken
- Works well, if physics provides clear and simple trigger signatures
  - **ATLAS / CMS** :
    - missing Et, high pt muons, jets, etc
- For some experiments, there are no such simple selection criteria
  - **LHCb**: look for B decays (secondary vertices)
  - **PANDA**: exclusive kinematic reconstruction of complete events (all reaction products measured)



PANDA Approach

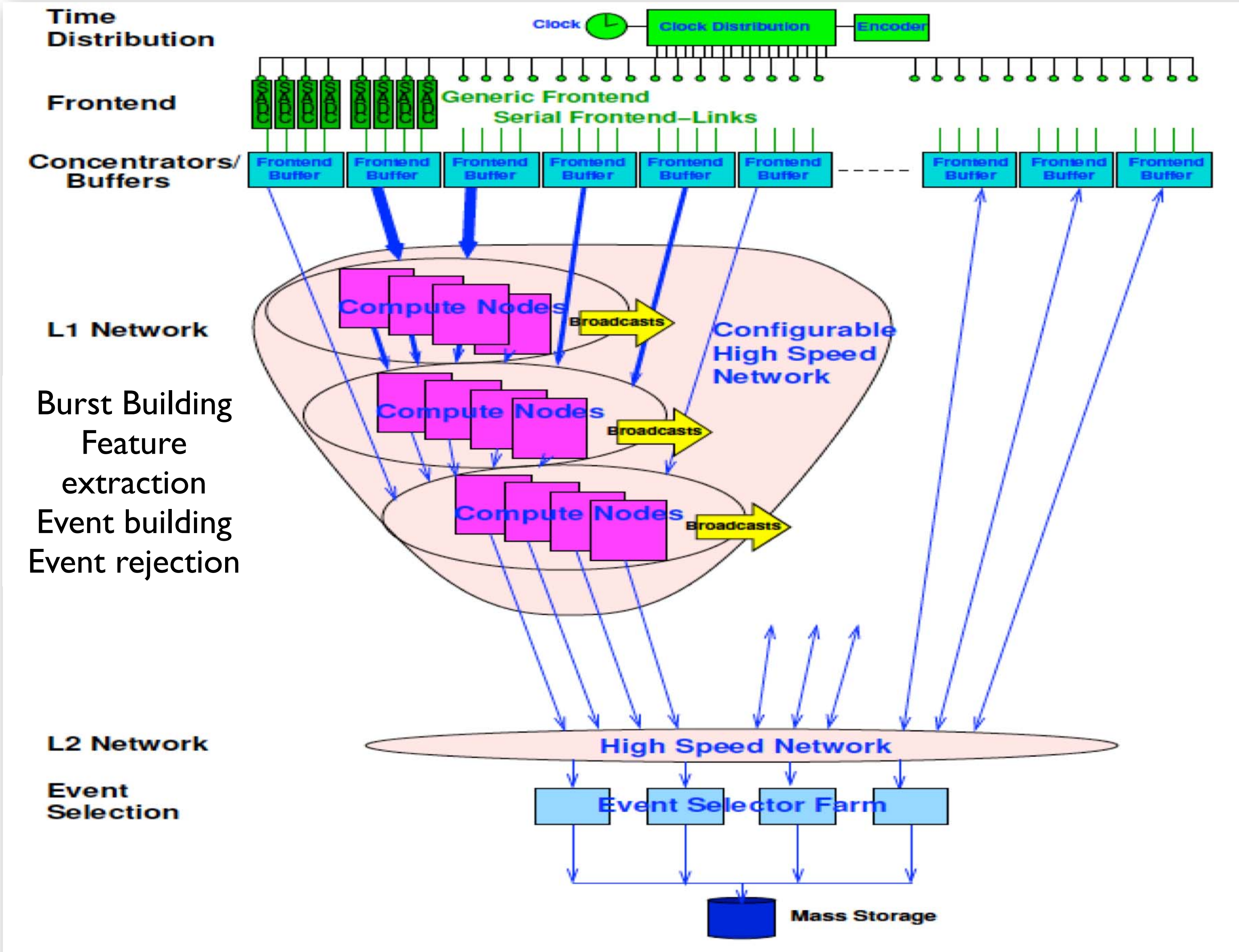
- Freely streaming data :“Trigger - less”
  - No hardware triggers
    - However, there will be event filtering, we do not record everything !!
- Autonomous FEE, sampling ADCs with local feature extraction
- Time-stamping (SODA)
  - Data fragments can be correlated for event building
- Caveat: the high-rate capability implies overlapping events !!!
  - average time between two events can be smaller than typical detector tim scales
  - This “pile-up” has to be treated and disentangled
  - Real-time event selection in this environment is very challenging and requires a lot of studies

Overlapping Events (Time-based simulations)



Challenges

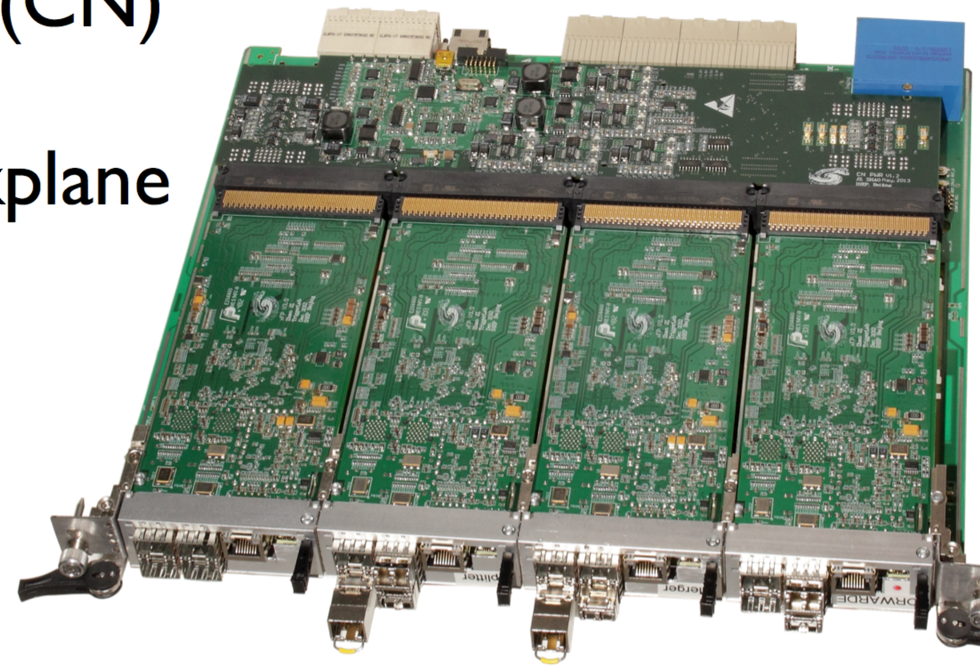
- How much can we reduce the primary data rate ?
  - Software trigger group (principal physics simulations)
    - Answer: maybe up to factor 1000, some loss of efficiency
- Caveat: event based estimate, but overlapping data @ 20 MHz
  - A priori, there are no “events”, there is just a stream of “data” from each sub-system
  - Worst case: if we cannot assemble events online, we have to store everything, because we cannot reject anything !
    - 200 GB/s -> 17 PB/day, compare to 30 PB mass storage/year @ FAIR Tier 0
      - Impossible !
  - Even running at 200 KHz only would exceed the available yearly storage capacity
- The PANDA physics program is not feasible without effective filtering, reducing the event rate by more than 2 orders of magnitude
- This works only if we are able to reconstruct most of the raw data in realtime. Massive challenge !
  - We need full time-based simulation and reconstruction software to judge feasibility and determine required resources (work in progress !!!)

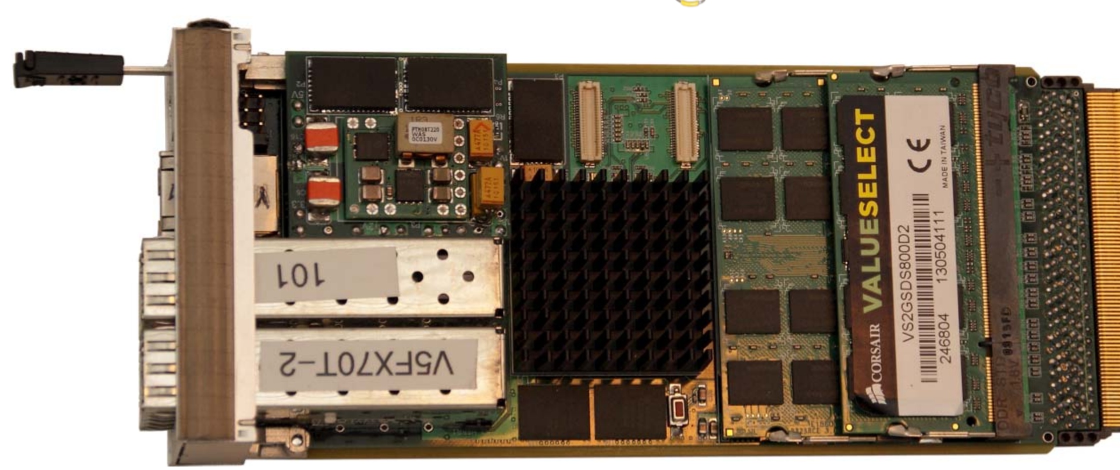


PANDA DAQ / Event Filter

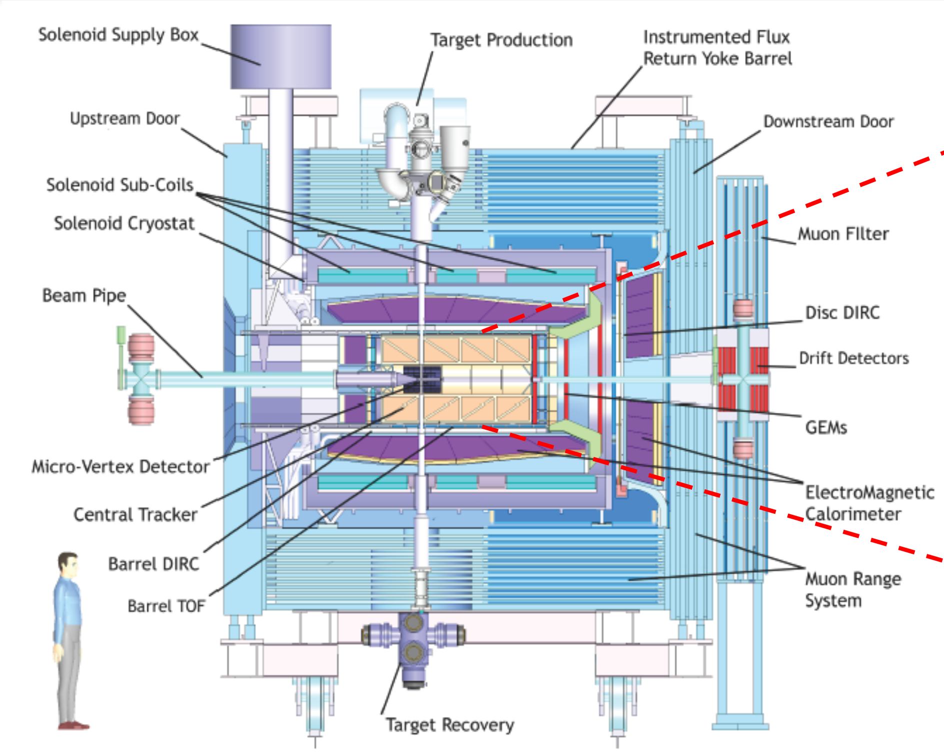
Building Blocks (L1 network)

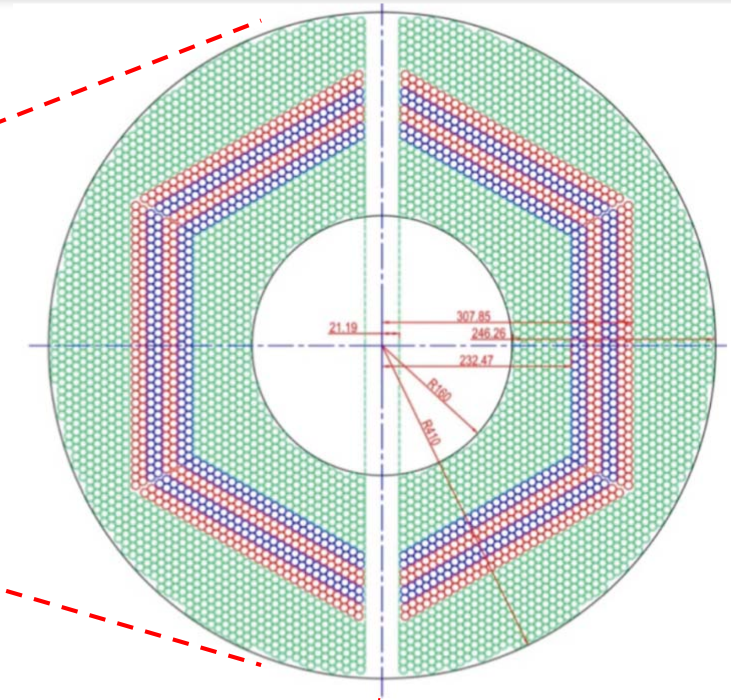
- FPGA based Compute Nodes (CN)
- ATCA standard, full mesh backplane
- 4 + 1 FPGA Virtex5 70FXT
  - Virtex 5 -> Kintex 7
- 16 optical links, GbE
- 18 GBytes RAM

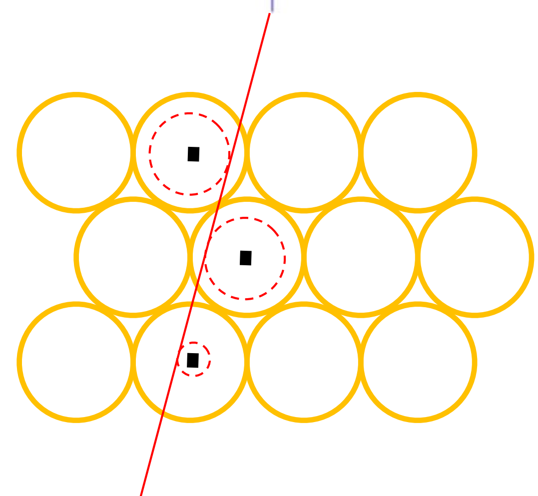




Application Example: Tracking for STT







➢4636 Straw tubes

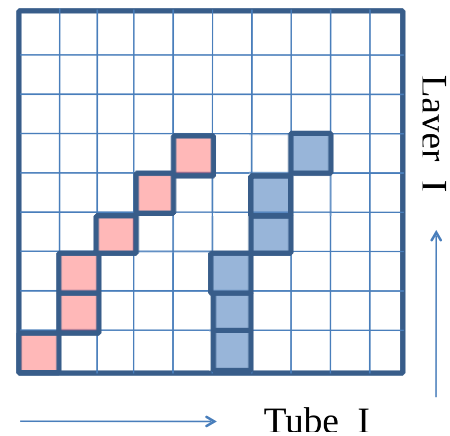
➢23-27 planar layers

- 15-19 axial layers (green) in beam direction
- 4 stereo double-layers for 3D reconstruction, with ±2.89 skew angle (blue/red)

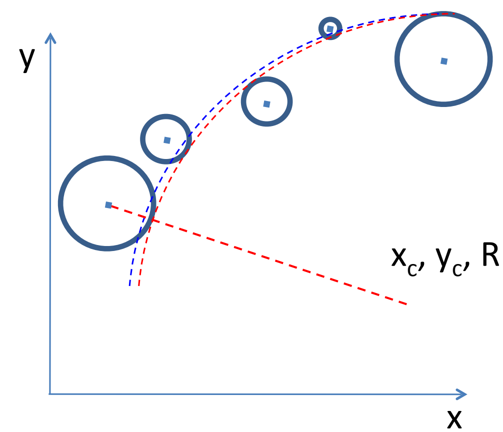
From STT : Wire position + drift time

Tracking algorithm

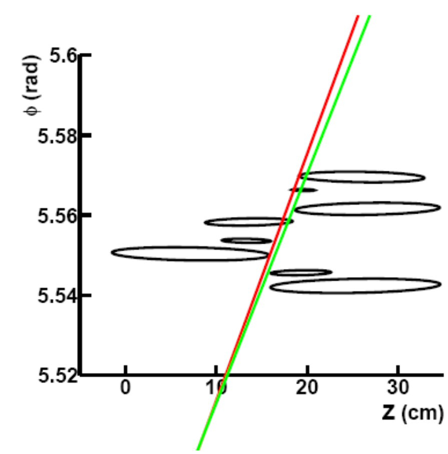
- "Road" search



- Helix parameter determination



  - Transverse momentum
  - Longitudinal momentum

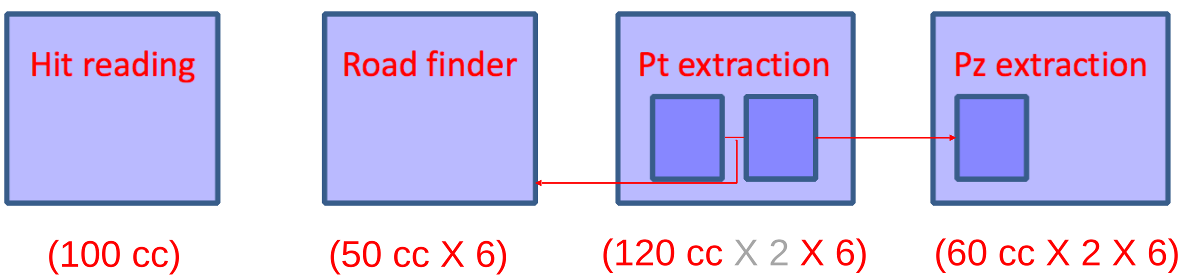


Results (VHDL implementation)

- Momentum resolution 3% @ 1 GeV/c

Device Utilization Summary			
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Flip Flops	25,022	50,560	49%
DCM autocalibration logic	14	25,022	1%
Number of 4 input LUTs	33,120	50,560	65%
DCM autocalibration logic	8	33,120	1%
Number of occupied Slices	21,563	25,280	85%

For one event with 100 hits (6 tracks): 7 μs



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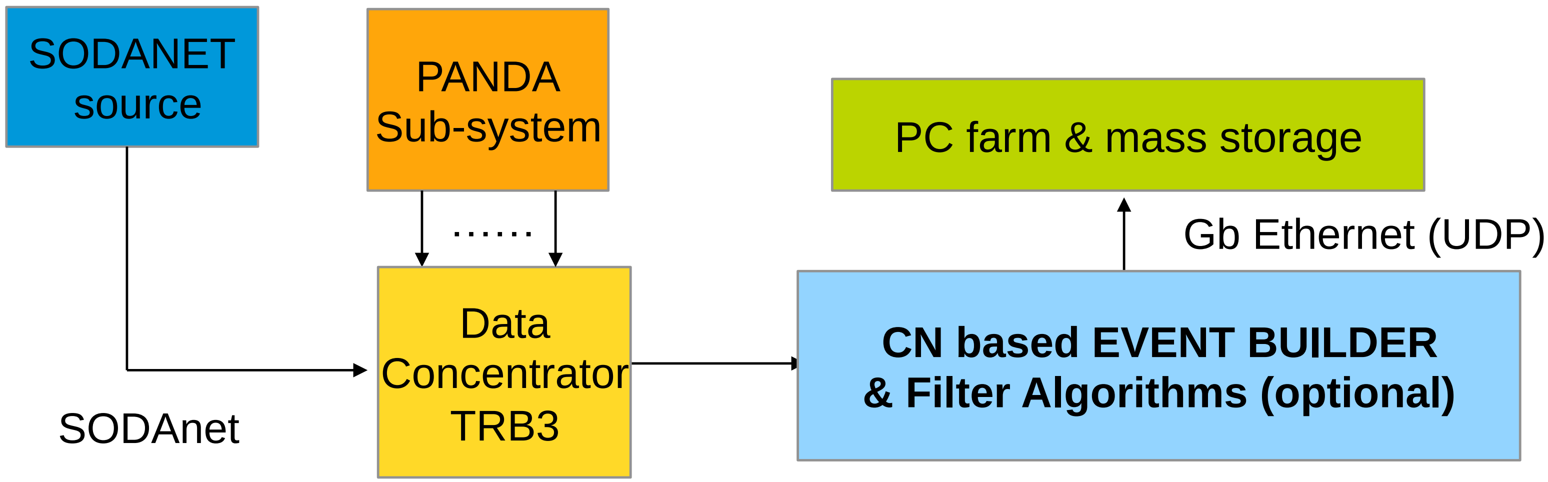
Current Activities

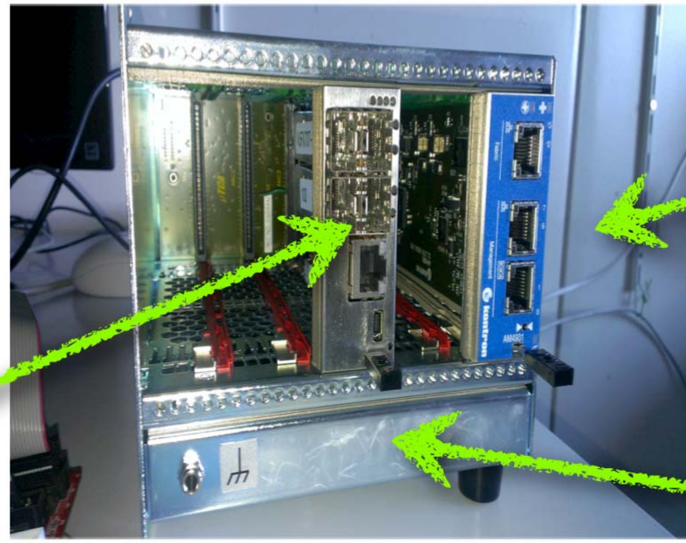
- Hardware
  - Move from Virtex 5 to Kintex 7 architecture
  - Set up toy DAQ system with scaled down architecture for detector prototype tests i realistic DAQ environment
    - Freely streaming, FEE feature extraction, event building, high level feature extractio on FPGA, L2 network processing with small farm for final event selection
  - Time-based simulations for full PANDA setup and critical benchmark channels
    - Determine realistic rejection rates at high luminosity
    - Define required bandwidth, computing resources and partitioning for L1/L2 networks
- Crucial input for DAQ TDR

Initial Setup (Toy DAQ) for Test Beams



- uTCA shelf with 1 to 4 xFP cards
- Supports up to 9 optical connections to data concentrators
  - Basic configuration with single xFP: 4 optical inputs
  - Extended configuration with 3 xFP for data input and 1 xFP for event building
    - Tracking, EMC shower handling, filtering etc. as an option
- Output rate limited by Gb Ethernet : (< 120 GB / s)
- Basic slow control functionality via Ethernet/EPICS (start/stop DAQ, file handling, event counters etc.)

Toy DAQ Hardware



Shelf manager (networked)

Compute Node xFP module

uTCA shelf

- xFP module (building block of ATCA Compute Node)
  - XILINX Virtex 5 70FXT FPGA
  - 4 GB DDR2 Ram
  - 4 optical links (up to 6.5 Gb/s)
  - Gbit Ethernet