



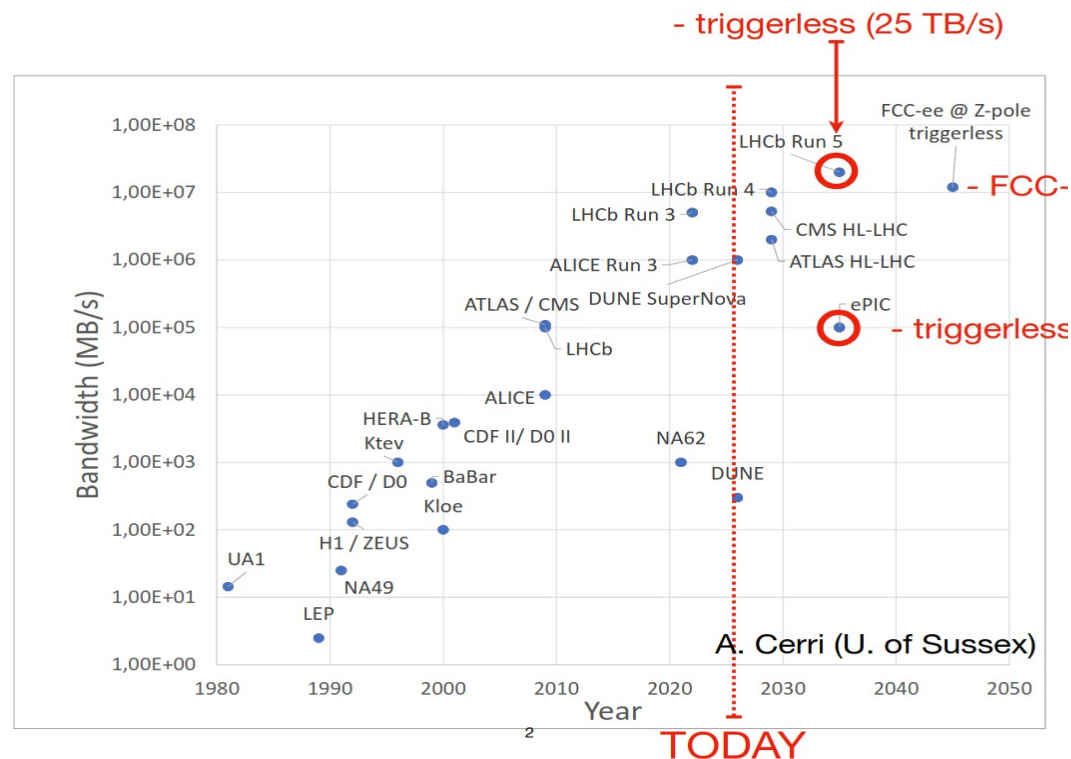
# BASKET+

Triggerless, intelligent DAQ for the BASKET detector at P2  
as a small-scale prototype for future particle detectors

- Modern readout strategies
- The BASKET detector for the P2 experiment at MESA
- Future applications
- H. Le Provost, I. Mandjavidze, M.Vandenbroucke, M.Boonekamp, CEA/IRFU

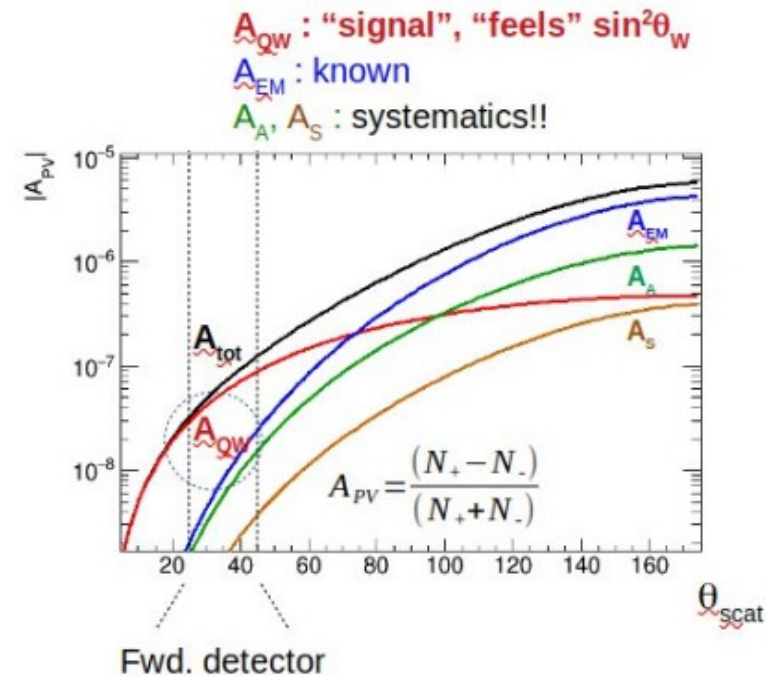
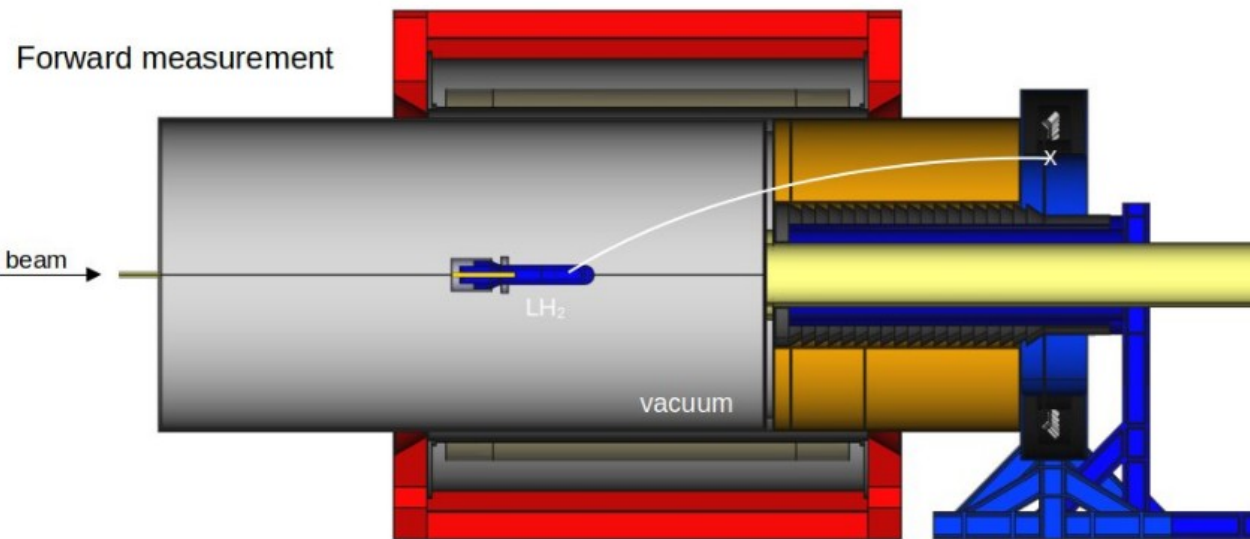
# Read-out demands of modern experiments

- Future hadron- and particle-physics experiments (FAIR@GSI, eIC/ePIC, AMBER, tau/charm factories, LHC/FCC....) expect event rates exceeding that of their predecessors by orders of magnitude, often reaching Terabytes/s
- Managing and interpreting such data volumes requires new strategies
- Trends:
  - On-chip, AI-assisted background rejection, reconstruction, data compression
  - Streaming (triggerless) DAQ
- This proposal aims at testing such ideas in the context of P2@MESA



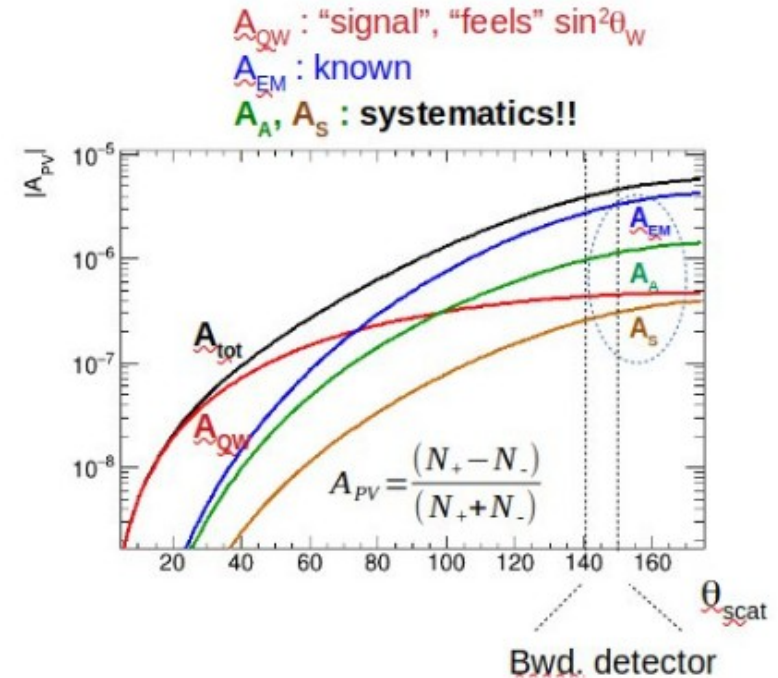
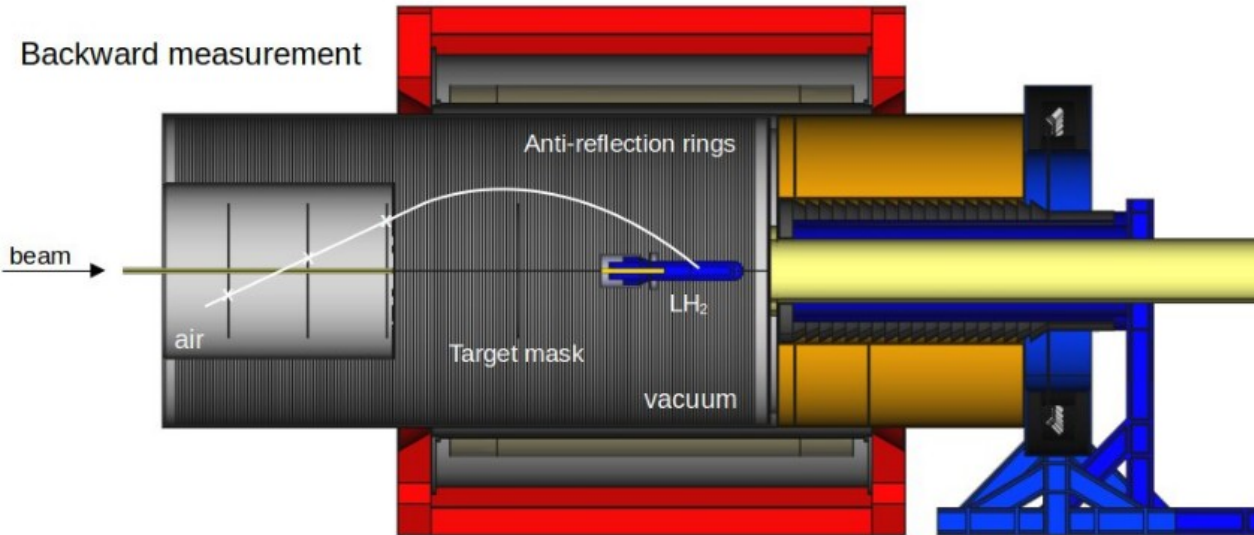
# The P2 experiment at MESA

- Precise determination of  $\sin^2\theta_W$  in parity-violating  $ep$  scattering at low energy
  - $A_{PV} \sim 5 \times 10^{-8}$ , measured to  $\sim 1\%$   $\rightarrow \delta \sin^2\theta_W = 0.14\%$
  - 100 GHz of signal: scattered signal current integrated in  $< 1$  ms time intervals

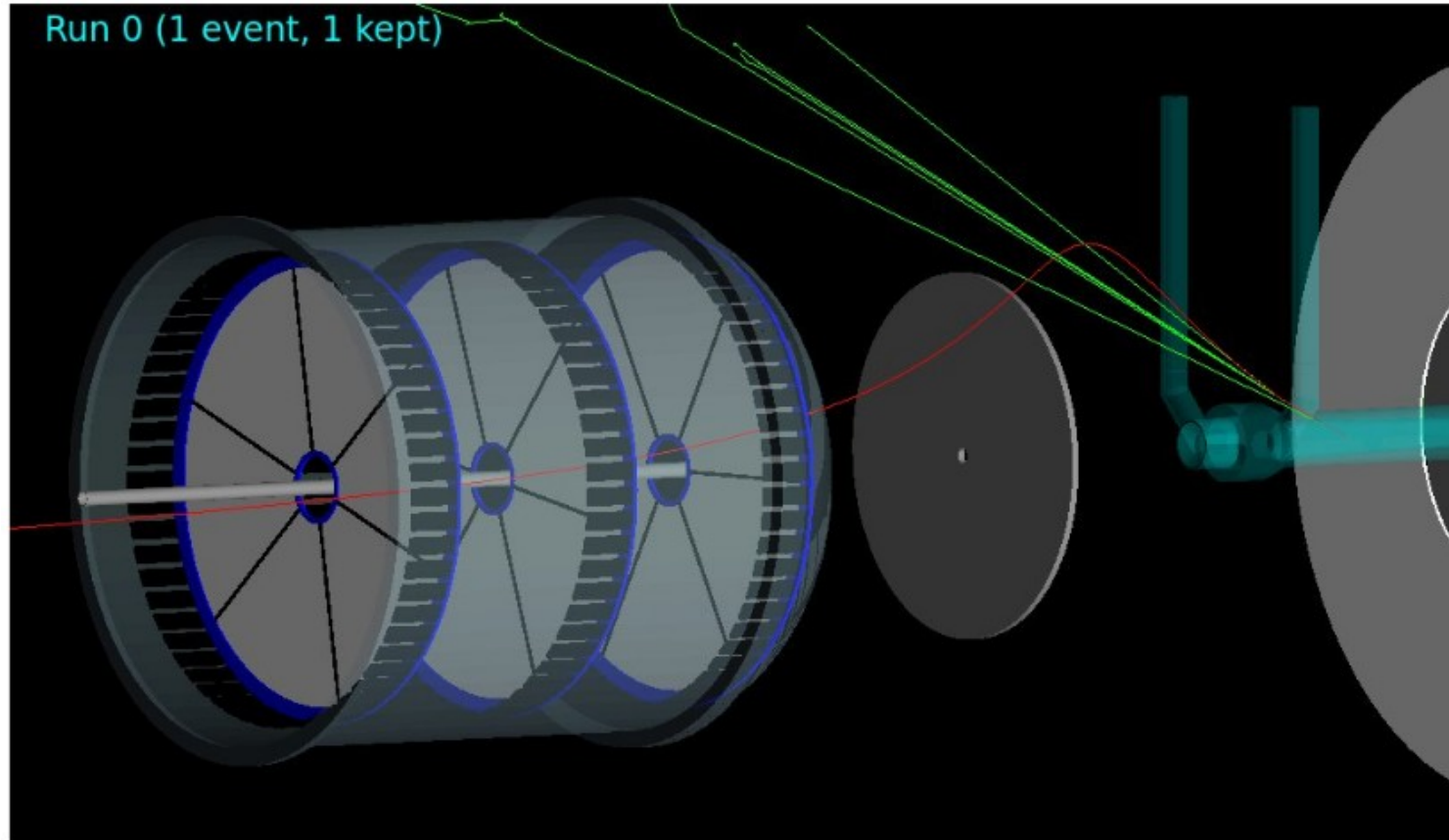


# The BASKET tracking detector for P2

- Complementary measurement at backward angles
  - reduces systematic uncertainties from proton form factors
  - ~100 MHz signal rate : event-by-event track reconstruction



# The BASKET tracking detector for P2



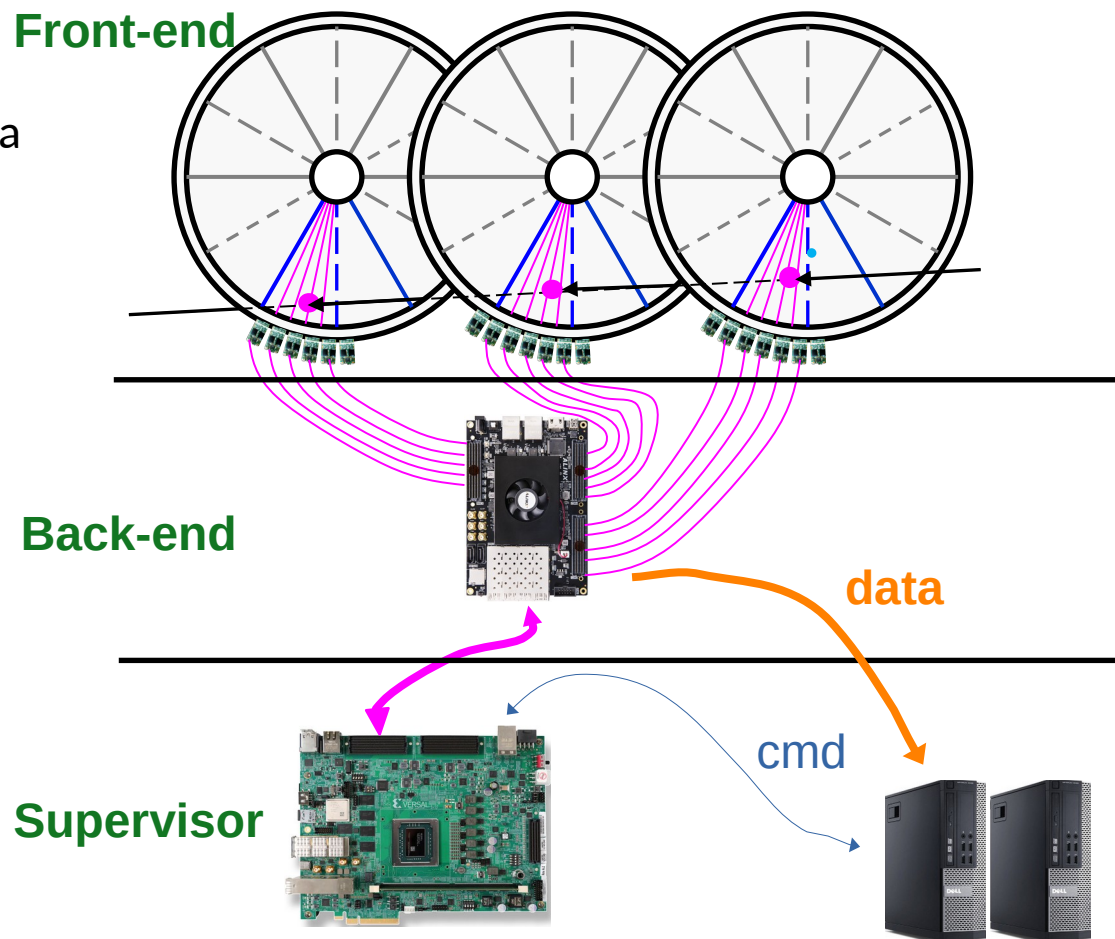
# Readout challenges and strategy

- 100 MHz of BASKET data, for ~2 months of data taking, leads to a raw data volume of about 10 Petabytes : impractical for both storage and offline processing
  - online pattern recognition, track reconstruction, background rejection, and histogramming
  - objective of data compression factor of about ~100
- **Present BASKET readout design** : above strategy implemented only for tracks that traverse the same angular sector in the three successive detector planes
  - Adequate for physics, but limits the readout acceptance
- **BASKET+** : using a high-capacity supervisor board, extend the algorithm to non-aligned sectors
  - Enhanced read-out capacity → enables runs at non-nominal MESA energies
  - Larger acceptance → enhanced physics output

# Readout challenges and strategy

## BASKET

- Accepts tracks within the vision area of a single back-end board
- Back-end:
  - Readout of 3 projective 30° sectors
  - On-line track finding (Space-time criteria)
  - Sends track info to PC : channel triplet and time
- Supervisor:
  - Synchronize backends
  - Clock, cmd, beam state (polarity)

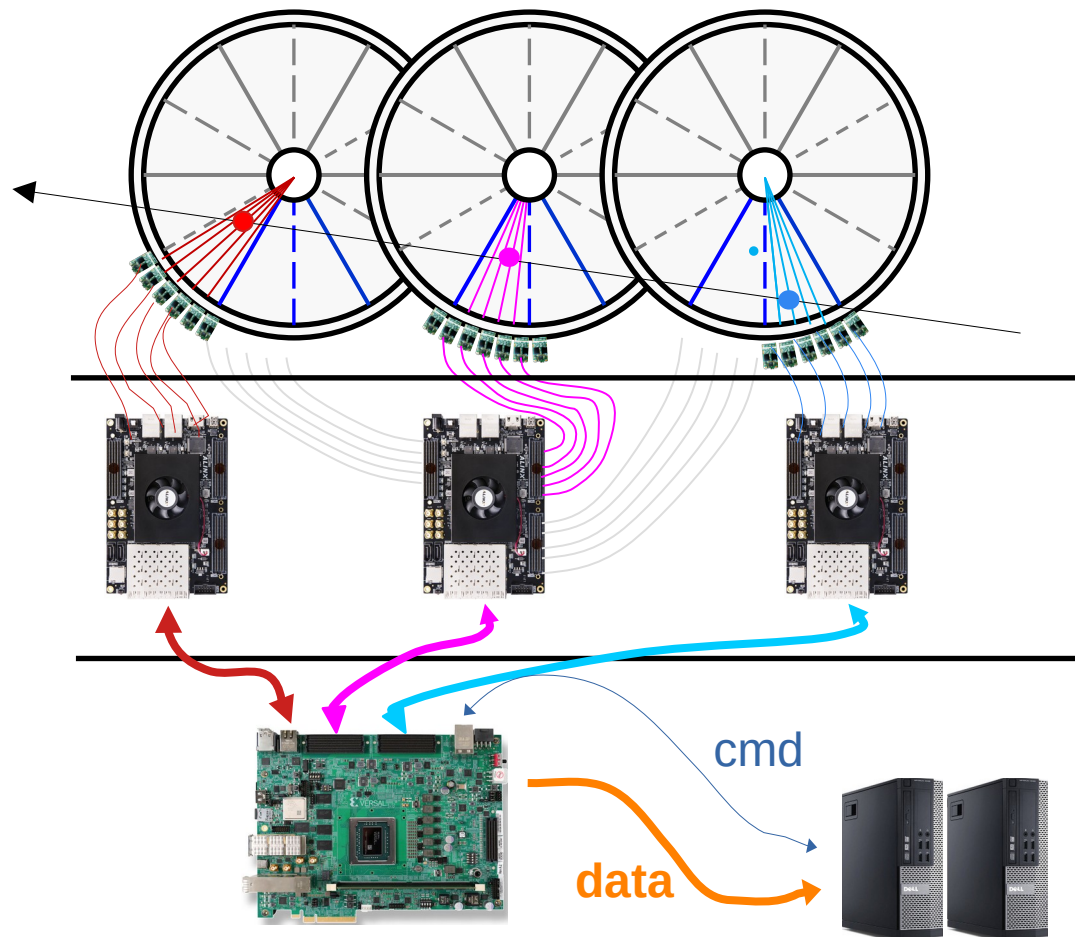




# Readout challenges and strategy

## BASKET+

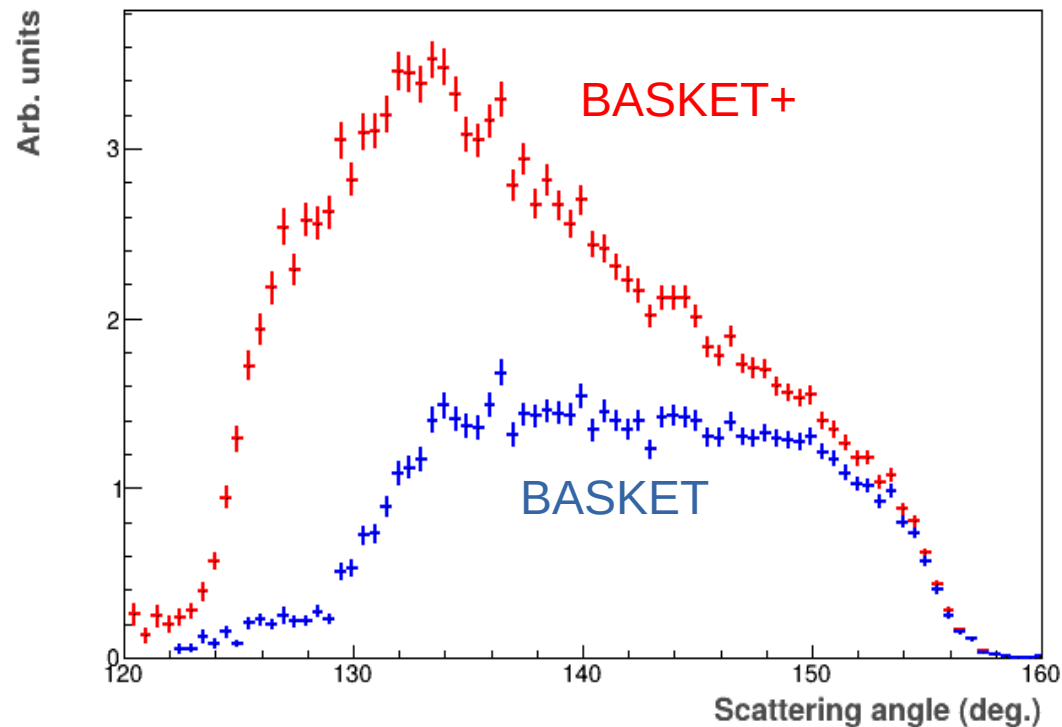
- Tracks span several backend vision areas
- Back-end:
  - Readout of 3 projective 30° sectors
  - Deliver data to supervisor after initial pre-processing
- Supervisor :
  - Synchronize backends
  - Clock, cmd, beam state (polarity)
  - On-line, AI-enhanced track finding and background rejection



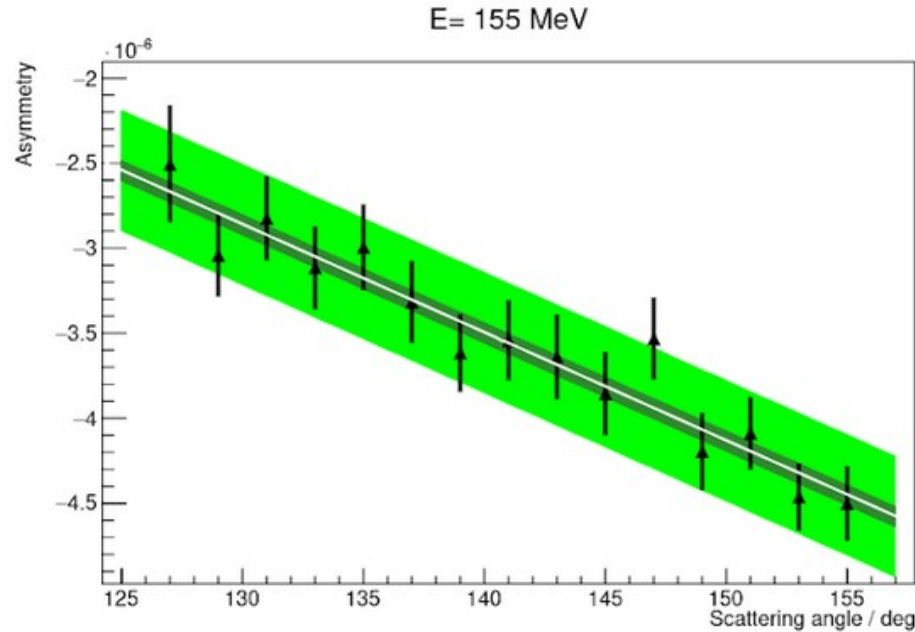


# Impact

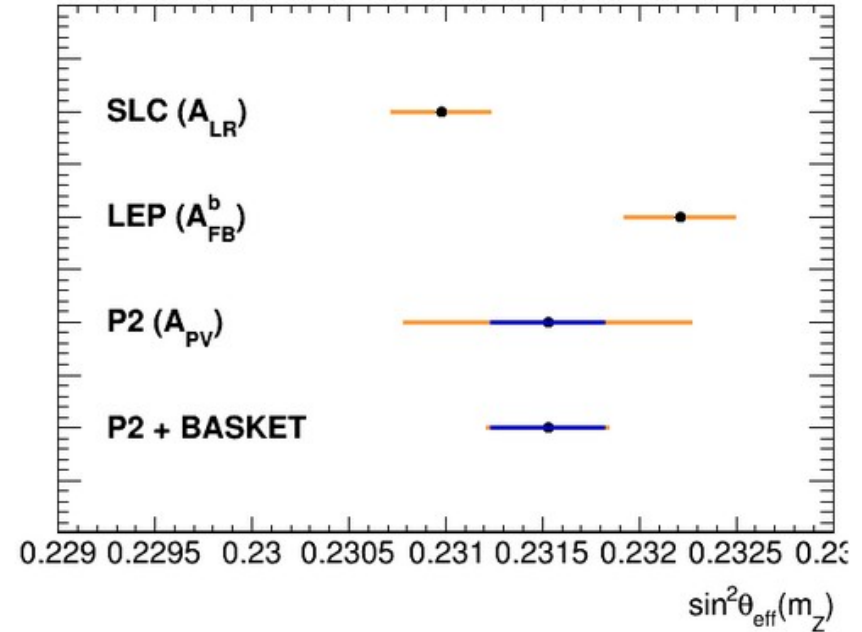
- Physics
  - Enhanced acceptance
  - Readout-rate  $\times \sim 3$
  - better measurement precision and determinations of the physical parameters
- Field
  - Many applications for DAQ at upcoming experiments :
    - GSI/FAIR (CBM and Panda)
    - EIC / ePIC
    - CERN (LHC, Amber; FCC)



# Scientific goal



Form-factor uncertainty in  $A_{PV}$  at backward angles, **without** and **with** BASKET data



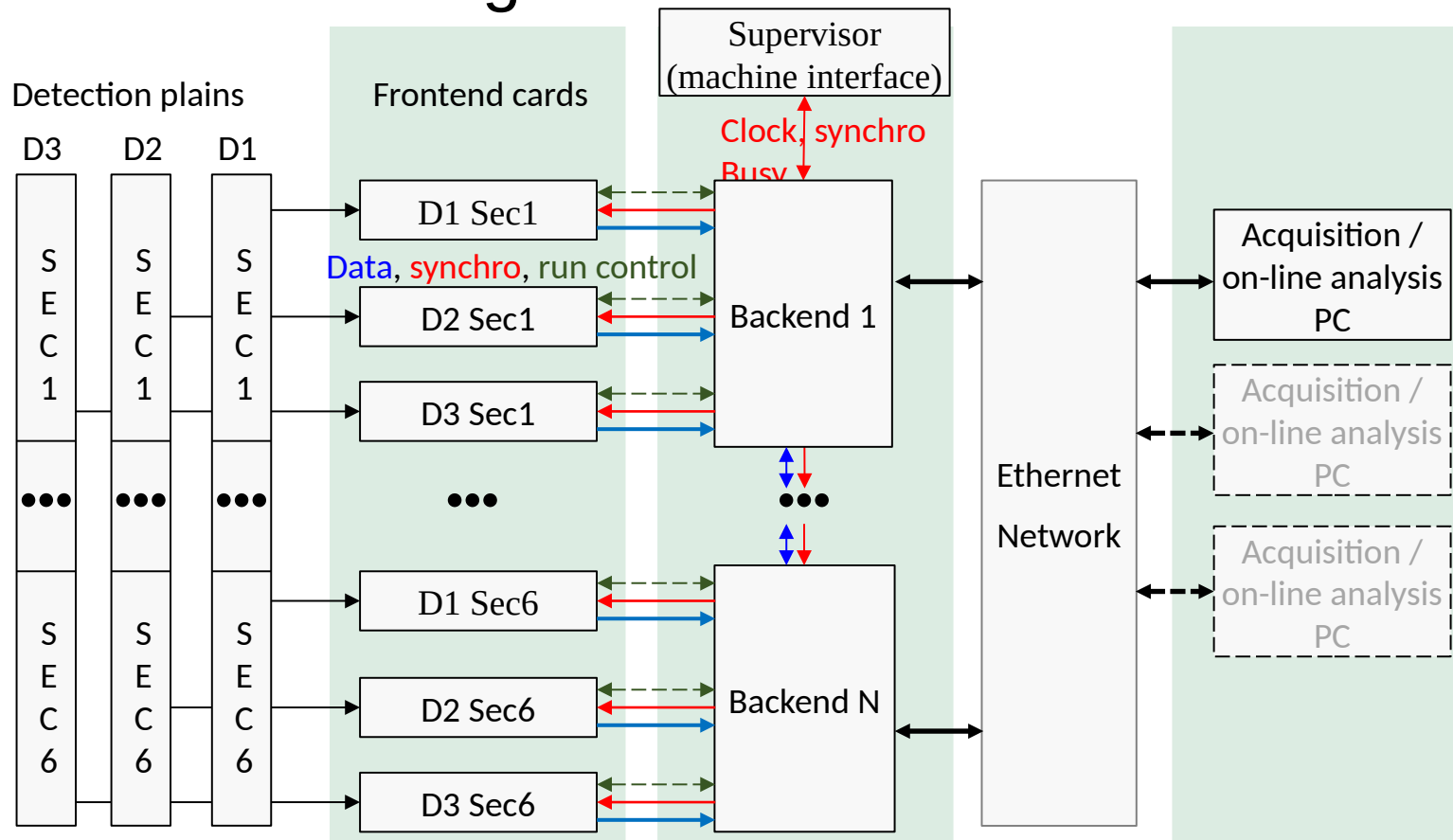
Impact of BASKET data on the determination of  $\sin^2 \theta_W$

# Summary

- Conclusions
    - Modern experiments expect very high rates, and rely on triggerless DAQ + intelligent data processing to manage the corresponding data volumes and ease offline analysis. New strategies are in order
    - BASKET is a high-rate tracking detector designed to measure elastic ep scattering with the P2 detector. BASKET+ is an opportunity to
      - Further enhance the potential of BASKET
      - develop and test ideas and architectures that will benefit the hadron- and particle-physics communities in the mid- and long-terms
  - Request
    - 45 k€ for three AMD boards, including one spare
    - 180 k€ postdoc researcher or computing engineer, three years(DAQ/FPGA expertise)
    - 120 k€ a PhD position for the scientific exploitation of BASKET+
    - 20 k€ travel
- Total 365 k€ direct cost only; 456 k€ including 25% indirect costs.

extra

# A 3-stage readout architecture

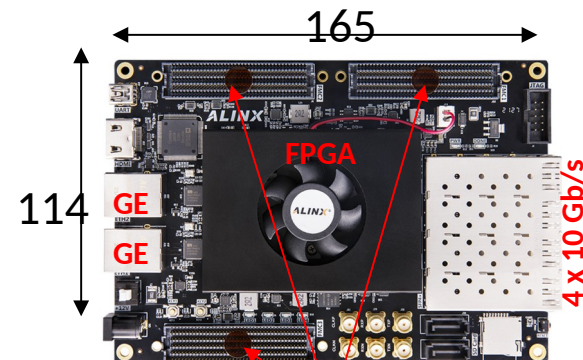
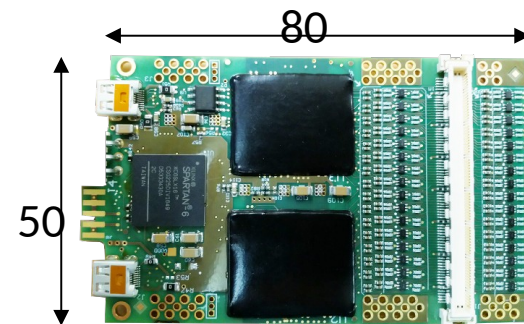


- Potential to perform on-line tracking in hardware

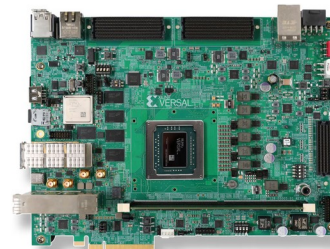
→ A backend treats projective parts of all detectors and transfers only track candidates

# Components of the readout architecture

- Frontend: SRS 128-channel VMM-based hybrid
  - Hosts two VMM3a ASICs (Atlas NSW)
    - Flexible very-frontend with large choice in gain and shaping
    - Streaming and triggered readout
    - 400 Mbit/s link per VMM chip
    - Few ns timing resolution
  - Produced and commercialized by SRS Technology – spinoff from CERN
- Backend: Mid-end AXKU040 development board
  - Hosts Xilinx Kintex UltraScale FPGA - XCKU040
    - ~0.5M flip-flops; 21 Mbit RAM; 2k DSPs; ~500 IO
  - 4 Gbyte DDR4 memory
  - 10 Gbit/s and 1 GE interfaces
  - 3 mezzanine connectors
    - Possibility to aggregate up to 16 frontends
  - Produced and commercialized by Alinx Electronic Limited
- Supervisor: High-end FPGA development kit
  - Tradeoff between logic and AI engine resources
    - e.g. AMD EK-VCK180 board – Logic-enhanced for traditional track finding
    - e.g. AMD EK-VCK190 board – AI-boosted for ML-based track finding

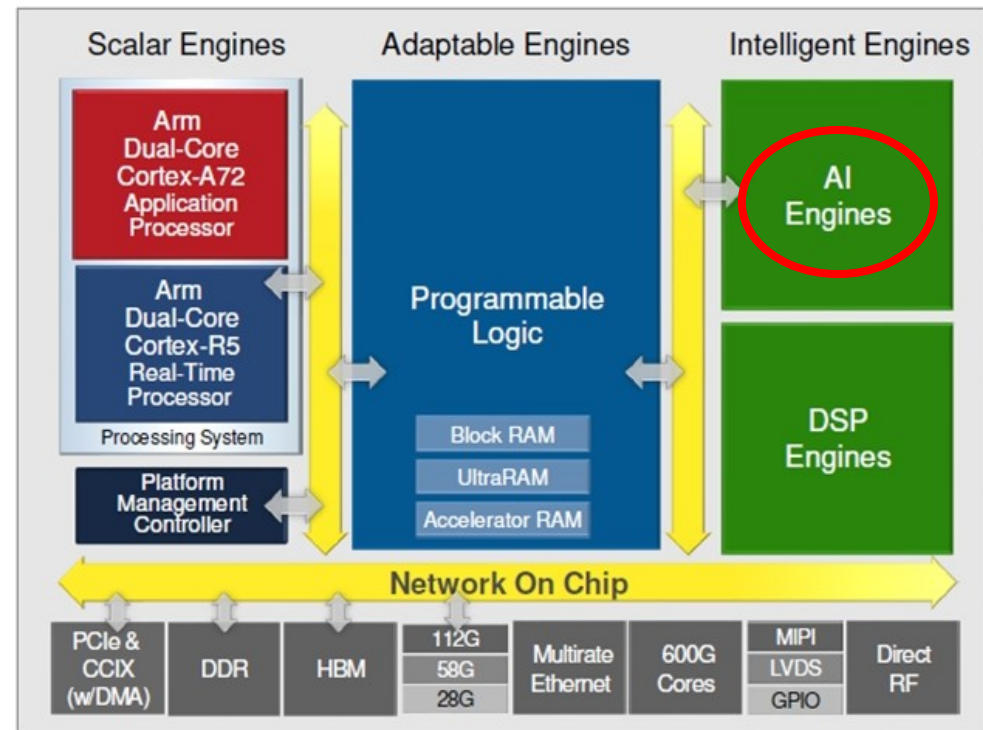


Mezzanine sites



# AMD Supervisor board Block diagram

- Firmware and software R&D : pushing the state of the art
  - High level synthesis approach
  - Use of cutting edge Versal ACAP devices from Xilinx / AMD
    - ACAP - Adaptive compute acceleration platform
  - Online track reconstruction using embedded AI engines



↑↑↑↑↑↑↑ ...  
Back-end data

↓  
PC



- IRFU is the world-leading laboratory for the construction of reliable, high-rate gaseous detectors
- This project aims at further enhancing the possible readout rates, to bring the techniques up to speed in view of future experiments
- A first implementation is proposed for the upcoming P2 experiment