Prospects for triggering in the PAX experiment

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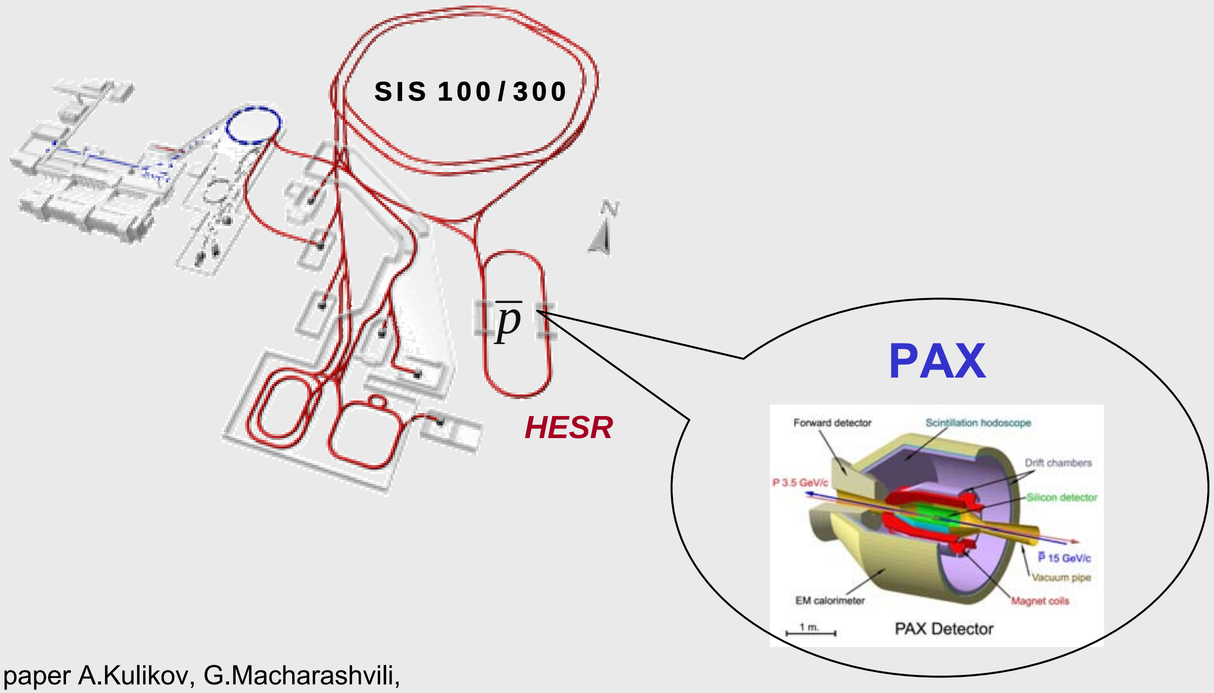
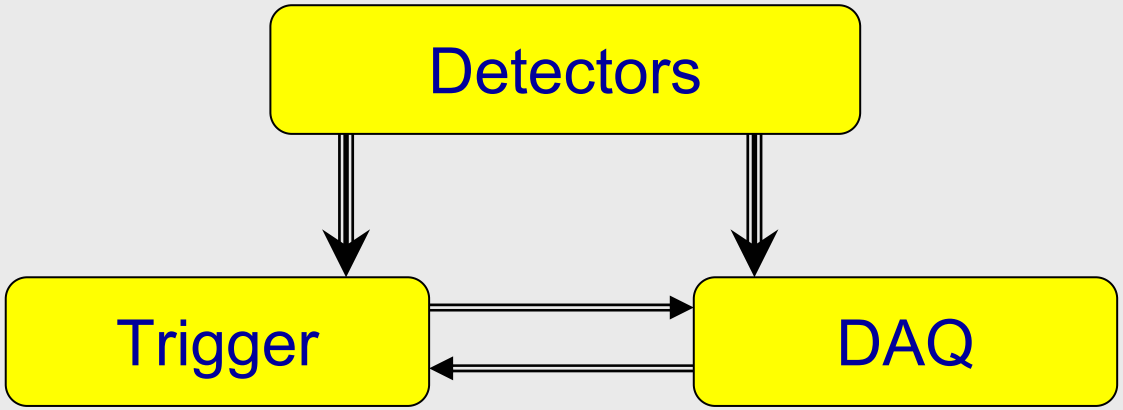


Based on the paper A.Kulikov, G.Macharashvili, subm. to Part.&Nucl., Letters

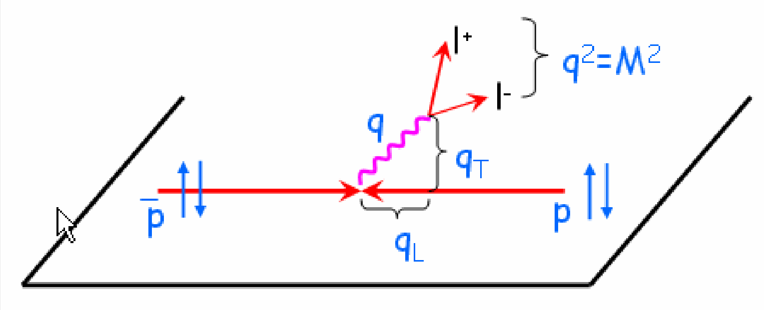
Experimental setup structure:



Trigger system should provide on-line selection of events of interest in order to decrease data flow to the level acceptable for the data acquisition system

Physics goals

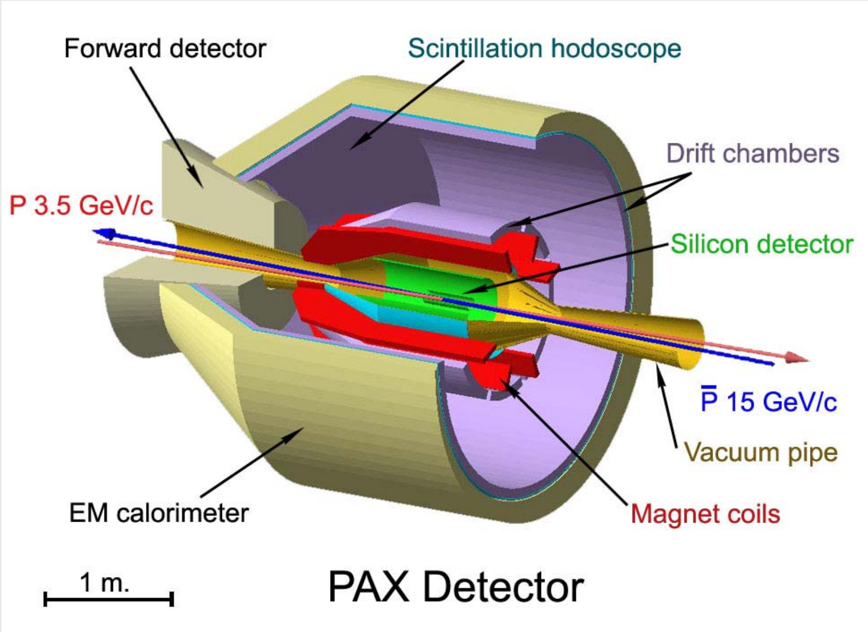
Main goal: first direct measurement of the **transversity** – distribution describing transverse quark polarization in transversely polarized proton.



Transversity distribution can be obtained through the measurement of transverse double-spin asymmetry A_{TT} in Drell-Yan production of lepton pairs in $\bar{p}\uparrow p\uparrow$ interactions.

Other tasks include measurement of single-spin asymmetries (SSA) in $\bar{p}\uparrow p$ and $\bar{p}p\uparrow$ interactions, measurement of the electromagnetic form factor of the proton, study of hard and soft $p\bar{p}$ scattering in polarized and unpolarized cases.

PAX detector



conceptual design

Detector requirements:

- large aperture
- reliable identification of electrons at the presence of high hadron background
- high resolution in invariant mass of the e^+e^- pair, which requires precise reconstruction of electron momenta, angles and energies
- detection of hadrons and measurement of their kinematic parameters
- measurement of energies of γ-quanta from radiative processes and decays of π^0 and η mesons

Which events have to be selected by a trigger system?

Drell-Yan processes for transversity and SSA measurements

transversity:

$\bar{p}\uparrow p\uparrow \rightarrow e^+e^- X$ with invariant mass of the e^+e^- pair $M^2 = 4 - 100\ GeV^2$ (and $1.5 < M^2 < 3\ GeV^2$)

SSA:

$\bar{p}\uparrow p \rightarrow e^+e^- X$ and $\bar{p}p\uparrow \rightarrow e^+e^- X$

Selection of e^+e^- pairs of high invariant mass has to be provided in conditions of large hadron background

Elastic $\bar{p}p$ scattering and other two-body hadron states

Criteria on coplanarity and total momentum and energy conservation

Processes with D- meson production

$c\tau$=317 μ

transversity via A_{TT} in the channel $\bar{p}\uparrow p\uparrow \rightarrow DX$ (complimentary to measurements via Drell-Yan processes)

SSA in $\bar{p}\uparrow p \rightarrow DX$ and $\bar{p}p\uparrow \rightarrow DX$ (permitting to disentangle the mechanisms of Collins and Sivers)

Selection of D-mesons:

semi-leptonic decays (branching ratio $D^+ \rightarrow e^+X$: ~17%) with use of electrons and accompanying particles in trigger selection

exclusive hadron decays $D \rightarrow K2\pi$, $D \rightarrow K3\pi$ (?)

New ideas will appear in upcoming years before the measurements !

Trigger requirements

Selection of Drell-Yan pairs at the presence of hadron background

$\sigma_{Drell\text{-}Yan} / \sigma_{p\bar{p}\,total} \approx 10^{-7}$

Expected interaction rate:
up to several MHz

Suppression $>10^3$ by the trigger system is required

Necessary to provide:

- **parallel running of different triggers**
- **possibility of a flexible change of the trigger configuration at transition from Phase 1 to Phase 2 and for study of other processes which may become interesting in future**

All available detectors can be used in the trigger logic:

scintillation hodoscopes
Cherenkov counters
electromagnetic calorimeter
Si microstrip detector
drift chambers

Methods of trigger selection

For selection of events it is possible to employ:

Electron identification by Cherenkov radiation
Local and total **energy release** in the calorimeter
Information about **multiplicity**
Track reconstruction in DC and SiDet
Reconstruction of particles' **momenta**
Calculation of the **invariant mass**

All requirements of the experiment can be fulfilled with a **fully computer-controlled two-level trigger:**

T1 – FPGA-based hardware processors -- hardware trigger
T2 – computing processors -- software trigger

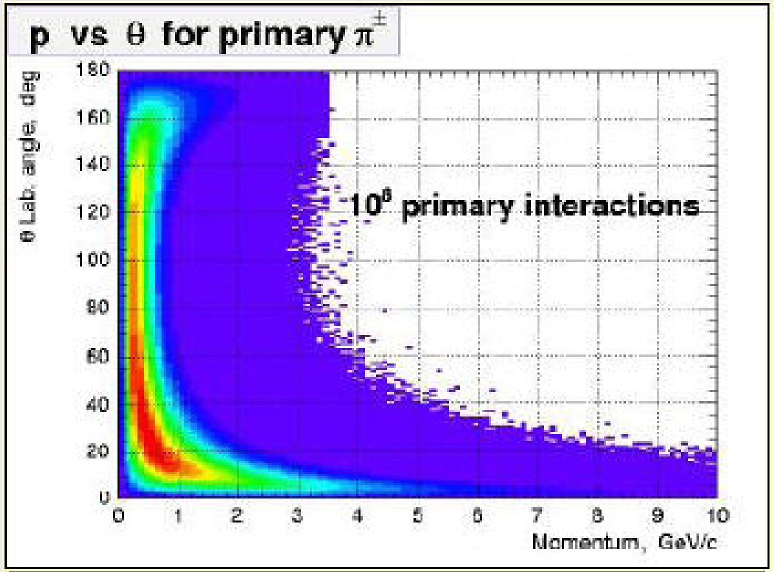
with digitization of data at the level of the front-end electronics and using pipeline memories for storage of data until the T1 decision.

On-line separation of electrons and hadrons

To a large extent separation is based on Cherenkov counters.
But this is not sufficient!

Gas radiator length <=60 см, hence gases with rather high refraction indices:
CO_2, Freon-12 (P^{π}_{thres} =4,873 and 3,003 GeV/c).

In experiment E835 Cherenkov counters had similar dimensions
(the length of 72—93 cm for CO_2 and 34—39 cm for Freon-12).
$N_{p.e.}$ from 5 to 20 was obtained with elaborated light collection system, К= 0.85—0.9 and a point-like target. In conditions of PAX light collection will be worse due to extended interaction region, ~30 cm.



Pions from high-momentum "tail" may produce Cherenkov signals.

Other causes of fake identification of primary electrons:

gamma conversion

secondary hadron interactions with emission of electrons

decays with emission of electrons

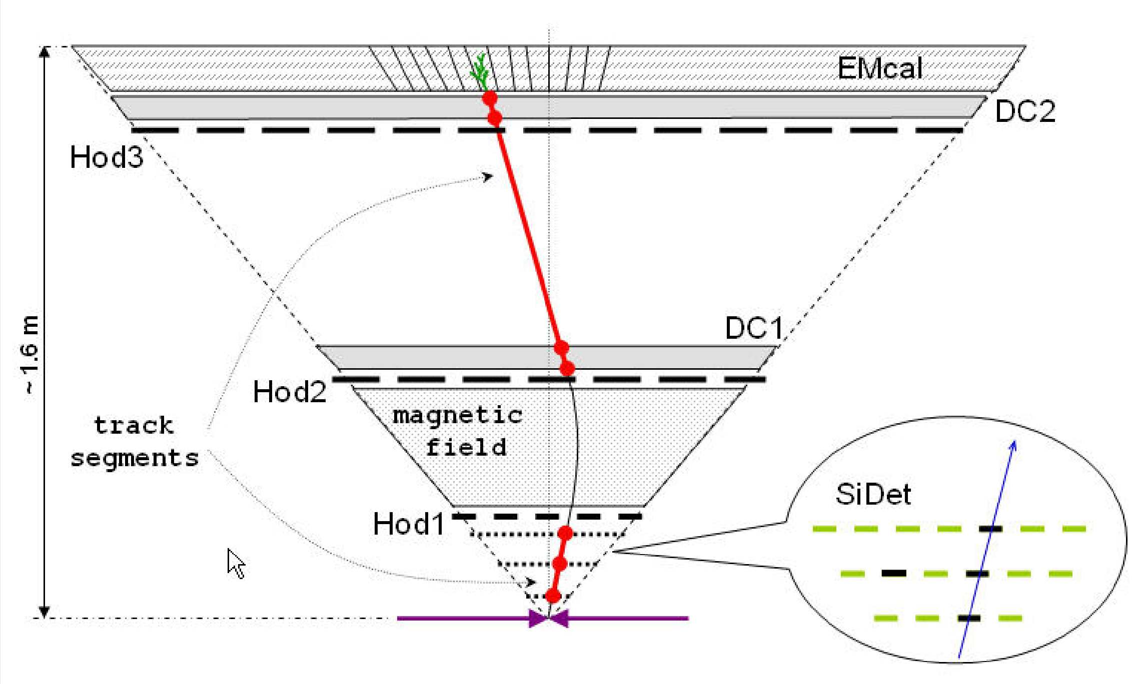
Therefore, in addition to presence of the Cherenkov counter signal, for identification of electrons at the trigger level it is necessary to use information from other detectors, too:

- check of signals in the hodoscopes and silicon detectors
- measurement of the particles' momenta and local energy deposits in the calorimeter
- check of matching of the tracks with fired calorimeter cells
- comparison of the measured energy and momentum for candidates to electrons

Different steps of such analysis may be fulfilled at different trigger levels

Use of tracking detectors in trigger

Tracking system of the PAX detector



Each of the two track subsystems (DC и SiDet) is outside the magnetic field region, therefore rather simple and fast algorithm of the track segment search could be implemented.

Scintillation hodoscopes Hod1—Hod3 localize the regions where the search for track candidates has to be made.

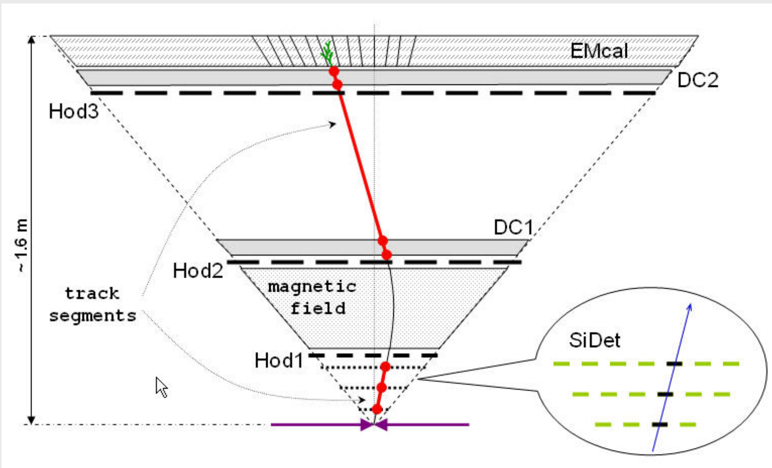
First level trigger (T1) *1*

Building of trigger "primitives", which are used to form T1:

HT hodoscope trigger: coincidences of Hod2 и Hod3 (allowed combinations of elements).

CHT Cherenkov trigger: signal in the Cherenkov counter cell, geometrically matching with the particle trajectory as defined by the hodoscopes.

DCT drift chamber trigger: straight-line track is found in DC (by wire numbers) crossing the hit counters of the hodoscopes.



For fast and effective generation of triggers HT, CHT and DCT, the PAX detector **has to be supplemented with the hodoscope plane Hod2** (absent in the original design).

First level trigger (T1) *2*

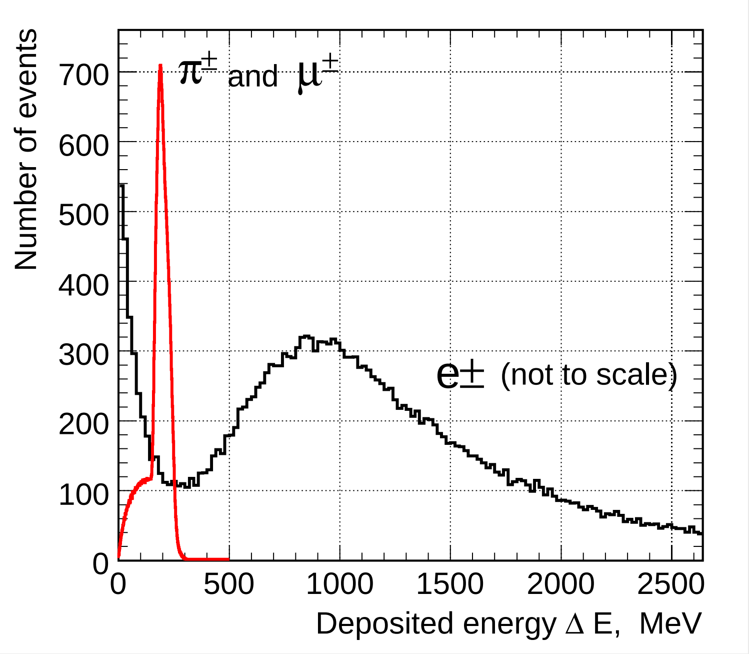
CALT calorimeter trigger: cluster signal exceeds the threshold.

When triggering is on charged particles, then the matching track is requested.

CALT(e) and CALT(h) correspond to different thresholds: for e and π.

CALT(γ) is formed for the cluster signal without track.

CALTOT – triggering on total energy release in EMCal.



ST trigger from Si microstrip detector: coincidence of signals from SiDet planes using coarse segmentation.

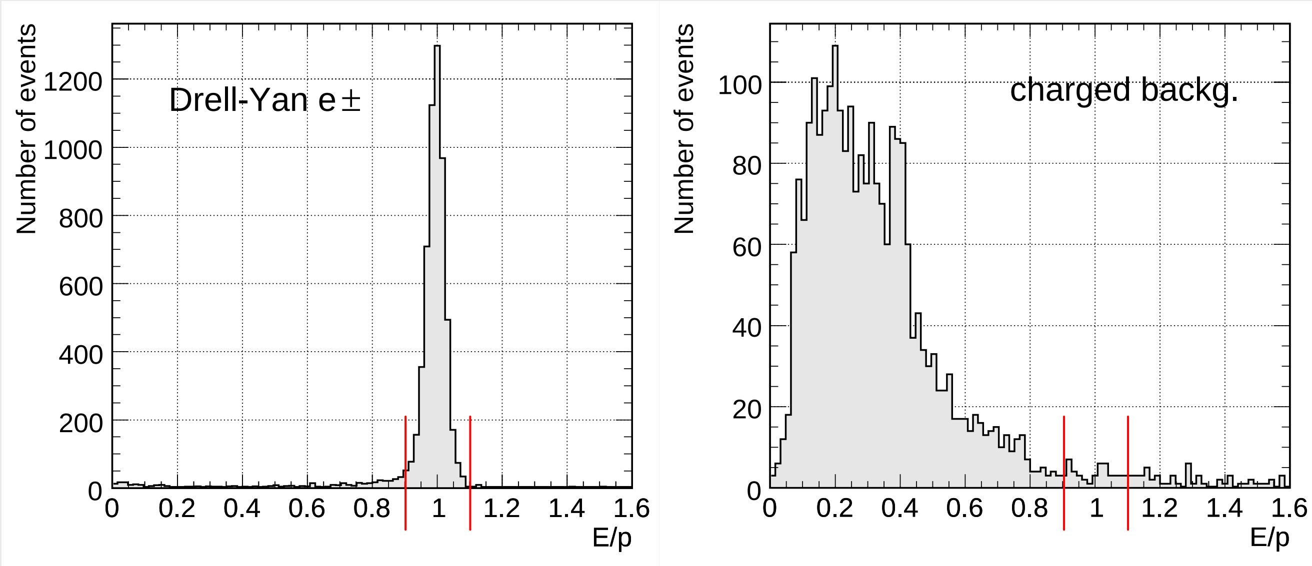
Using the trigger primitives, first the **combinations are formed corresponding to candidates for π, e, γ.**

Then from these preliminary identified particles the **trigger formula is constructed** for selection of the required type events: **e^+e^-X, h^+h^-** etc.

Second level trigger (T2)

- Track reconstruction in DC with use of drift times. χ^2 selection.
- Search for track segments in SiDet with more fine granularity than at T1 level.
- Linking of track segments in DC and SiDet.
- Vertex reconstruction. Selection on the vertex coordinates.
- Finding of momenta of the particles.
- More correct identification of electrons through comparison of measured E and P.
- Invariant mass reconstruction.

Selection of electrons using E/P criterium



0.9 < E/P < 1.1

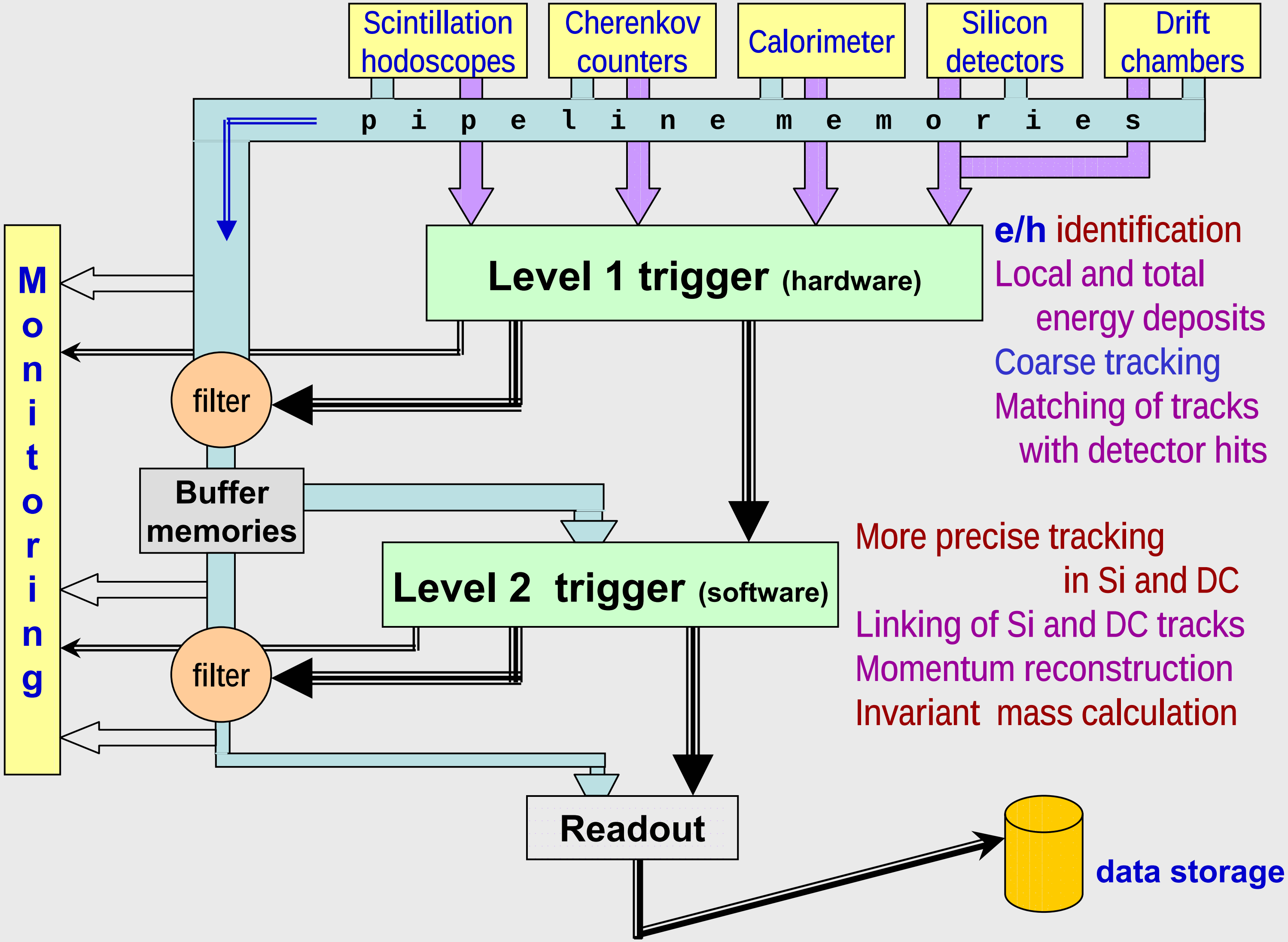
K ≈ 50

For faster event acquisition with T2 algorithms, the ***pointers*** obtained at the level T1 can be used:

***the numbers of wires*-candidates to DC tracks**, found when the signal DCT is generated

***regions of interest* in SiDet**, defined when the signal ST is produced

Probable trigger architecture



e/h identification
Local and total energy deposits
Coarse tracking
Matching of tracks with detector hits

More precise tracking in Si and DC
Linking of Si and DC tracks
Momentum reconstruction
Invariant mass calculation

A.Kulikov Tbilisi, 7.09.2006

Is not such system too complicated and non-adequate to the physics tasks of the experiment?

No, because

- similar systems have been realized in many experiments
- needed hardware components are available on the market and their performance is permanently improving
- excellent physics program of the PAX experiment can only be fulfilled with an equally excellent experimental setup
- such system can be easily reprogrammed for study of other processes with the PAX detector