Reflections about EXChALIBUR, the exclusive 4π detector for EXCLUSIVE measurements of hadronic interactions needed for deeper understanding of QCD

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Presented on the Workshop:

New opportunities in the physics landscape at CERN

11/13 May ’09
Geneva

The provocative title is intended to call for the attention, emphasizing the brainstorming nature of this proposal in the spirit of the call for abstracts: "Proposals at all stages of advancement are requested and novel ideas are particularly encouraged."

The acronym means:

EXClusive **HA**dron and **L**epton **I**nstrument for
Basic **U**niversal **R**esearch.

One is looking for the answer to two questions:

Can exclusive experiments help to understand QCD?

Is it possible to build complete 4pi detector?

One tries to identify the technical limits
which could be reachable within 5 to 10 years in the quest for the ideal particle physics detector in the SPS energy range.

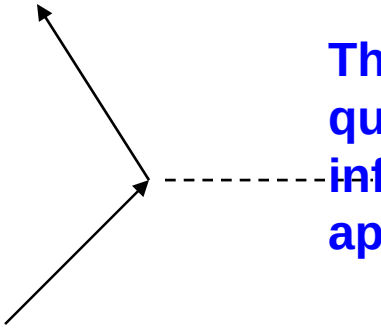
Why is it so difficult the QCD?

LEPTONS

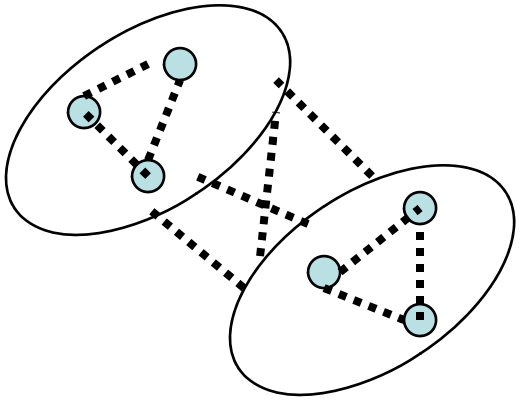
HADRONS

Point-like particles

Extended objects in space



The GENERIC EXCLUSIVITY would give qualitatively new massive amount of information to work out new theoretical approaches.



Simple QED-vertex

Complicated ***space-time*** evolution

One should be aware of difference in coupling constant, too!

Key elements of EXChALIBUR

ACT (Active Carbon Target):
Light Ion trigger device and mirco-vertex detector

Si-Box: Tracker and low energy de/dx PID

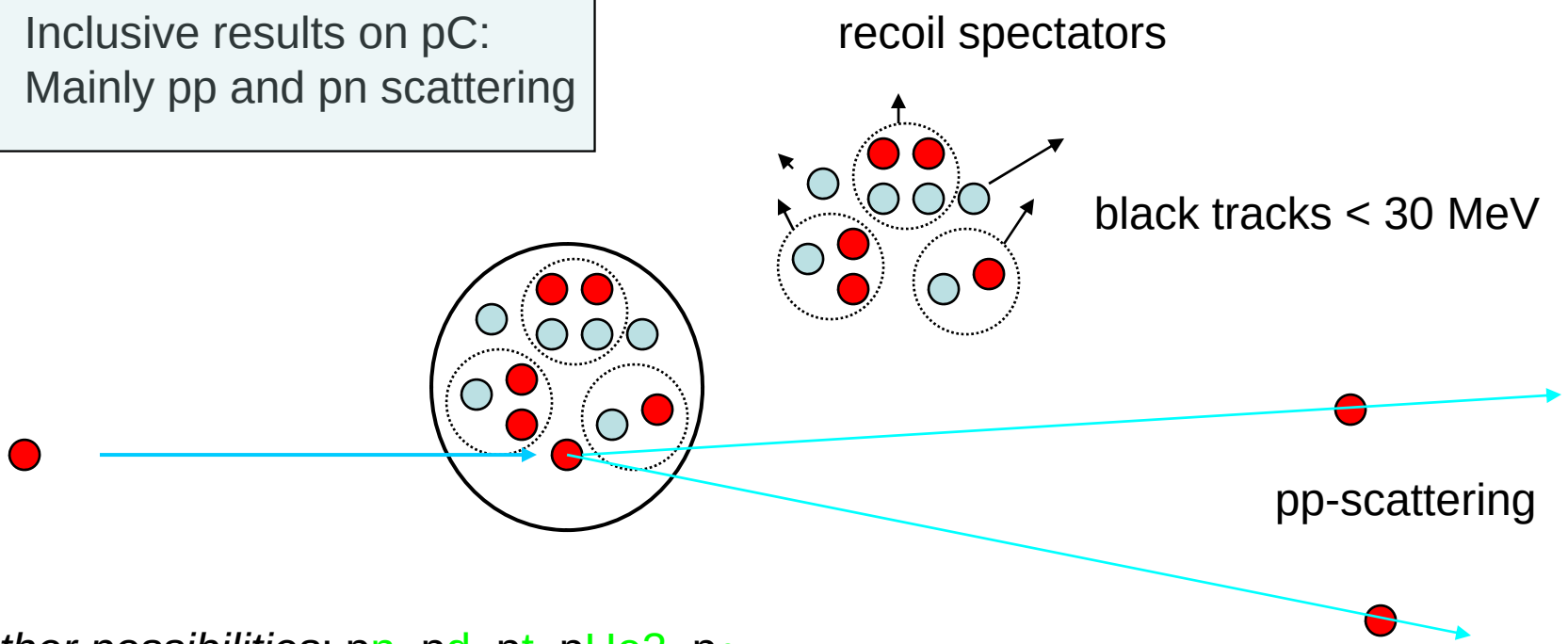
PhT (PhotonTracker):
EM calorimetry + high energy de/dx PID

ImCalo (ImpactCalorimeter):
neutron and Klong detection

Additional: **ToF and Muon** are not discussed here

ACT: Light ION targets in CARBON nucleus

Inclusive results on pC:
Mainly pp and pn scattering



Other possibilities: pn, pd, pt, pHe3, pα

Typical ranges: α-particle 5.5 MeV 14 micron , proton 30 MeV 2 mm

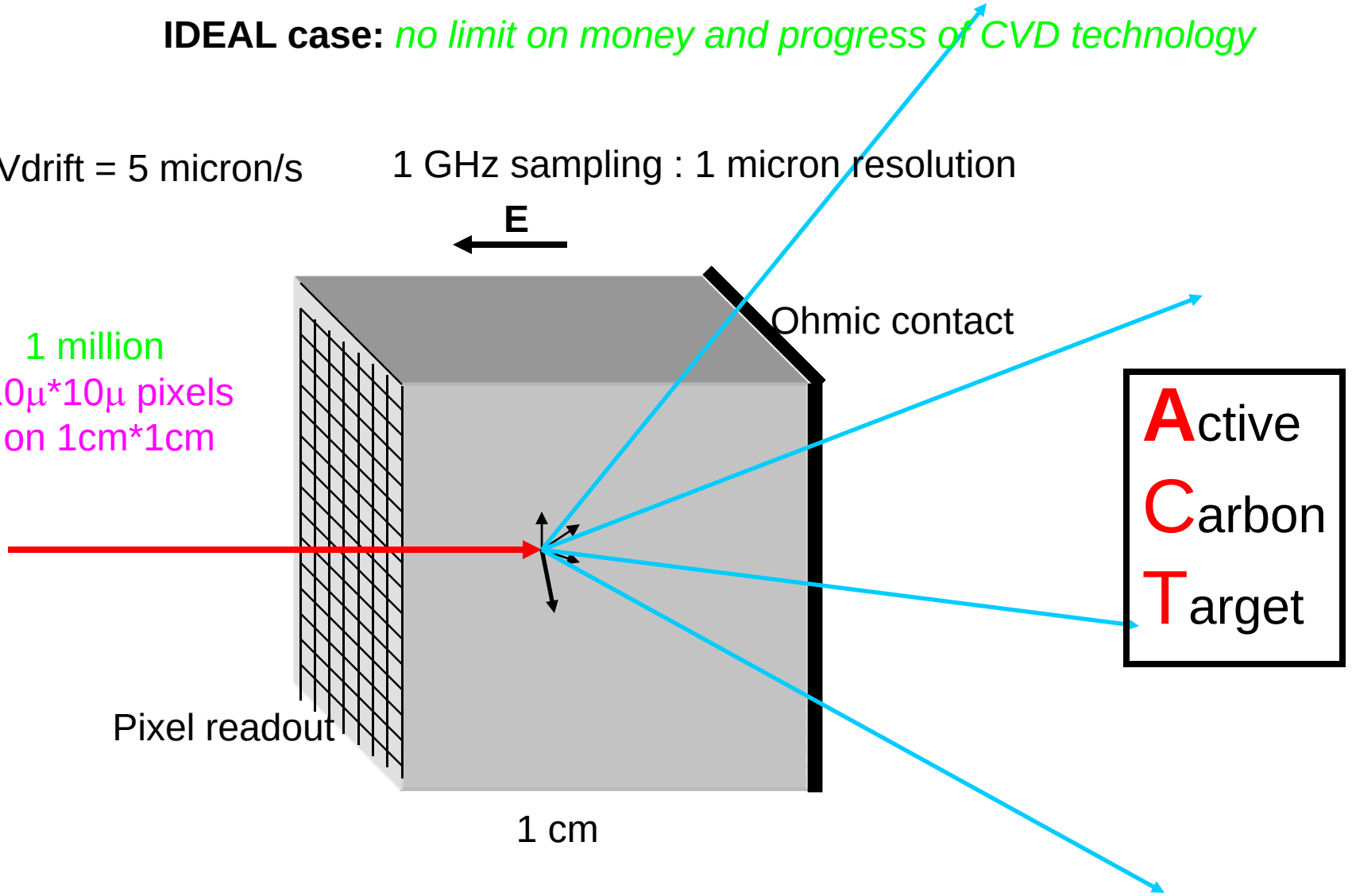
Software trigger: total „black energy" < BlackMAX, calibrated by elastic scatterings and no „grey tracks".

DIAMOND-TPC

IDEAL case: *no limit on money and progress of CVD technology*

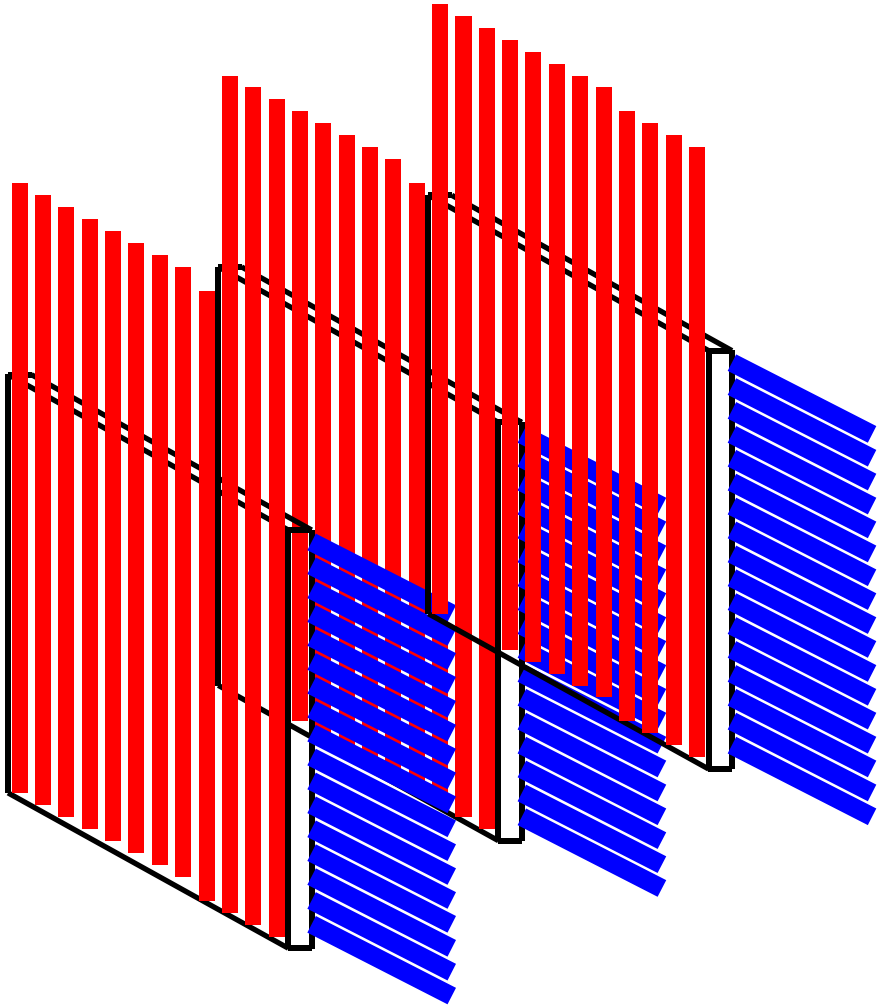
Vdrift = 5 micron/s

1 GHz sampling : 1 micron resolution

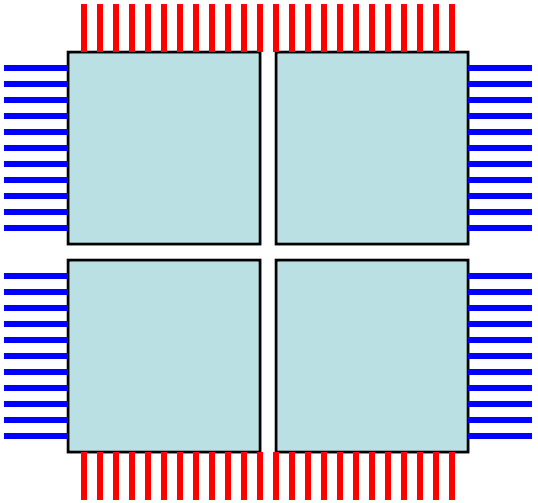


Carbon - UNIVERSAL target material: p, n, d, t, He3, He4

More realistic present technology: **„ELECTRONIC EMULSION”** layers



or



20 layers of 0.5 mm

X and Y strip readout 10 layers of 10mm*10mm*1mm

Today: 4mm*4mm*0.4mm in GSI and 5mm*5mm*0.5mm in CMS

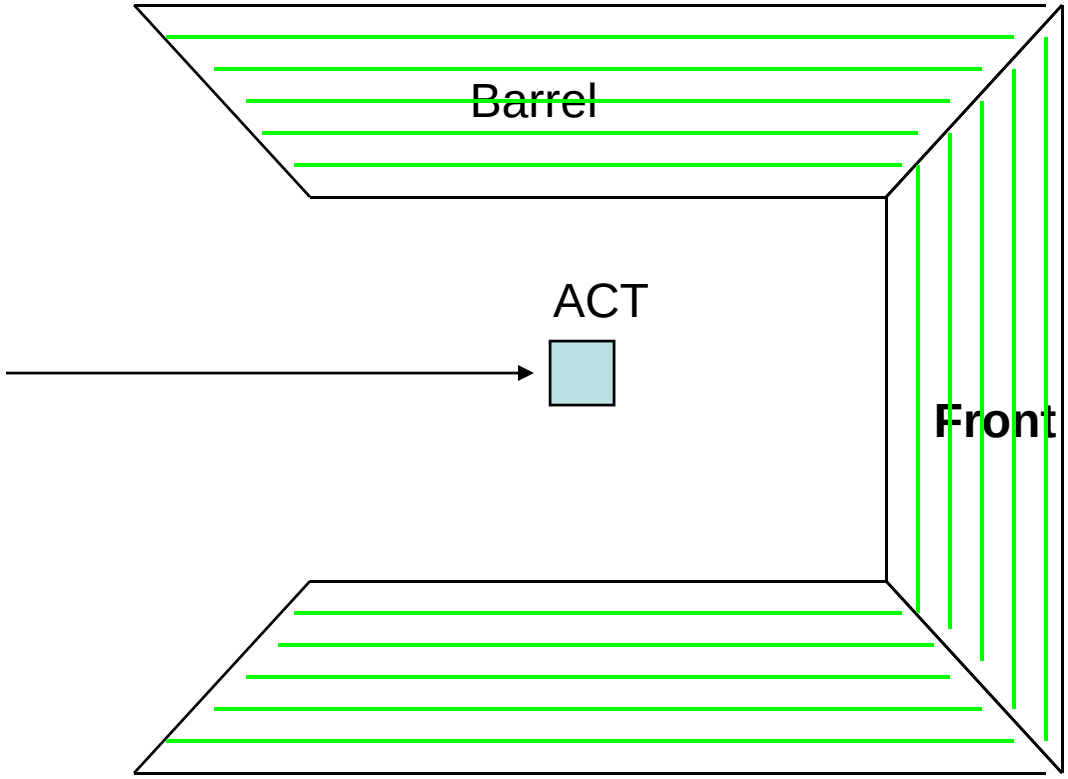
CERN/LHCC 2007-002
LHCC-RD-012
Status Report/RD42
January 15, 2007

Development of Diamond Tracking Detectors for High Luminosity Experiments at the LHC

The RD42 Collaboration

- scCVD diamond has be produced in production reactors in sizes larger than 1 cm^2.
- scCVD diamond produced from production reactors now regularly reaches full charge collection without any observable space charge.

Si-Box



5 SDD layers

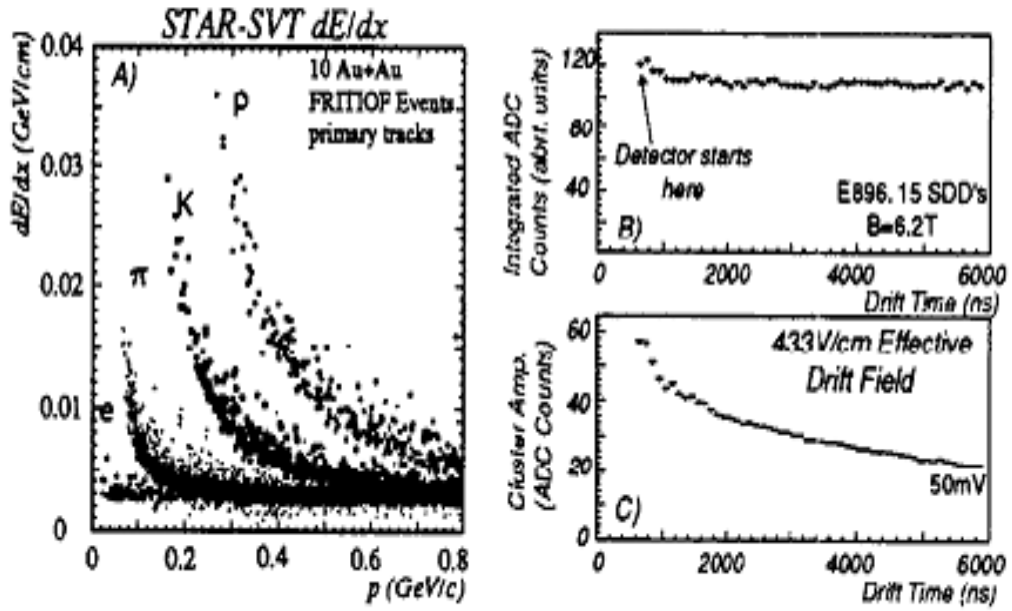
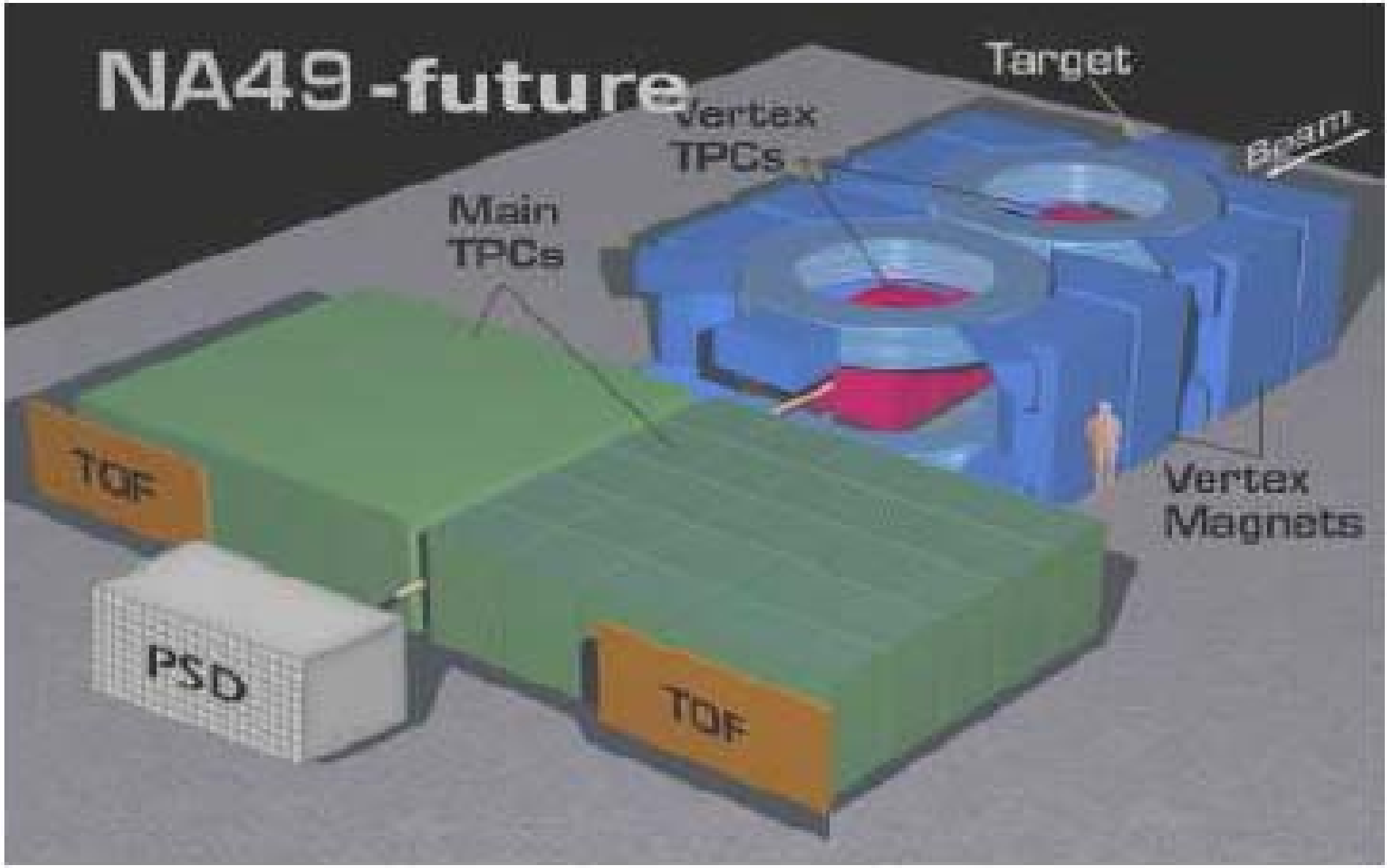


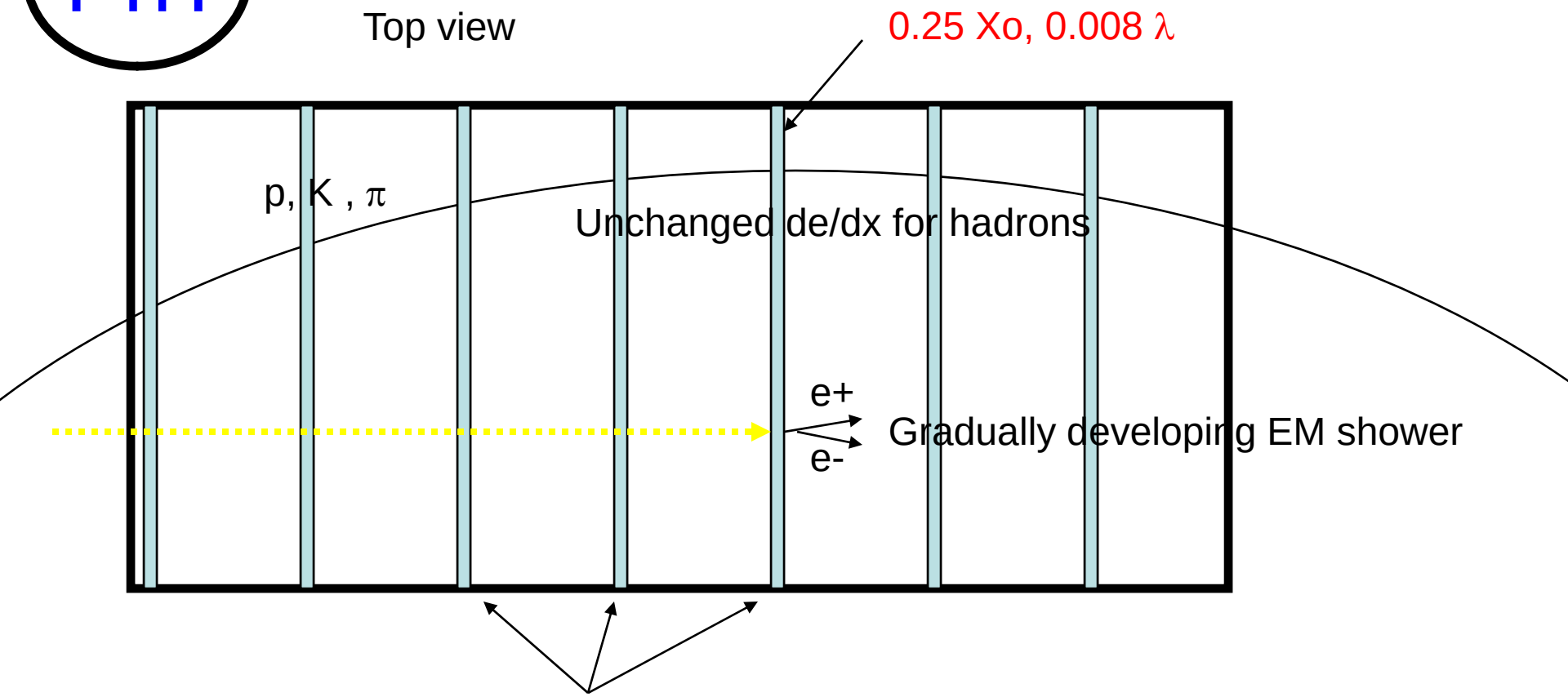
Figure 3. A) The expected dE/dx for tracks in the STAR SVT. B) The integrated charge of hits in a SDD vs. drift distance. C) The decrease in amplitude for these hits with drift distance. The SVT will run at 500V/cm which increases the peak amplitude.

The NA61/SHINE experiment at the CERN SPS



PhotonTracker(1)

PhT



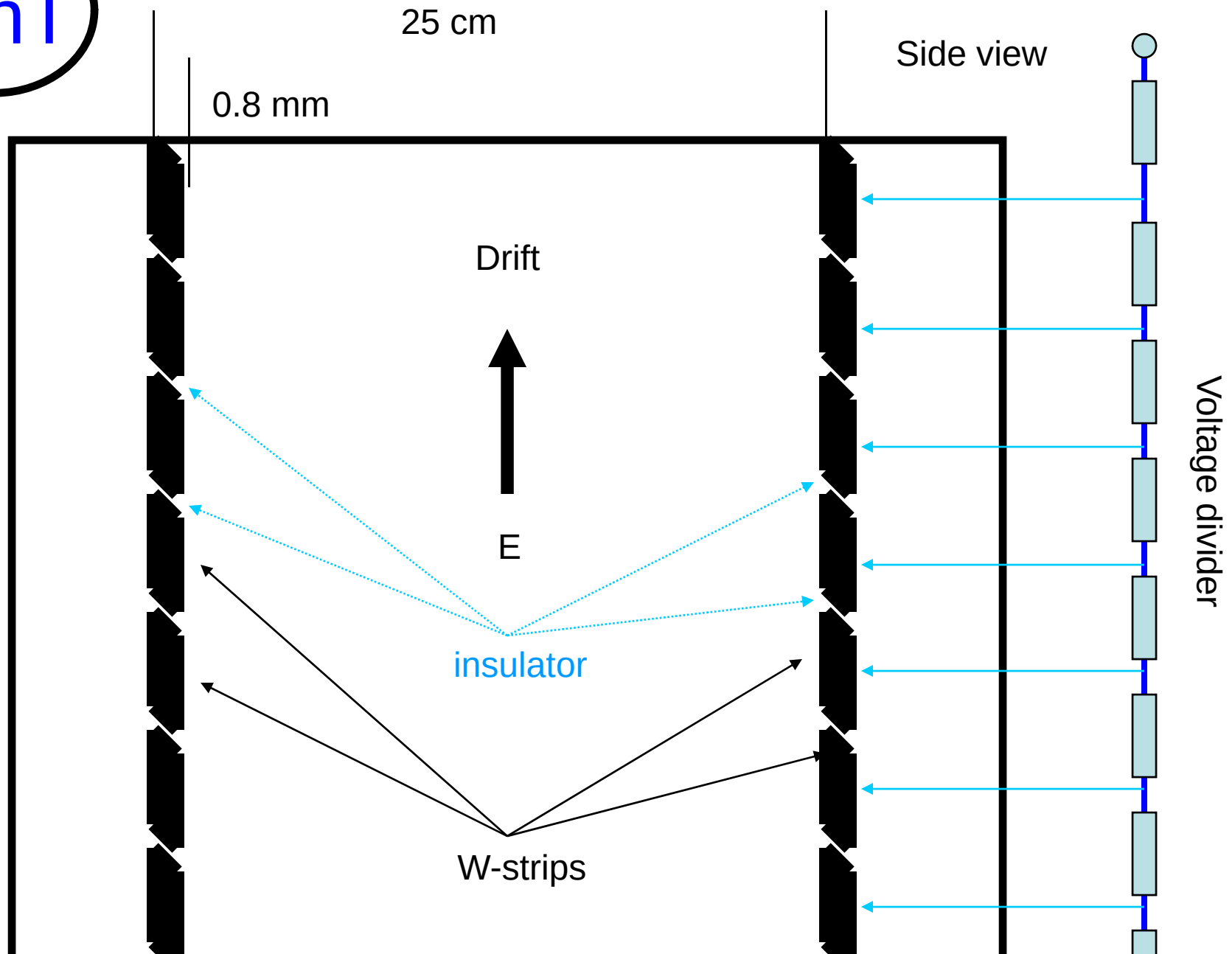
Standard TPC with W-strips in 1Tesla magnetic field

25 cm cells with 0.8mm = 0.25 Xo W-converters where λ interaction length=30Xo

20 cells : total 5 Xo and only 0.17 λ interaction length, NOEFFECT for p, K, π

PhotonTracker (2)

PhT



Impact Calorimeter for neutral hadrons

ImCalo

Consequences of EXCLUSIVITY:

In ACT, Si-Box and PhotonTracker all charged particles and photons are detected.

Only neutrons and Klongs remains undetected,
Due to barion and strangeness conservation the total number of neutrons and Klongs will not exceed 4.

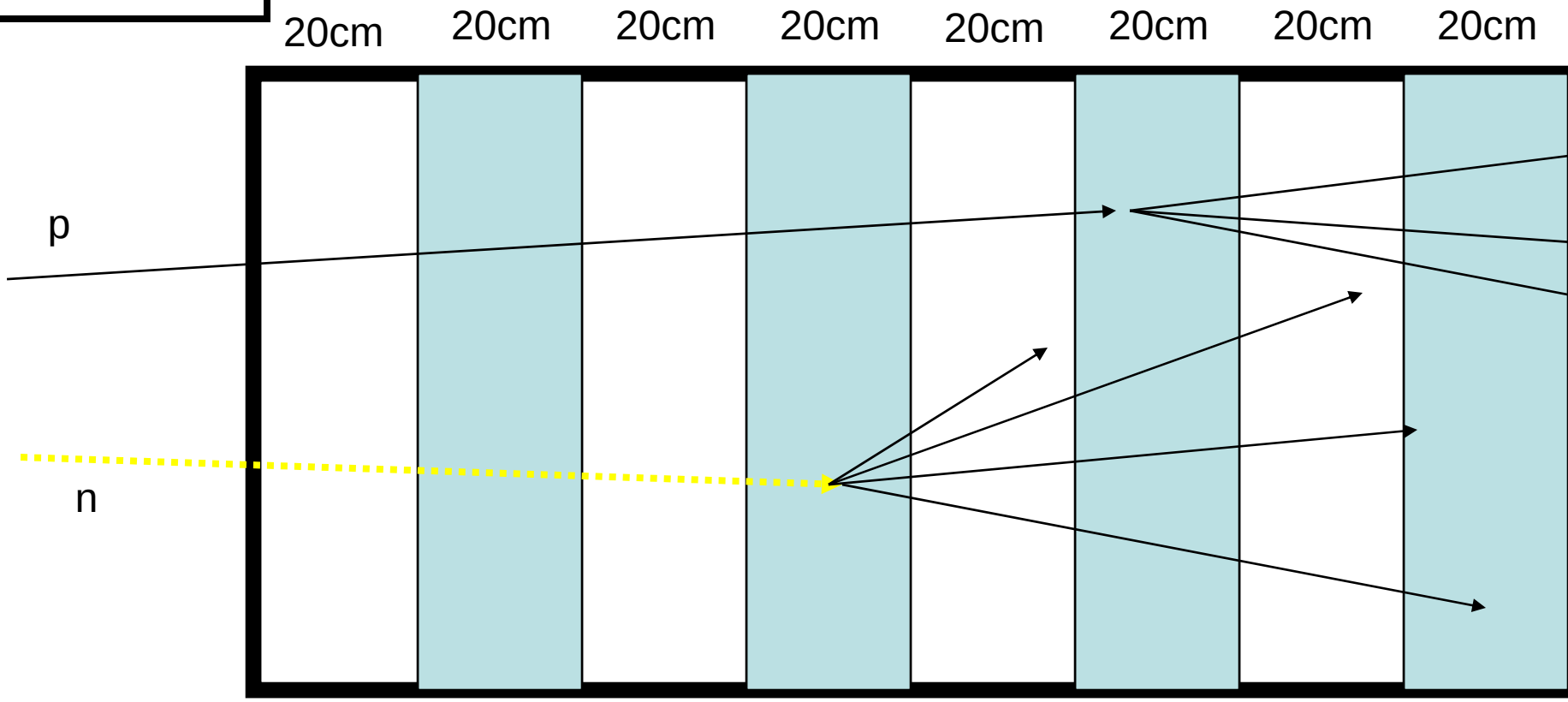
Accurate IMPACT POINT measurement complemented by crude calorimetry is enough to calculate more accurate energy values from energy-momentum conservation

ImpactCALO = PhotonTracker: TPC with Polyethylene(CH2) absorber blocks

Field-cage can be created by high resistivity coating on the CH2 surface

Cheap Impact Calorimeter

ImCalo



TPC pad readout pattern is optimized for local vertex reconstruction

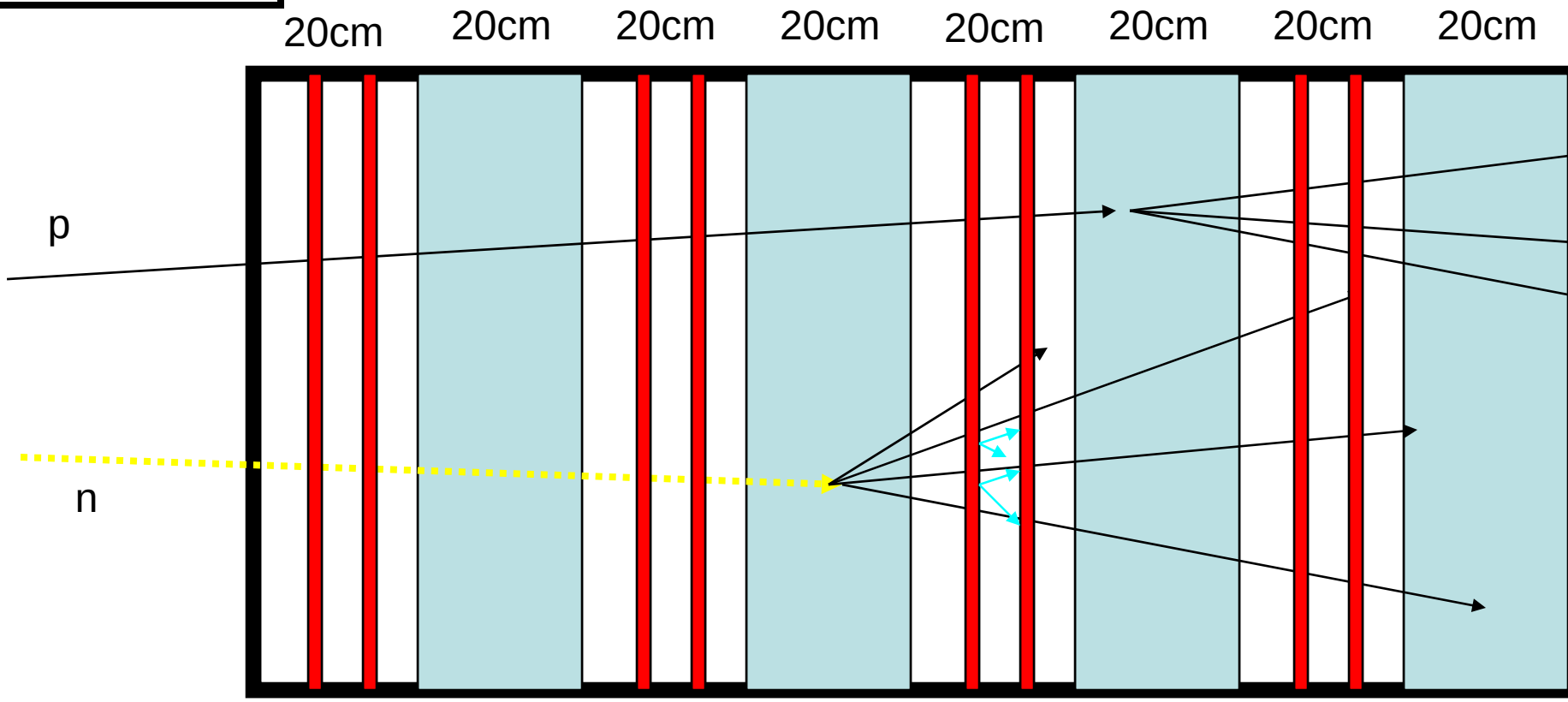
20 cm Polyethylene: 0.47 Xo and 0.25 λ interaction length

16 periods gives total length 6.4 m with 4 λ interaction length

Showers from charged hadrons can be used for calibration.

EM compensated Impact Calorimeter

ImCalo



EM component is identified by 1 Xo lead plates.

20 cm Polyethylene: 0.47 Xo and 0.25 λ interaction length

16 periods gives total length 6.4 m with 4 λ interaction length

DAQ

Triggerless data acquisition.

Beam intensity: 10^5 - 10^6 particle/s , spot size sigma = 2 mm

Interaction rate: 100 – 1000 ev/s

Each channel is continuously read out by a token ring.

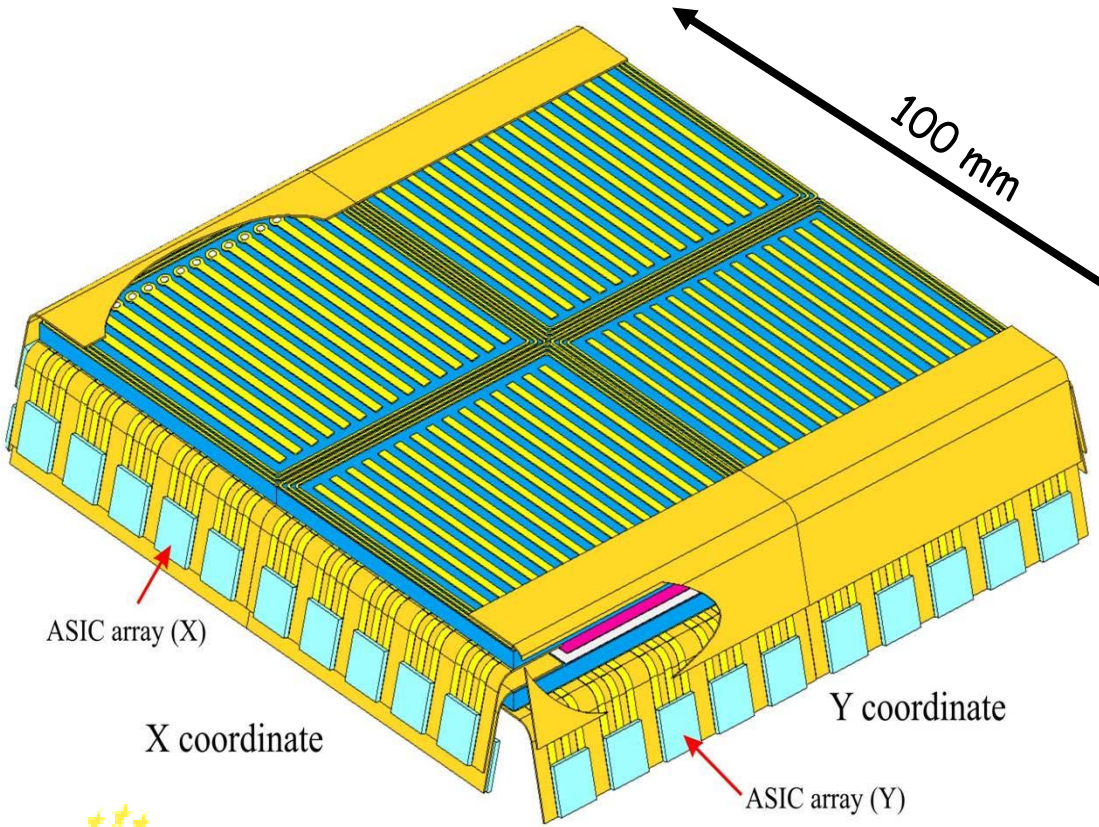
Parallel processing by SIMD farm

Each hit has LOCALITY (XY) + TIME(t) + AMPLITUDE(Energy) Recorded.

DATA DRIVEN System: Single hits are looking for association with others relying on locality and time.
Successfull associations create OBJECTs.
Simpler objects are building up higher classes….

DETNI-A ^{157}Gd/Si Detector Module

Data Acquisition System for N-XYTER



Goals

- 10^8 n/sec in 100 cm^2
- with 2 views, 2 hit/strip: 400 MHz strip hit rate
- with 5 Byte/hit: 2 GByte/sec data

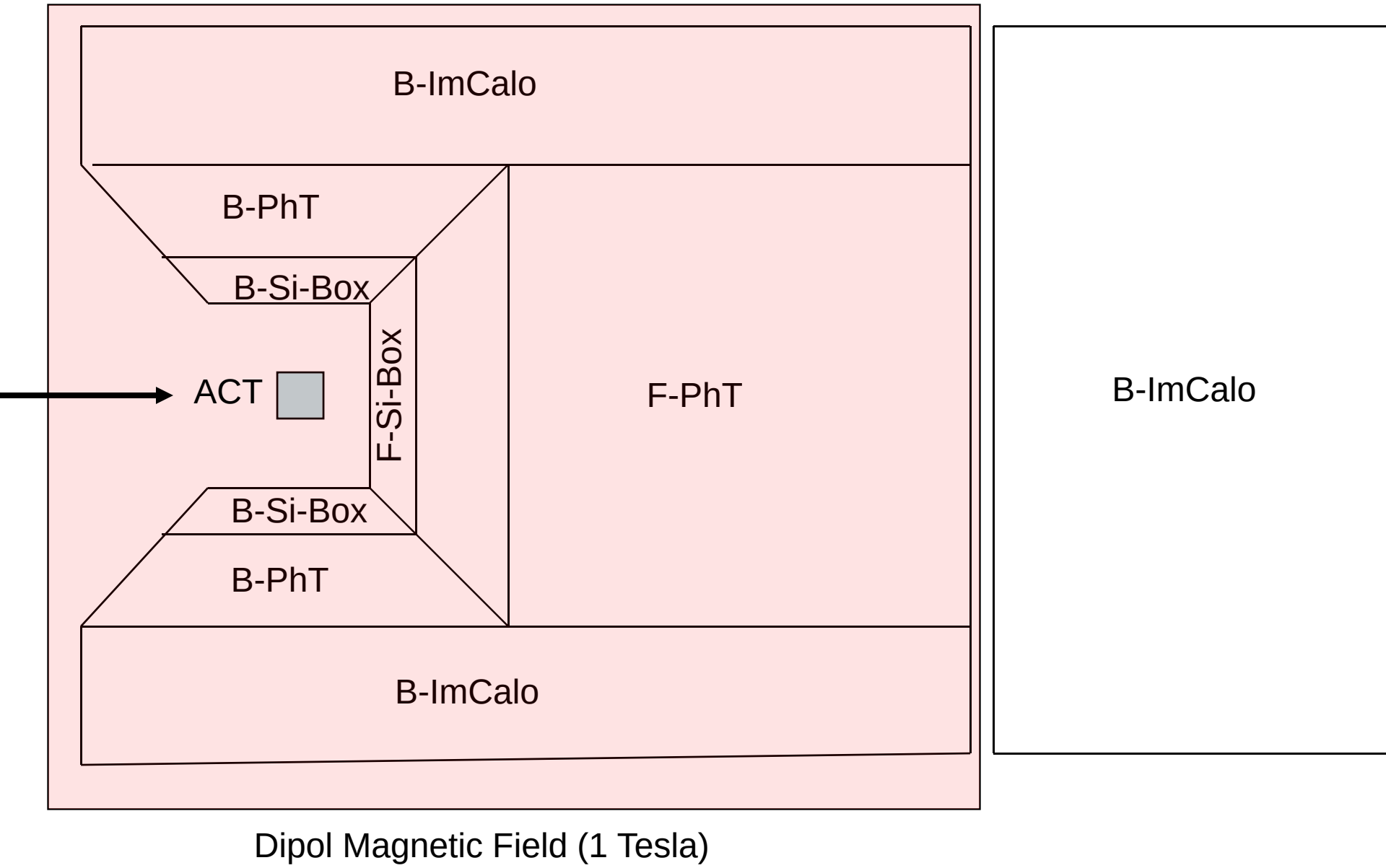
Consequences

- 128 channel ASIC
- 20 chip/module
- 20 MHz/chip
- 100 MByte/chip

Separate ADC and TDC for each (!!) channel

slide courtesy C.J.Schmidt

EXChALIBUR



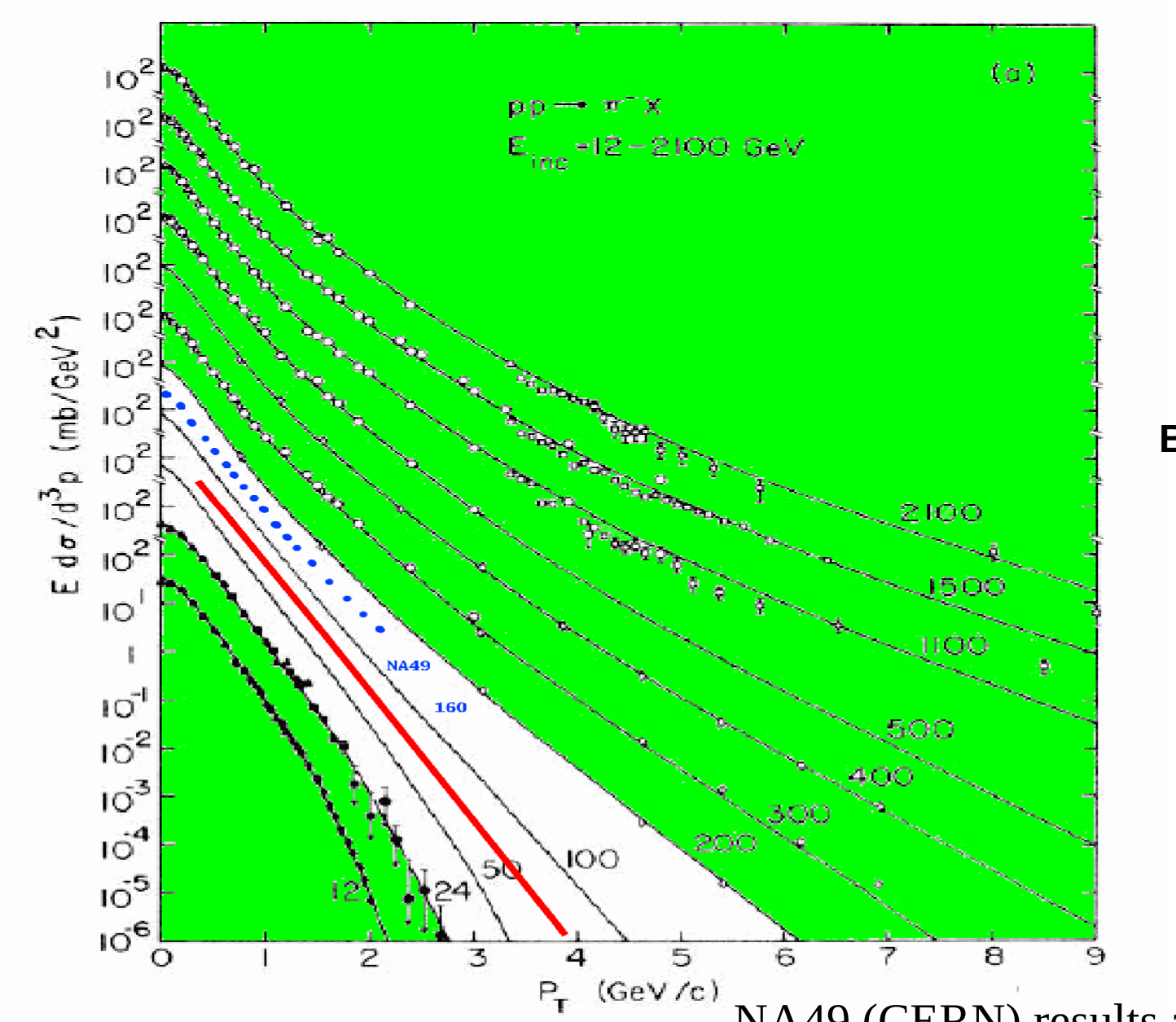
Dipol Magnetic Field (1 Tesla)

Why should it be built at SPS?

The SPS energy range is full of mysteries which were completely forgotten after the closure of ISR.

One can just enumerate few examples:

-Mysterious transition of inclusive spectra around 80 - 90 GeV energy from convex to concave form.
-Emergence of Cronin-effect in pA interactions is completely unknown: energy, centrality particle type dependence, particle correlations.
-Practically no medium or high pT data between beam energies 24 and 200 GeV.
-Is there a Critical Point on the AA phase diagram? (Hopefully the YES/NO answer will be given soon by NA61/SHINE experiment, but the finer details calls for deeper studies.)
-Is there threshold for Jet-quenching which was observed at RHIC at higher energies?
-How the jets are emerging???
-Where are the glueballs, pentaquarks,...?
-etc.



Beier (1978)

NA49 (CERN) results at 158
FODS (IHEP) at 70 GeV

NA49

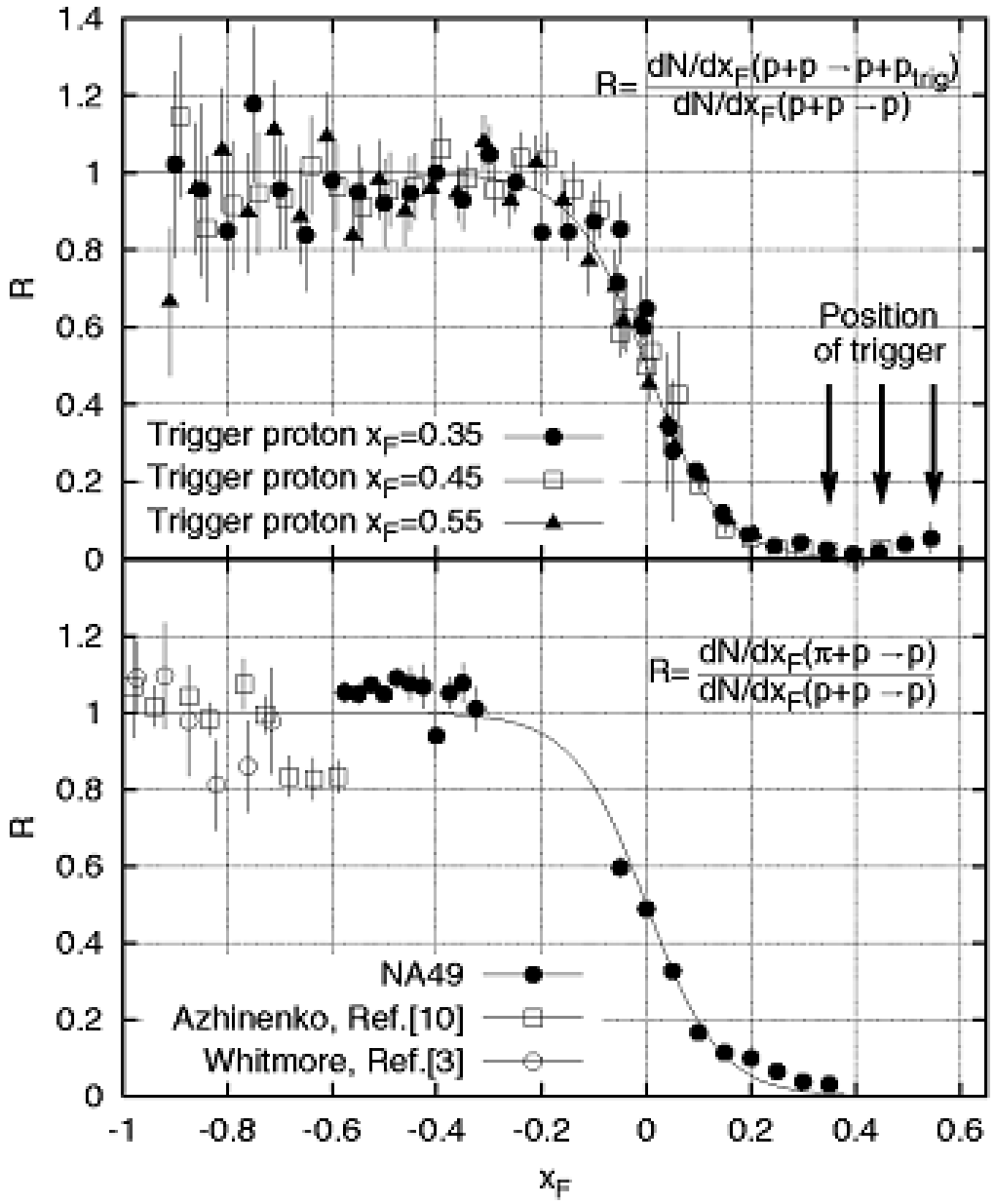


Fig. 4. Net proton density $(p - \bar{p})$ ratio with pion and proton beam (*lower part*) and ratio of correlated and inclusive net proton density in $p + p$ collisions (*upper part*)

Due to the fact that in this region the **multiplicities** are still relatively **modest** one have more chance to identify characteristic features.
Bohr was using the spectral lines of Hydrogen and not the ones of Lead.

In short: We should find "the Lyman and Balmer series" for QCD. Due to the fact that QCD is so many times more complicated than QED we need EXA-Bytes instead of the few Bytes of Bohr.

The complication is mainly arising from the fact that the **hadrons are extended objects in space** in contrast to point-like leptons. In this situation one should grab any possibility to collect new information which can provide insight into the space-time evolution of this complex system.

The aim of this proposal calls for not an immediate concrete action, but to initiate the discussion for a longer range project which could lead to definite design of a dedicated exclusive experiment in 5 years from now.

It is clear, that exclusive experiments have more information than the inclusive ones, what is not clear, is this information enough for a breakthrough.

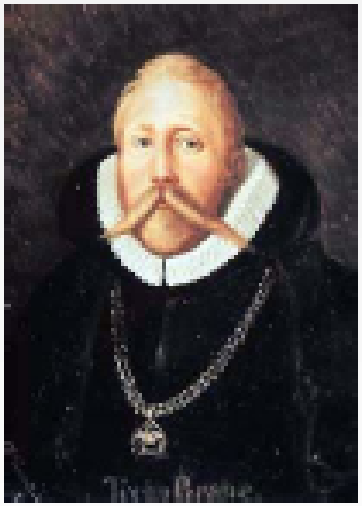
Pessimists can say: *There is no such information*.
But I ask: *Please prove it without trying to measure it!*

Historical ANNEX

Tycho Brahe and the Orbit of Mars

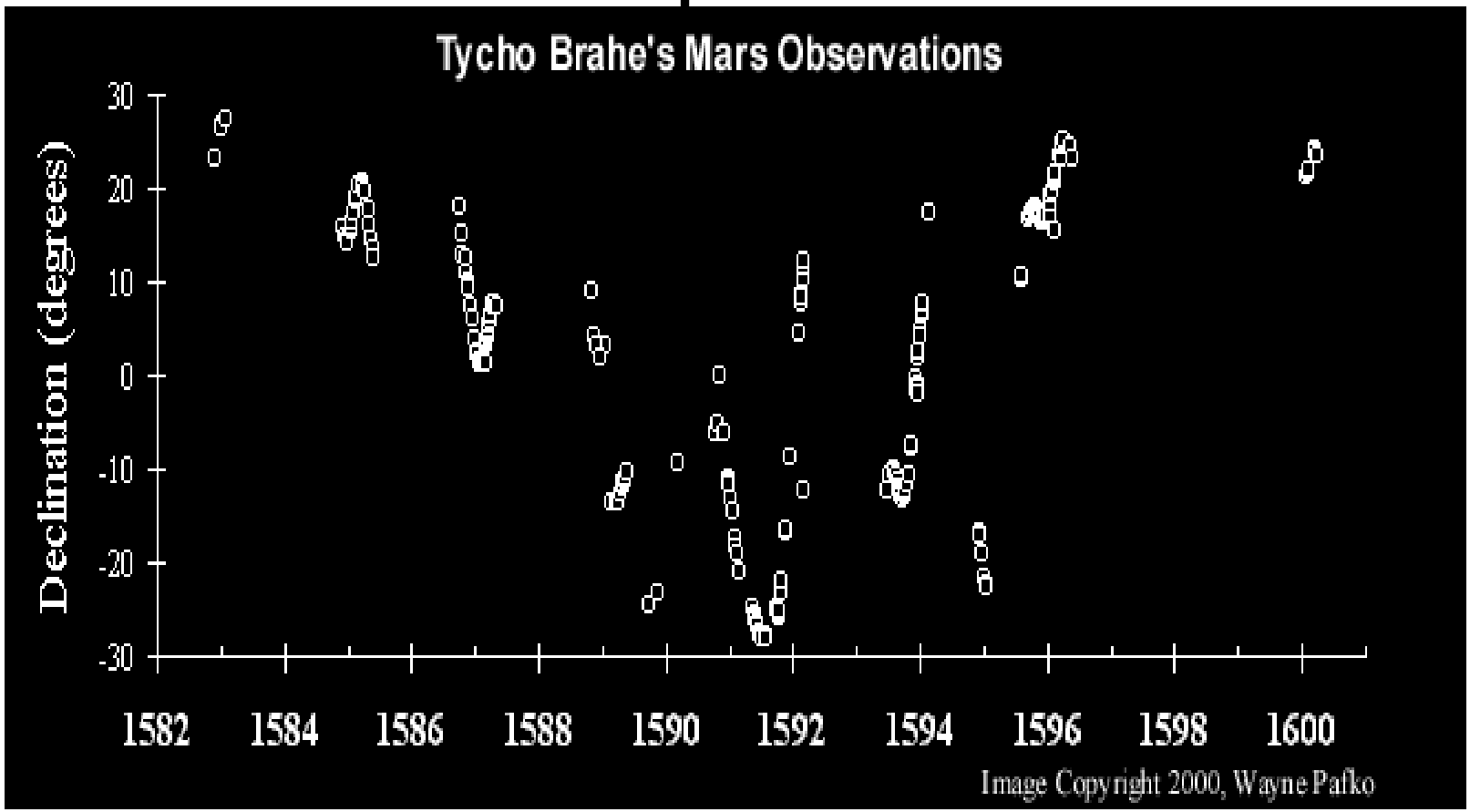
I've studied all available charts of the planets and stars and none of them match the others. There are just as many measurements and methods as there are astronomers and all of them disagree. What's needed is a long term project with the aim of mapping the heavens conducted from a single location over a period of several years.

Tycho Brahe, 1563 (age 17).



- First measurement campaign
- Systematic data acquisition
  - Controlled conditions (same time of the day and month)
  - Careful observation of boundary conditions (weather, light conditions etc…) - important for data quality / systematic uncertainties

The First Systematic Data Acquisition



- Data acquired over 18 years, normally e every month
- Each measurement lasted at least 1 hr with the naked eye
- Red line (only in the animated version) shows comparison with modern theory

Some More Thoughts on Tycho

- Tycho did not do the correct analysis of the Mars data, this was done by Johannes Kepler (1571-1630), eventually paving the way for Newton's laws
- Morale: the size & speed of a DAQ system are not correlated with the importance of the discovery!