# Online Monitoring for the Silicon Tracker of the LHCb Experiment

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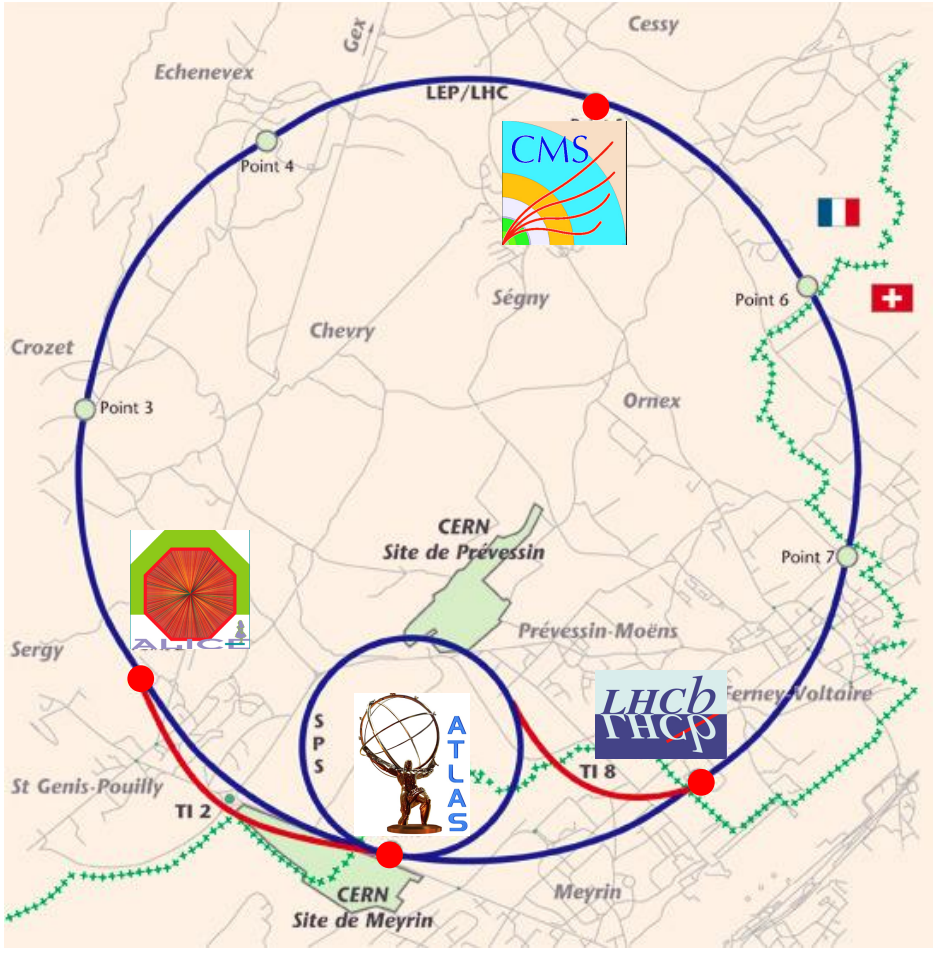
# Outline

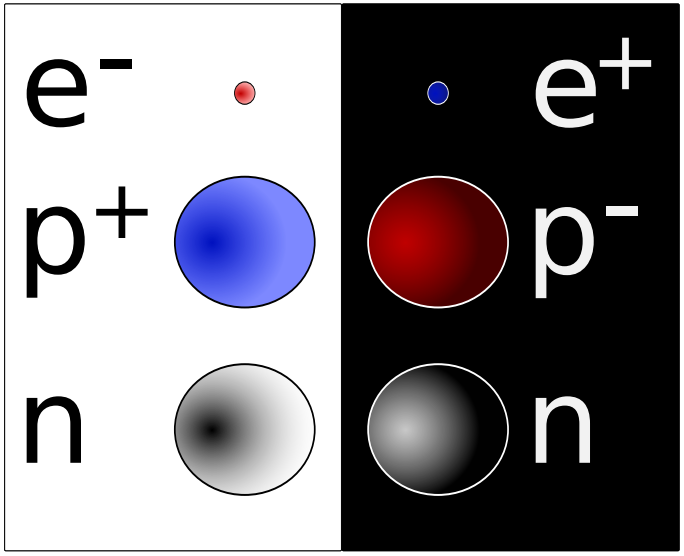


# The LHC (The Large Hadron Collider)




- underground ring-tunnel
- 27 km circumference
- over 5000 proton bunches in 2 beam pipes
- protons accelerated to almost speed of light ($E_{kin}$ = 7 TeV)
- collisions at 4 interaction points (every 25 ns)
- expected restart: Sept/Oct 2009

# Physics Motivation




anti-particle twin of normal particle with opposite charge

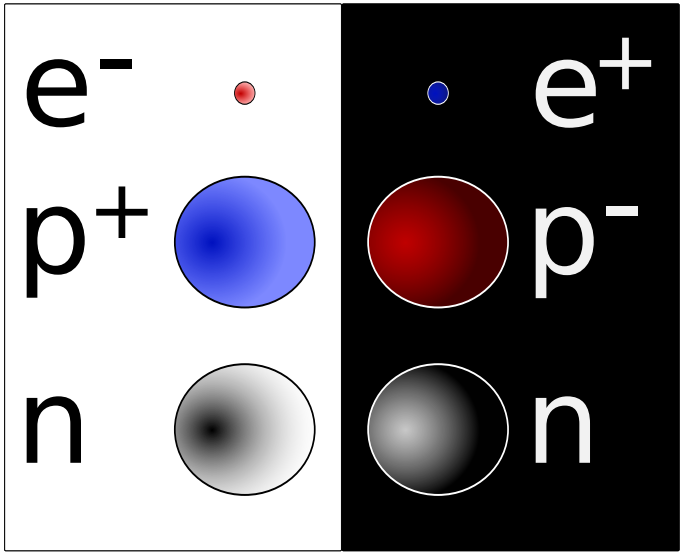
- Big Bang produced equal amounts of particles and anti-particles
- no anti-matter in known universe
- few processes affect particles and anti-particles differently
- present model of processes can not explain the huge difference

Goal: Study these processes and look for new effects.

# Physics Motivation - Details

- LHCb looks at CP violation and rare B meson decays
- CP violation observed in weak interactions
- CKM mechanism of Standard Model can explain CP violation
- current results consistent with predictions
- but too small to explain matter/anti-matter asymmetry
- new source of CP violation needed

# Physics Motivation

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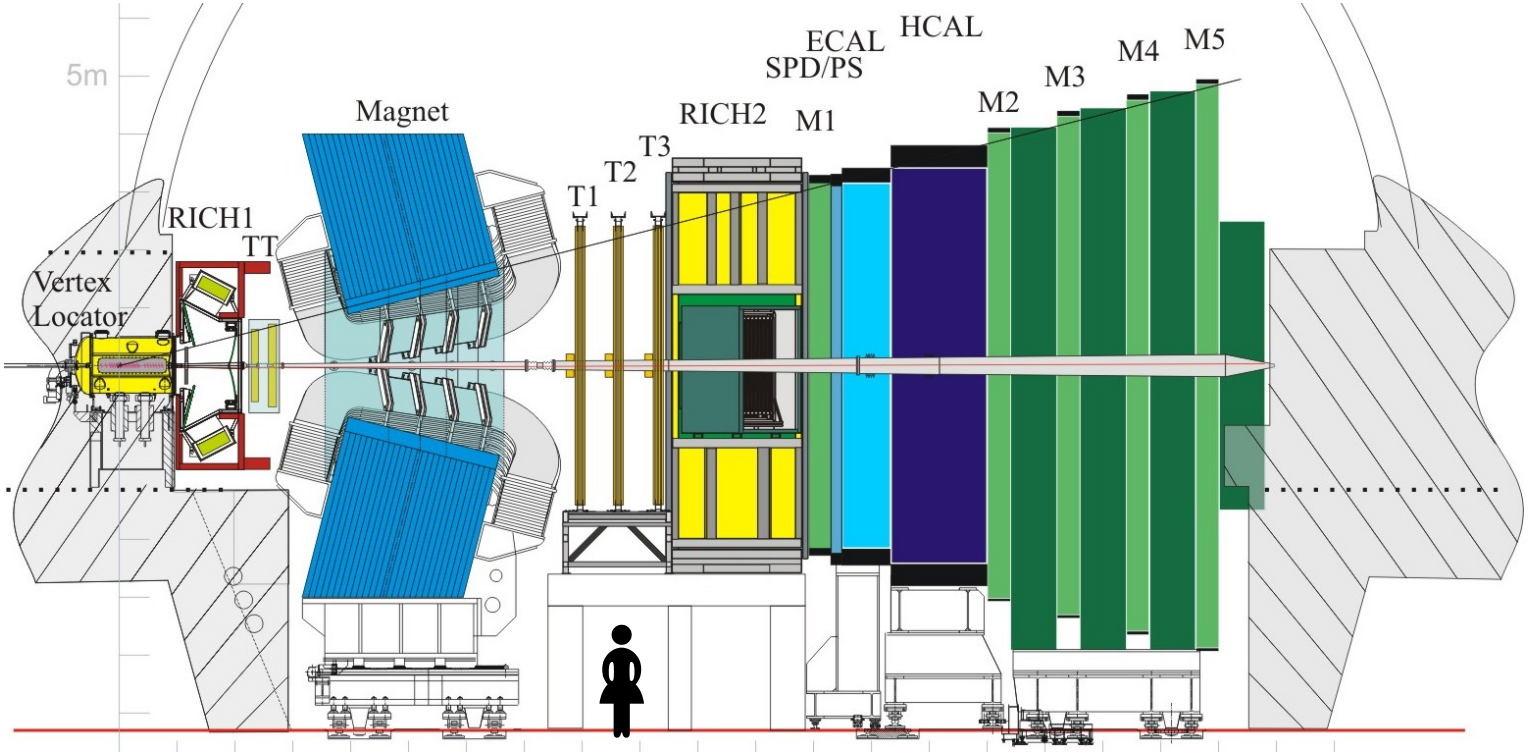


- consists of many subdetectors
- each measuring different properties of particles (e.g. energy, momentum)
- UZH contribution is the Tracker Turicensis (TT)

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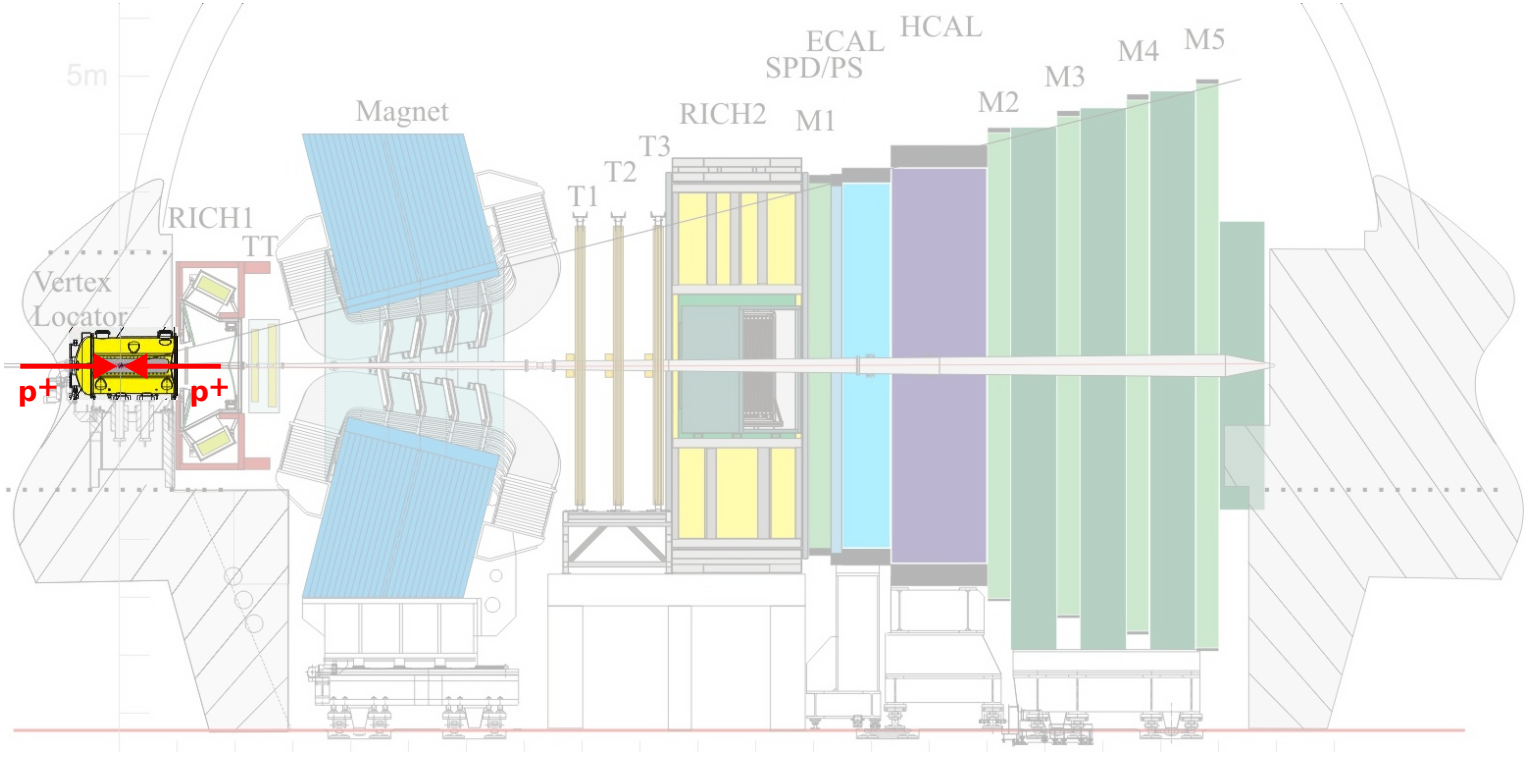


## Proton collisions

1. create new particles
2. new particles decay
3. properties of decay products measured (e.g. flight path)

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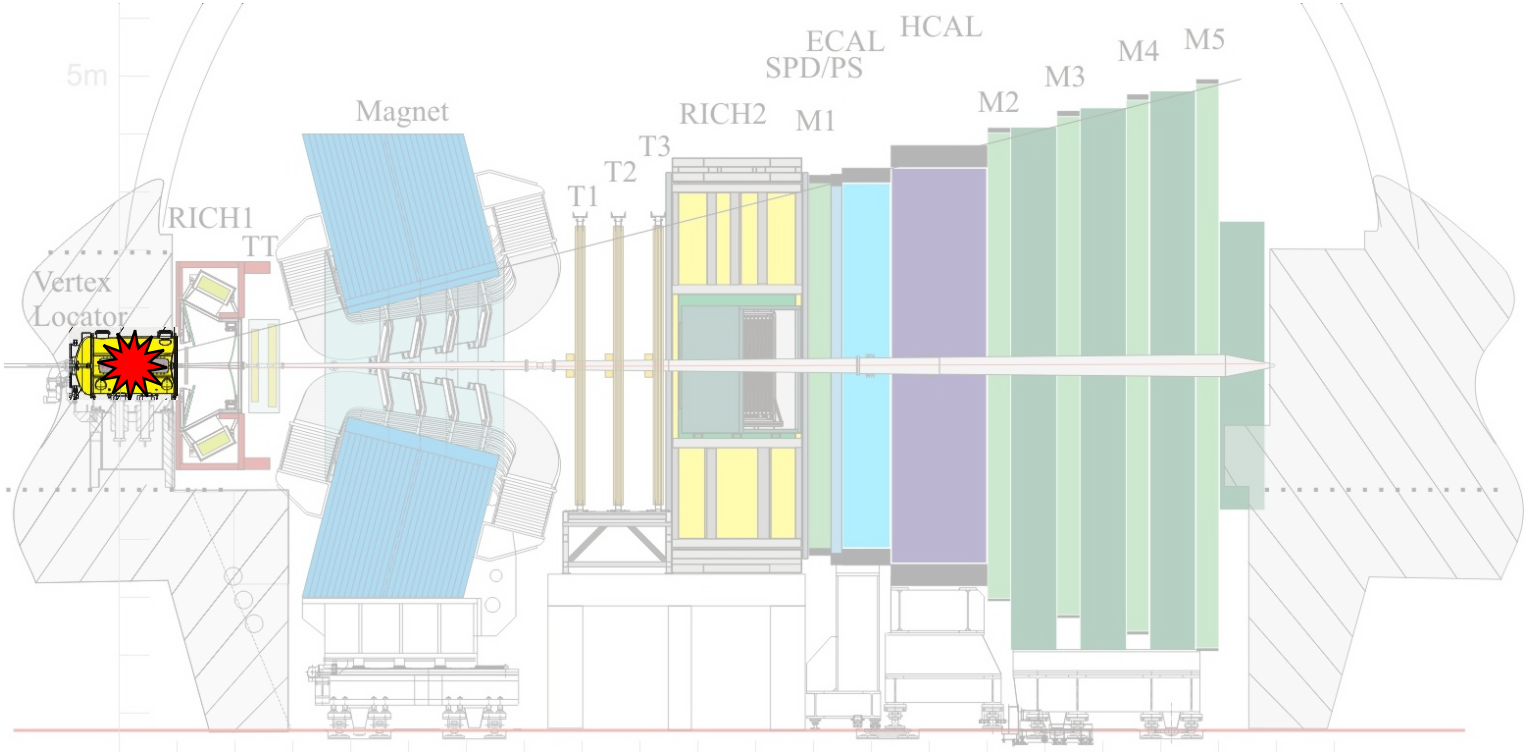


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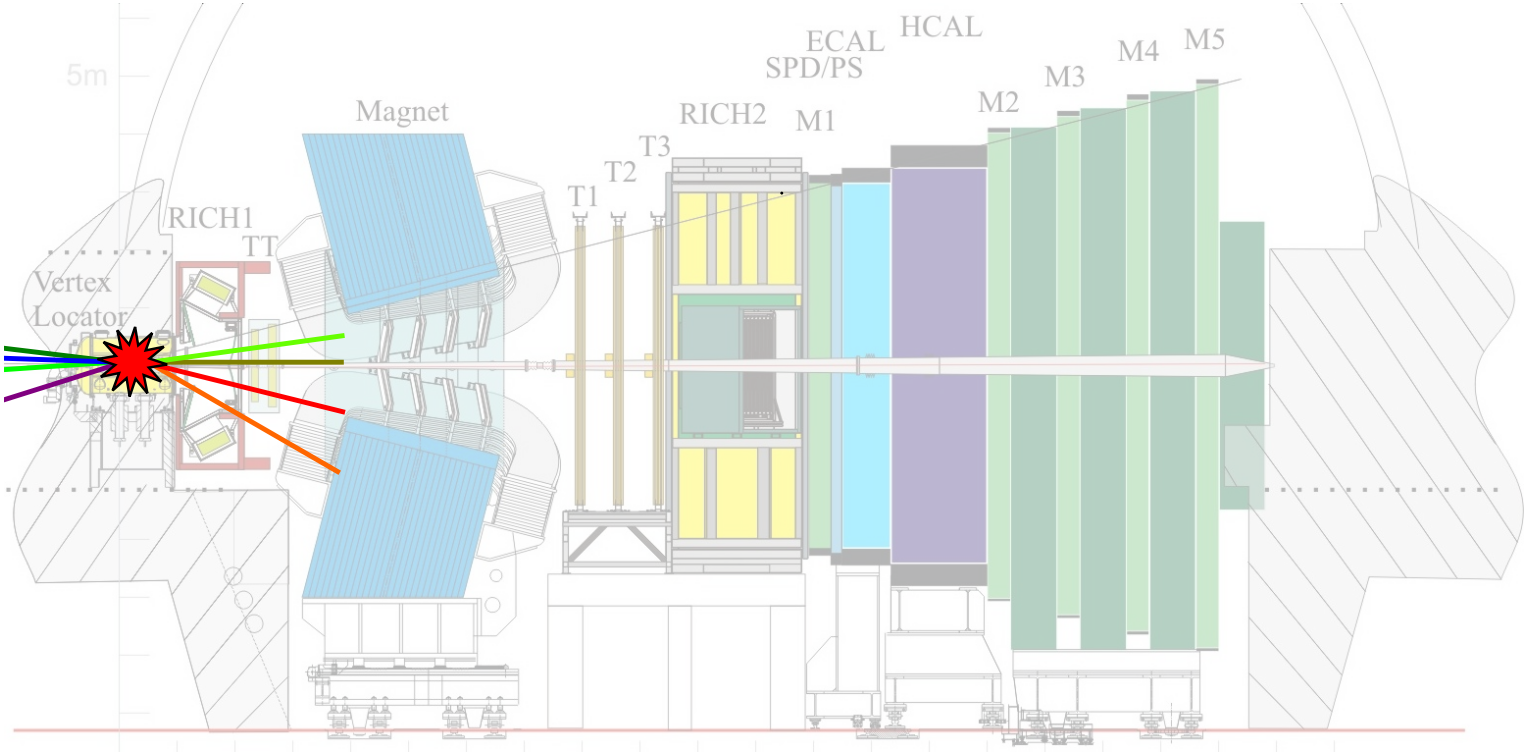


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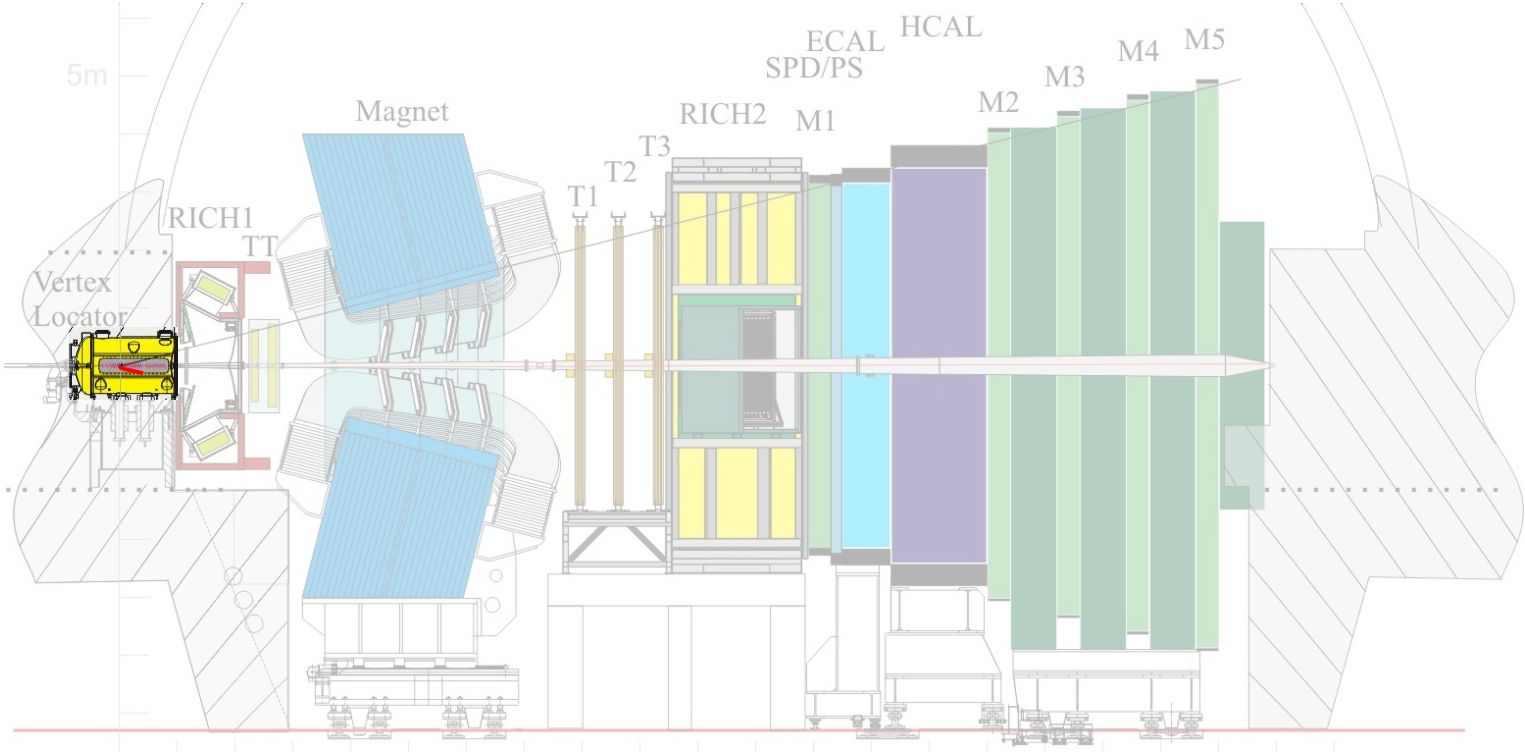


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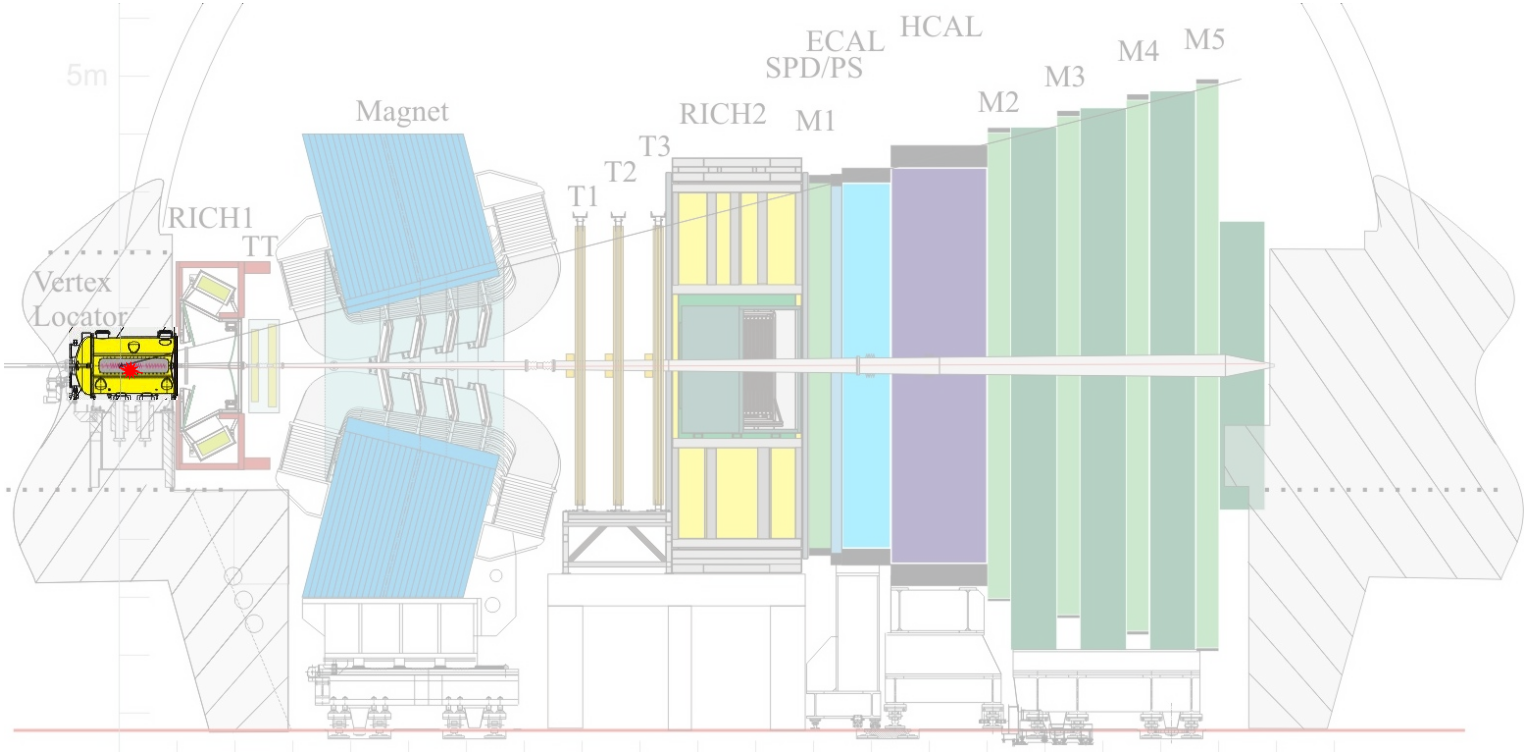


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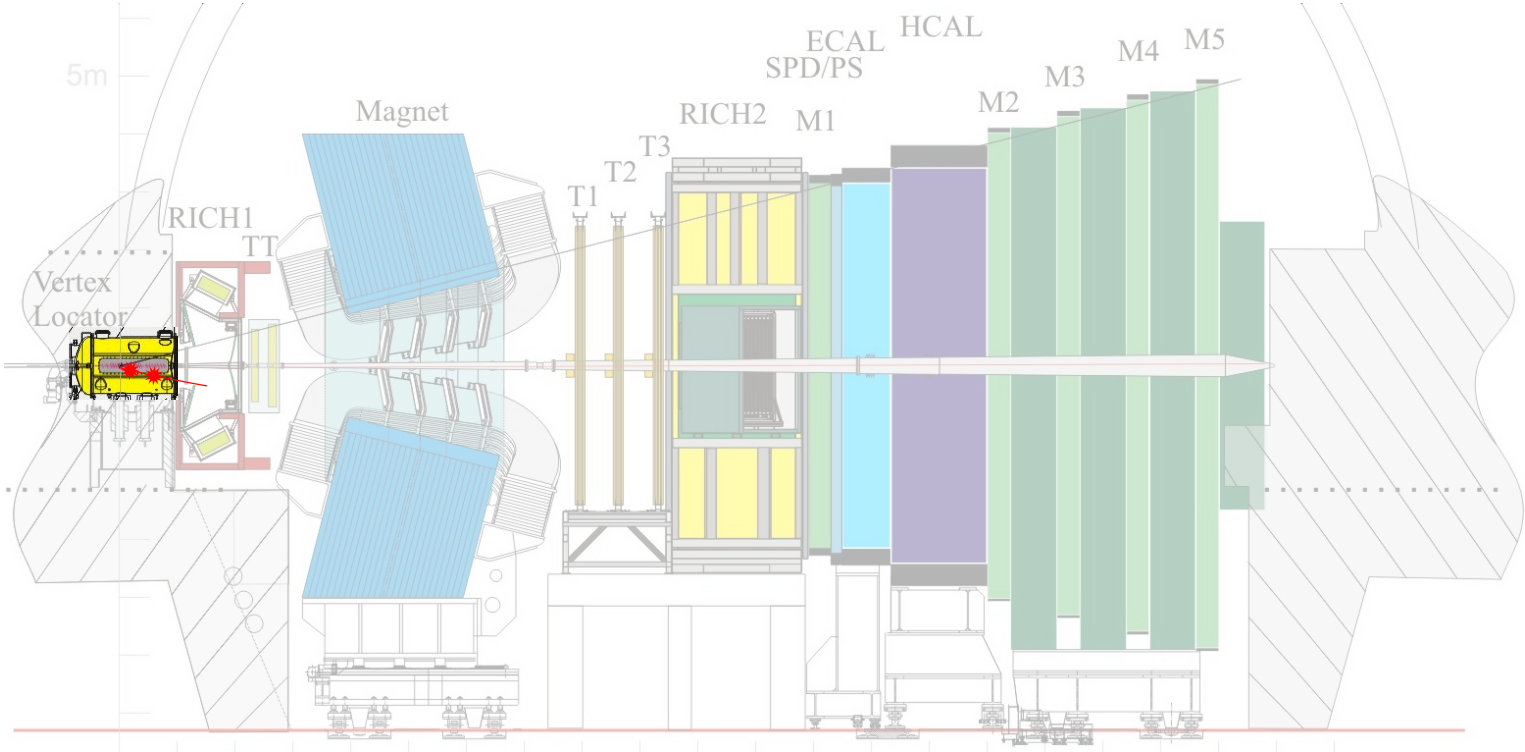


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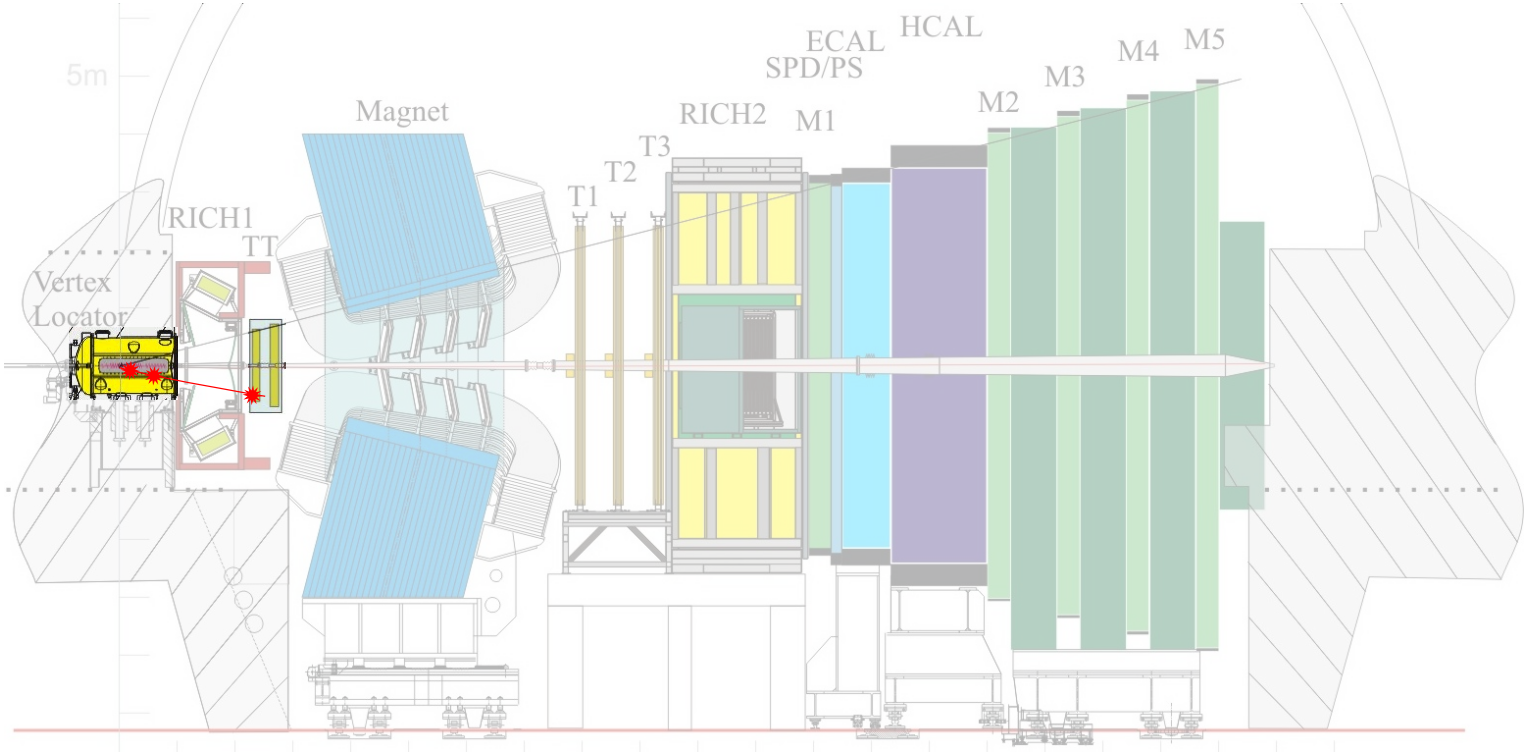


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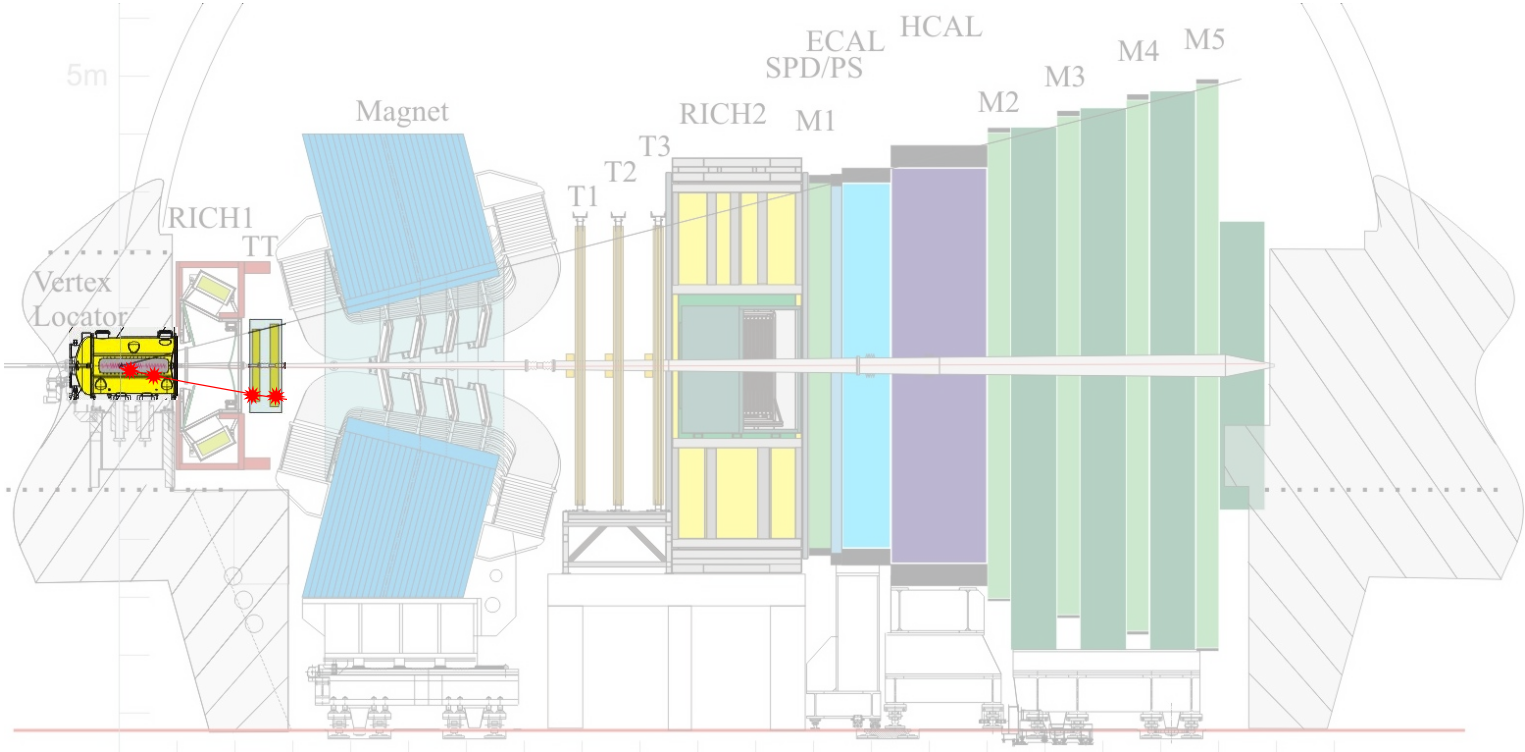


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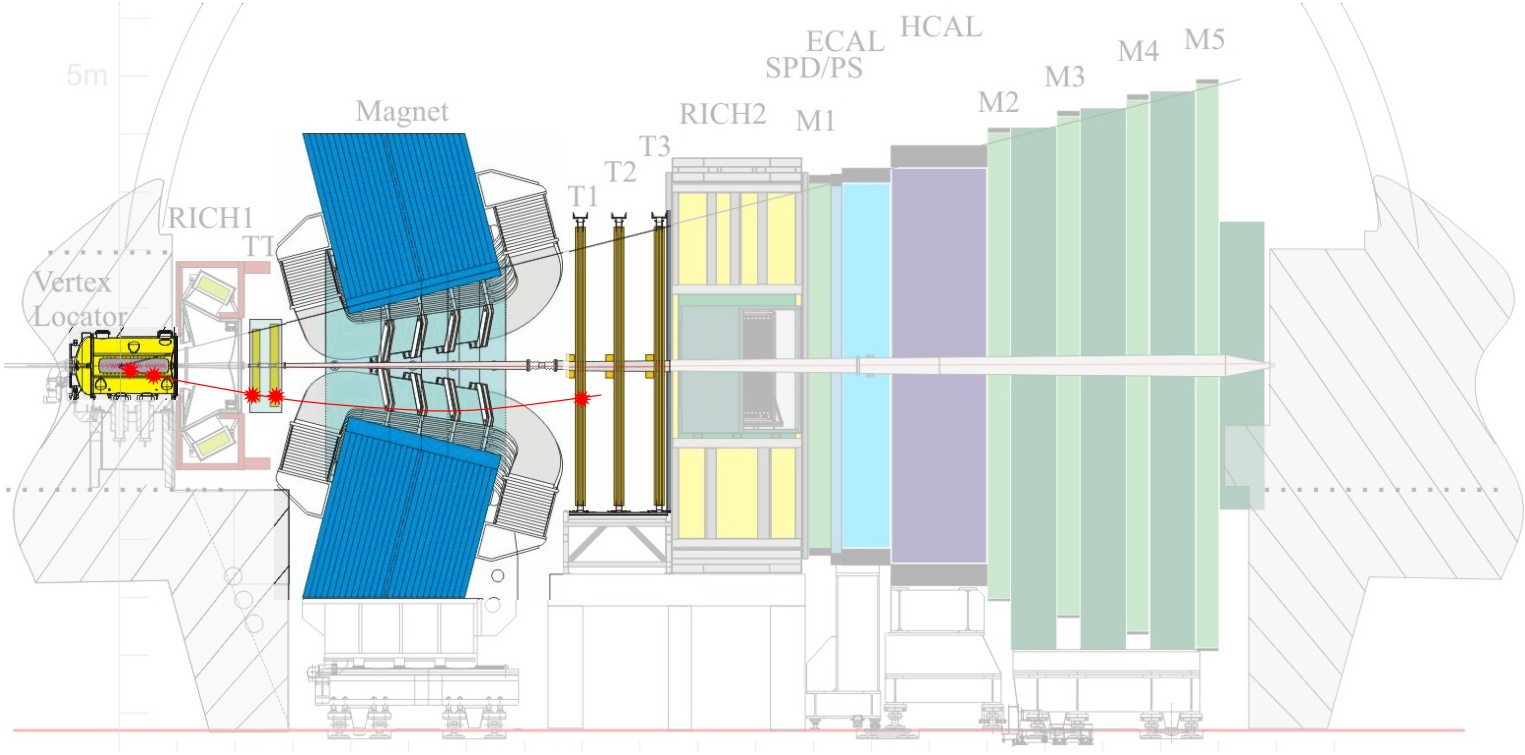


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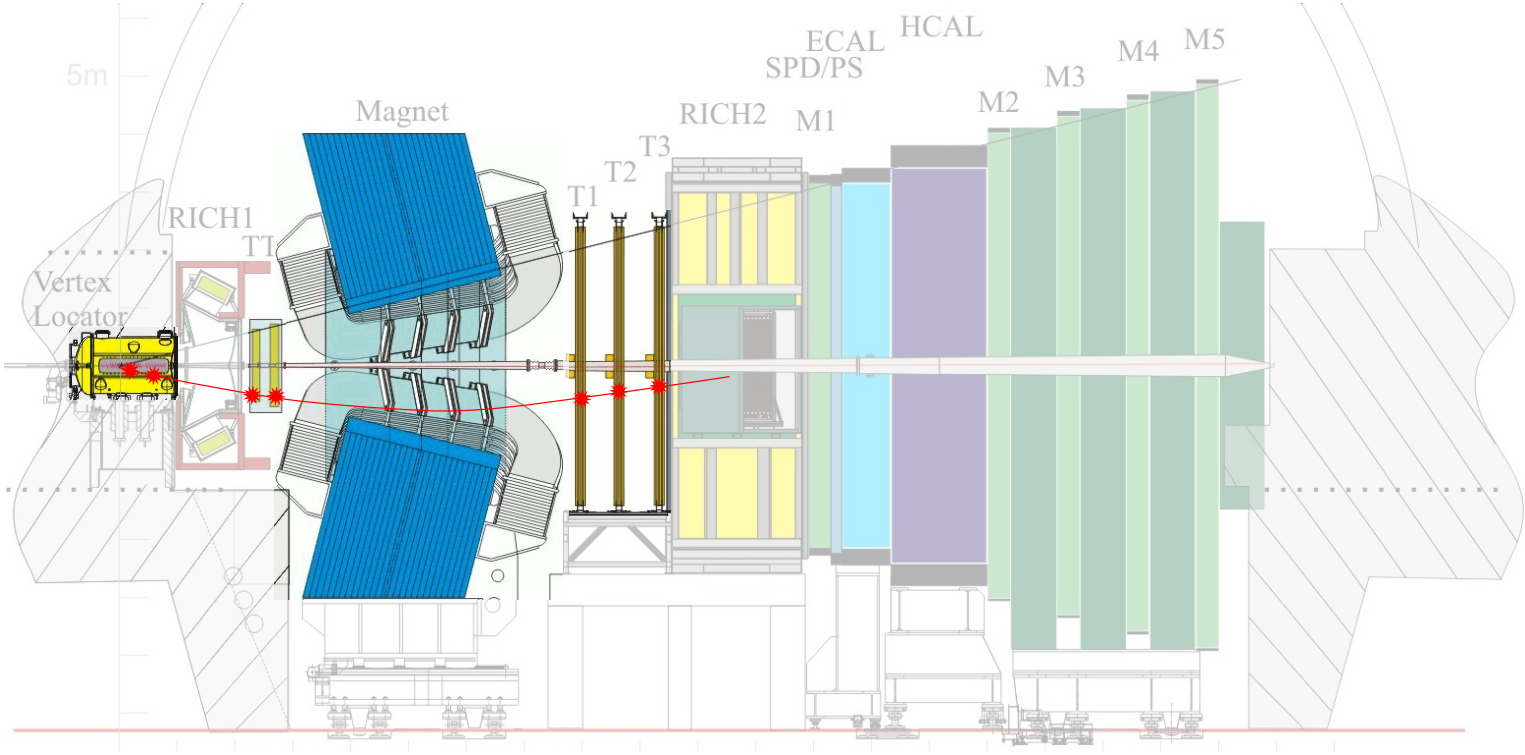


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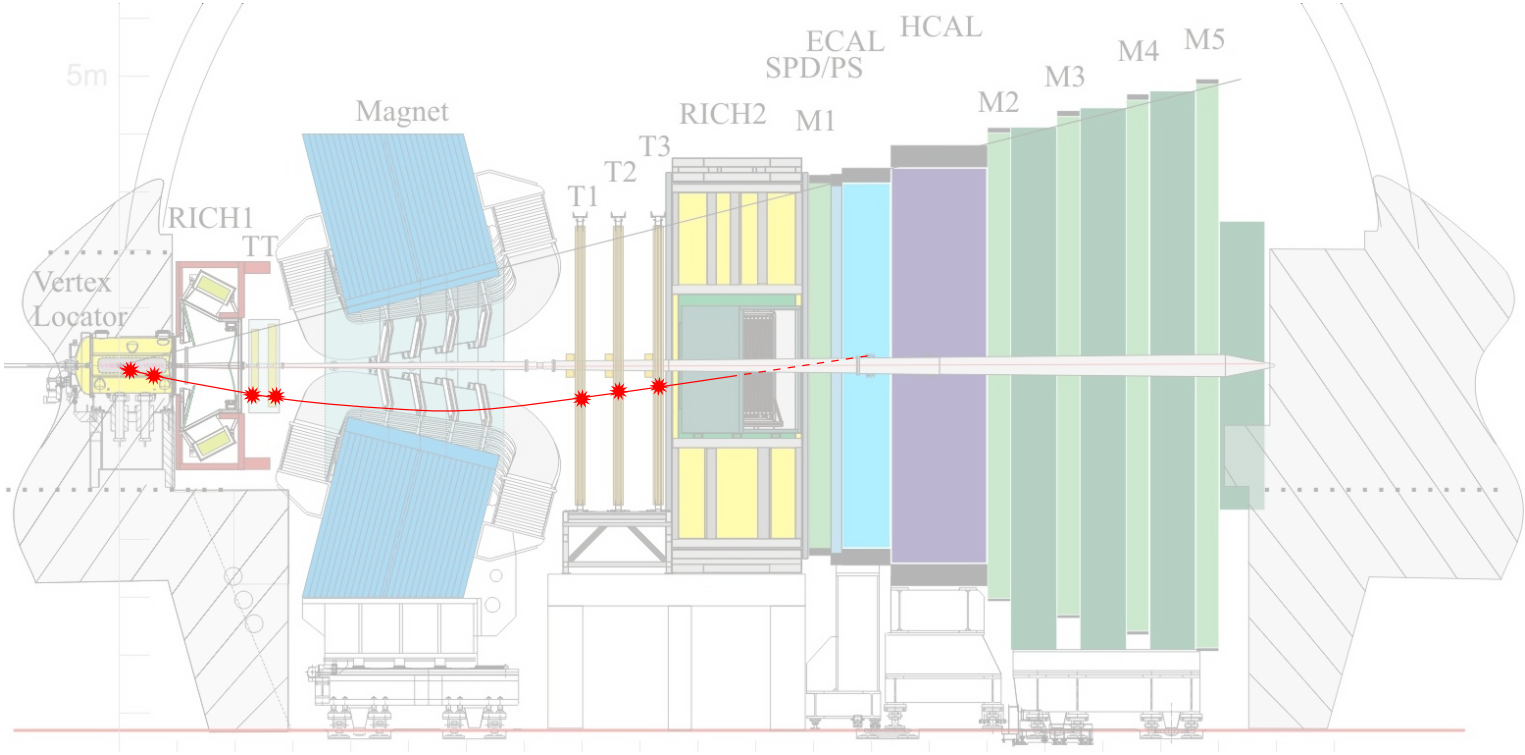


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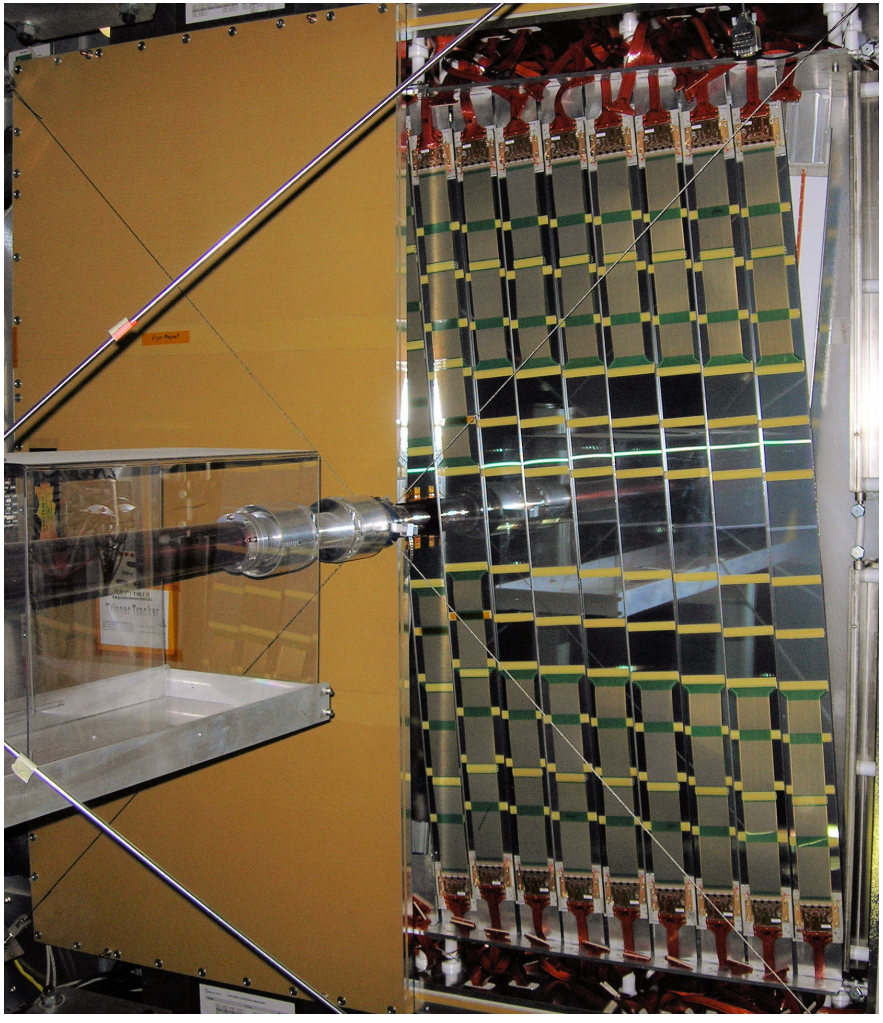
# Silicon Strip Detector



## Detector hardware

- tracking detector
- 4 layers
- 1036 silicon sensors
- 143360 channels in total

## Reading out

- 128 channels in one Beetle readout chip
- 32 channels in one port

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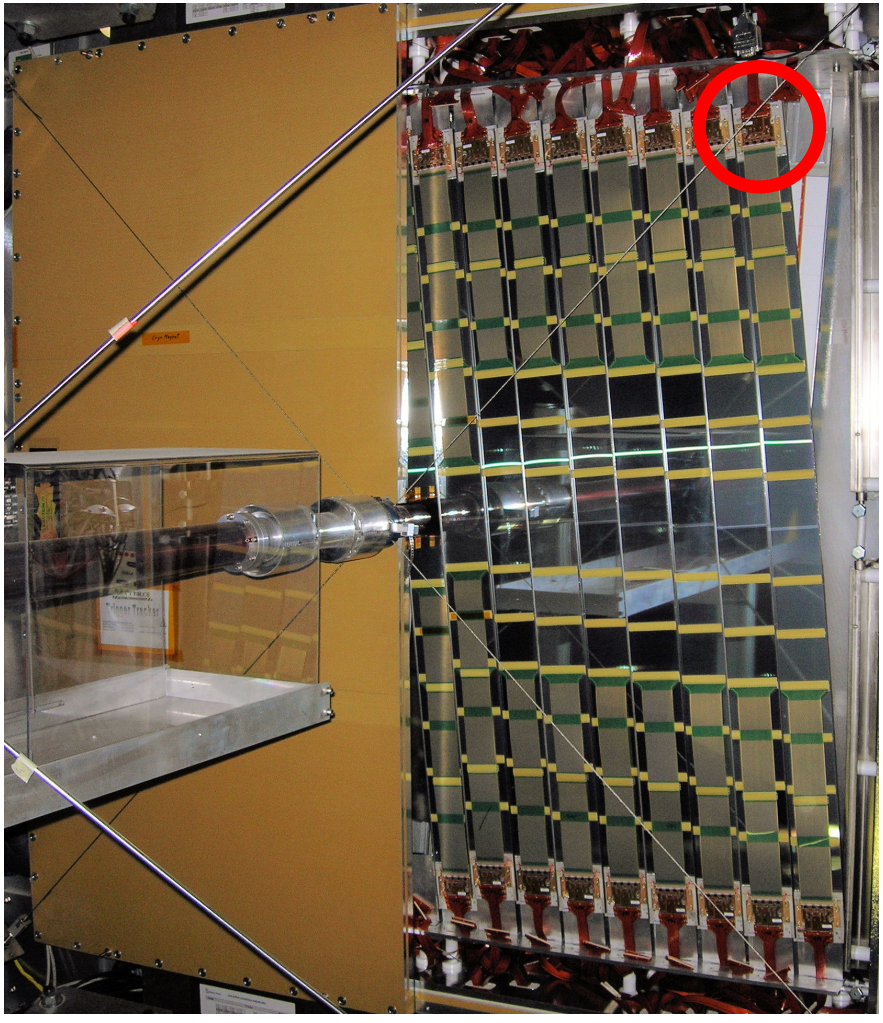

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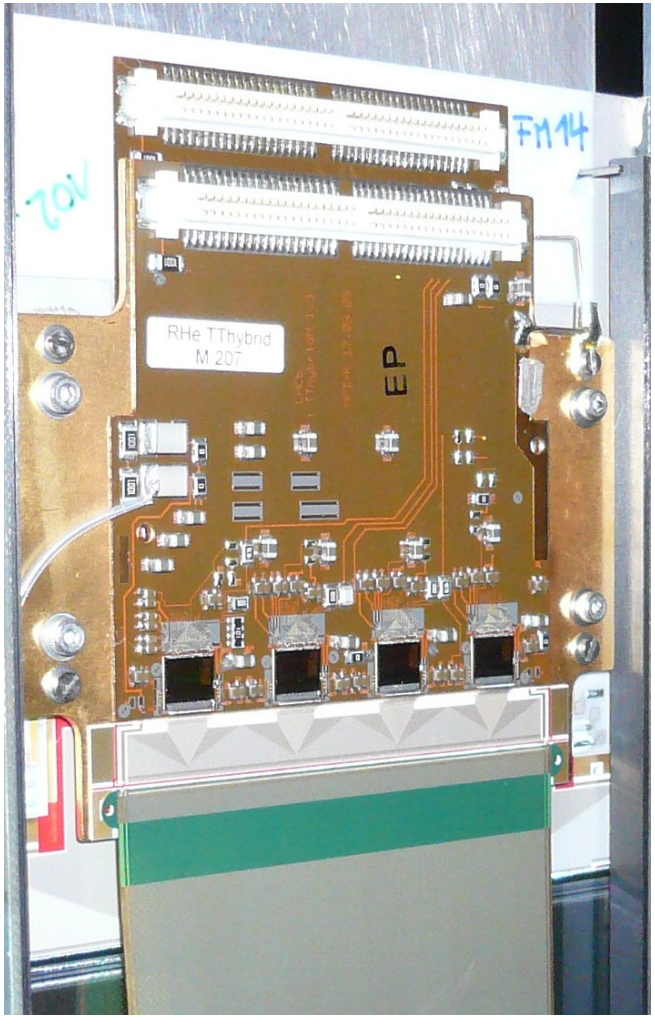


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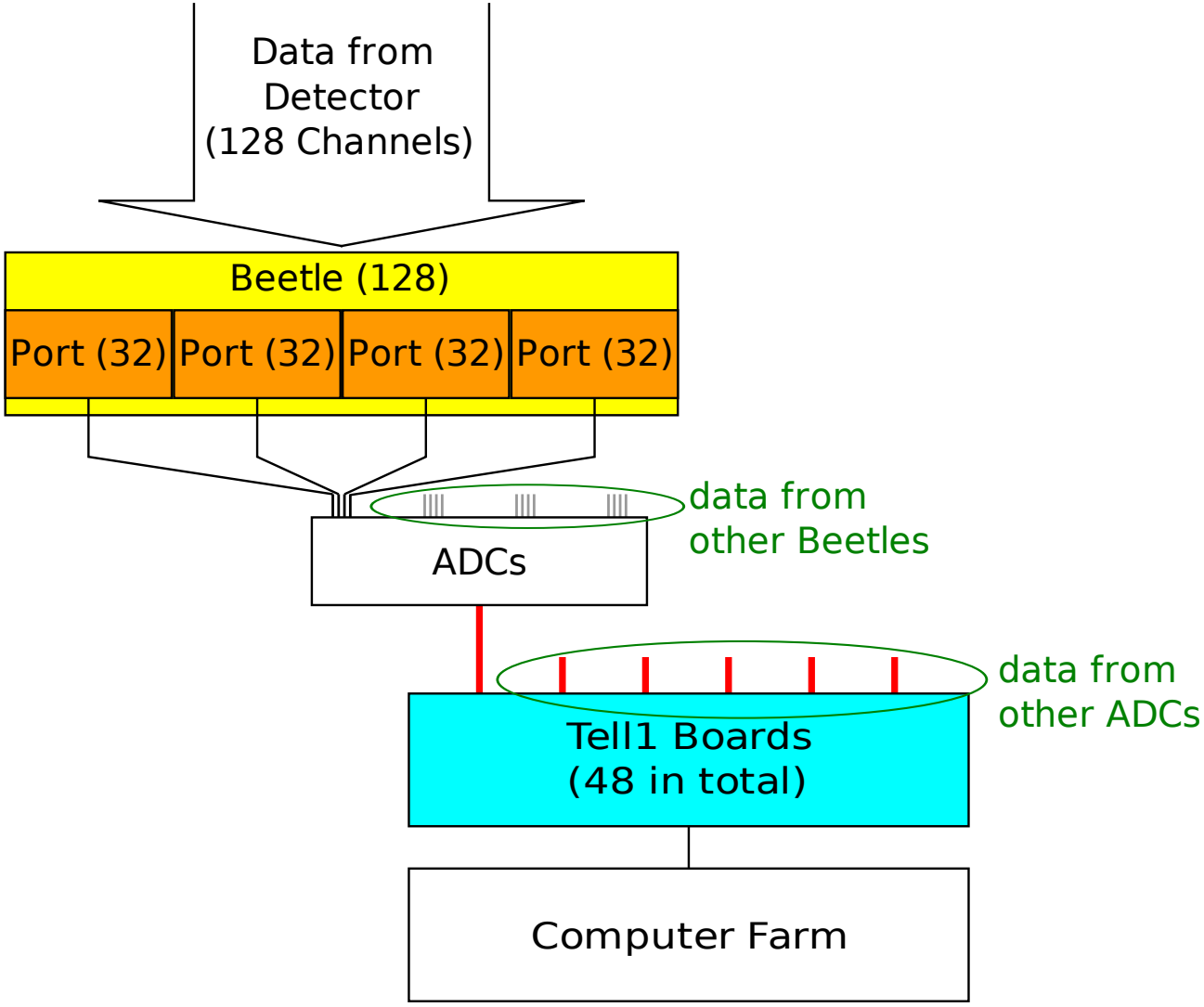
# Readout Electronics

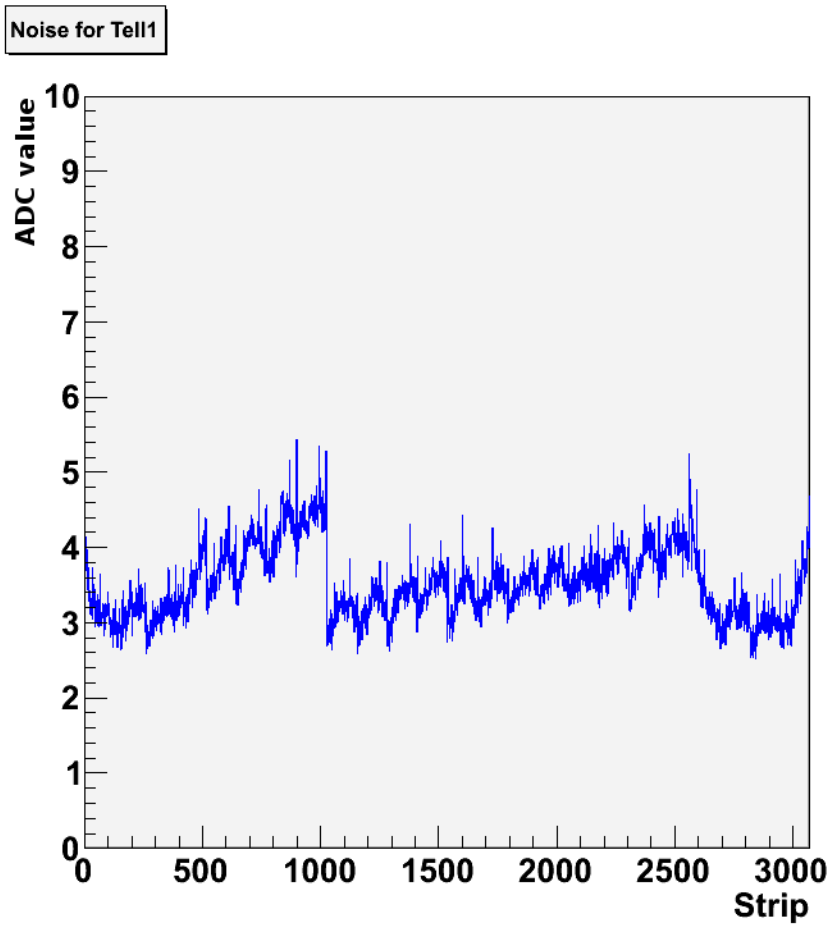


# What did I do?

Part 1: Enhance Online Monitoring

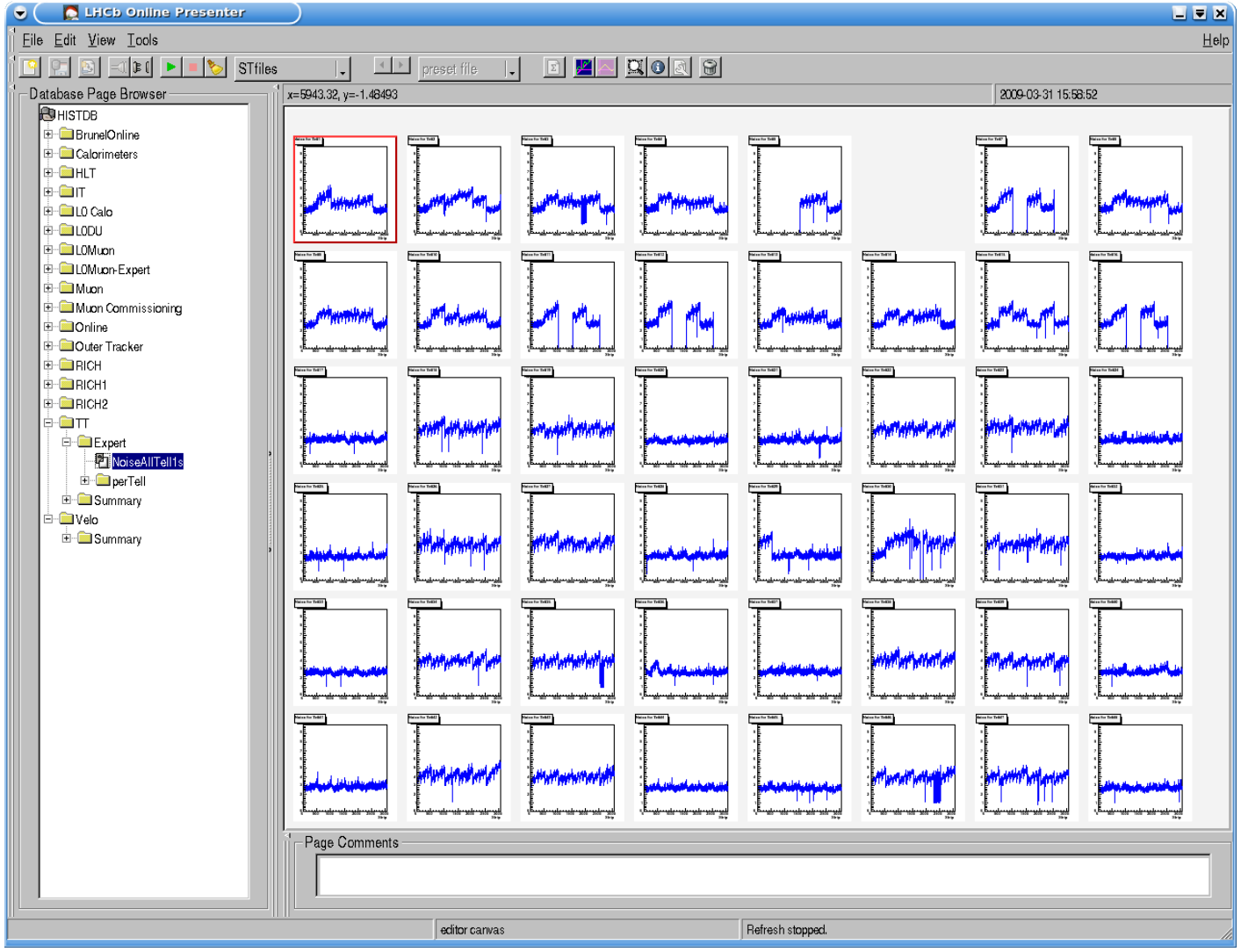
Part 2: Study Common Mode Subtraction Algorithms

# Online Monitoring

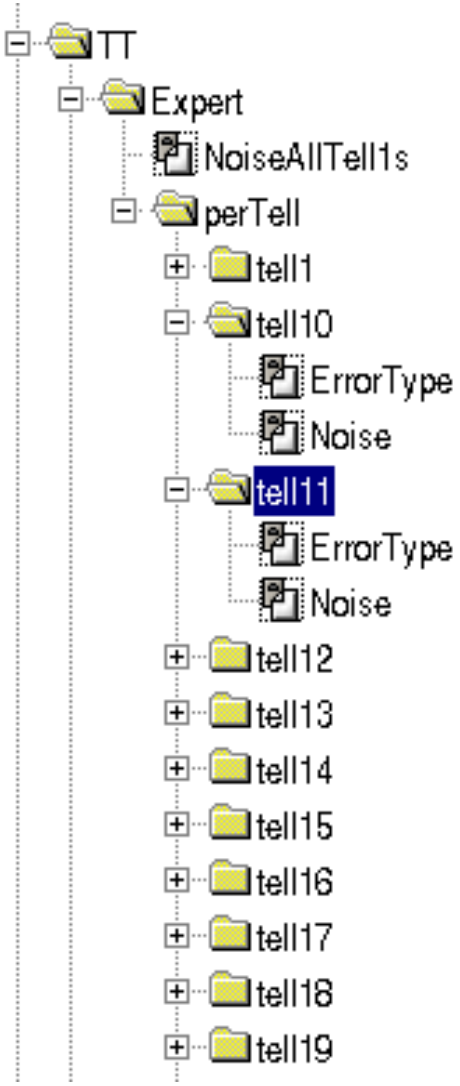



- important to get fast feedback
- continuously analyse data
- create histograms (e.g. of noise)
- display for person on shift

# Display Monitoring Pages



# Tool to Automate Configurations




- 48 Tell1 boards
- create pages per Tell1 board
- very tedious and error prone to setup by hand

- implemented tool to automate
- tool is not TT specific
- already used by two other subdetectors

# Example Code

```
folderBase = "Expert/perTell/tell"
page       = "Noise"

histoSet   = "CMS/cms_$tell"
histoNum   = range(1, 49)

for num in histoNum:
    id = str(num)
    createHistAlg.PageNames.append(
                  "/"+folderBase+id+"/"+page)
    folderHistos = []
    folderHistos.append(histoSet+id)
    createHistAlg.HistoNames.append(folderHistos)
```

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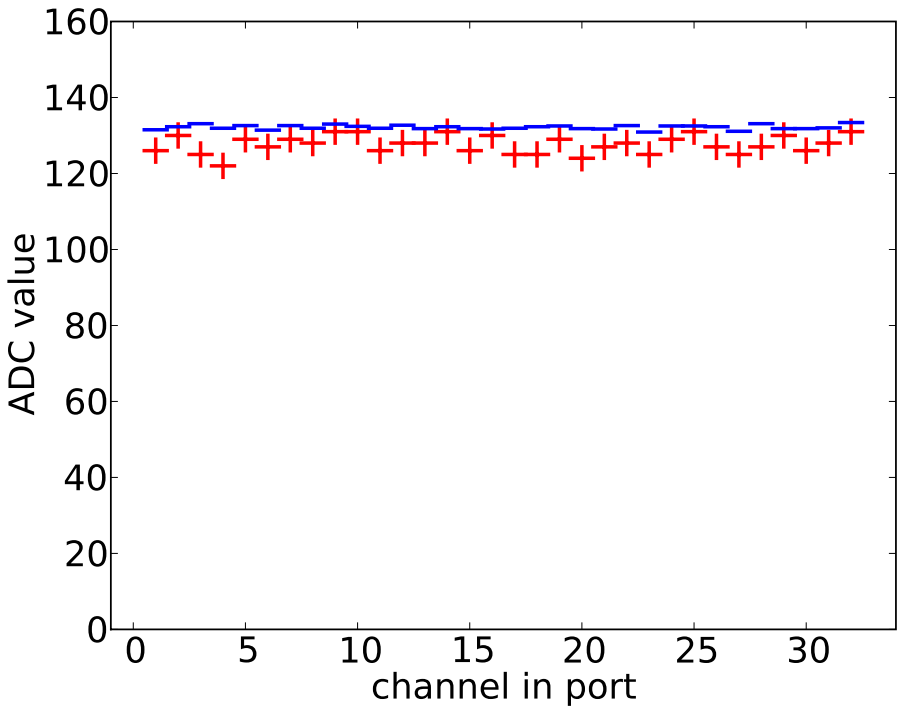
# Raw Noise




- readout registers ADC value even without particle
- ADC value fluctuates around pedestal
- pedestal different for each channel
- pedestal is subtracted
- rms of this fluctuation: raw noise

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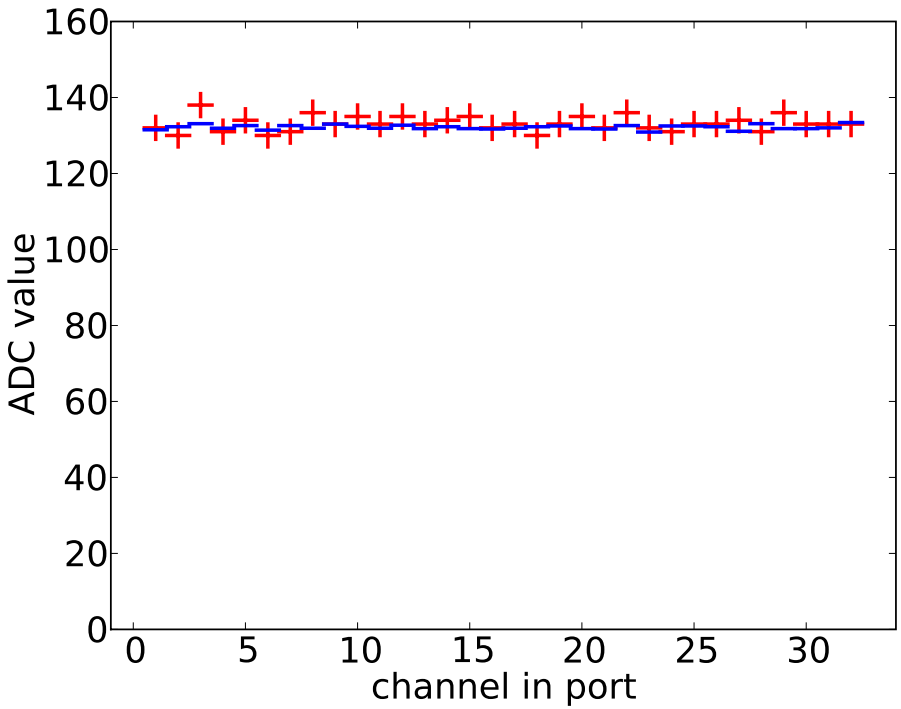


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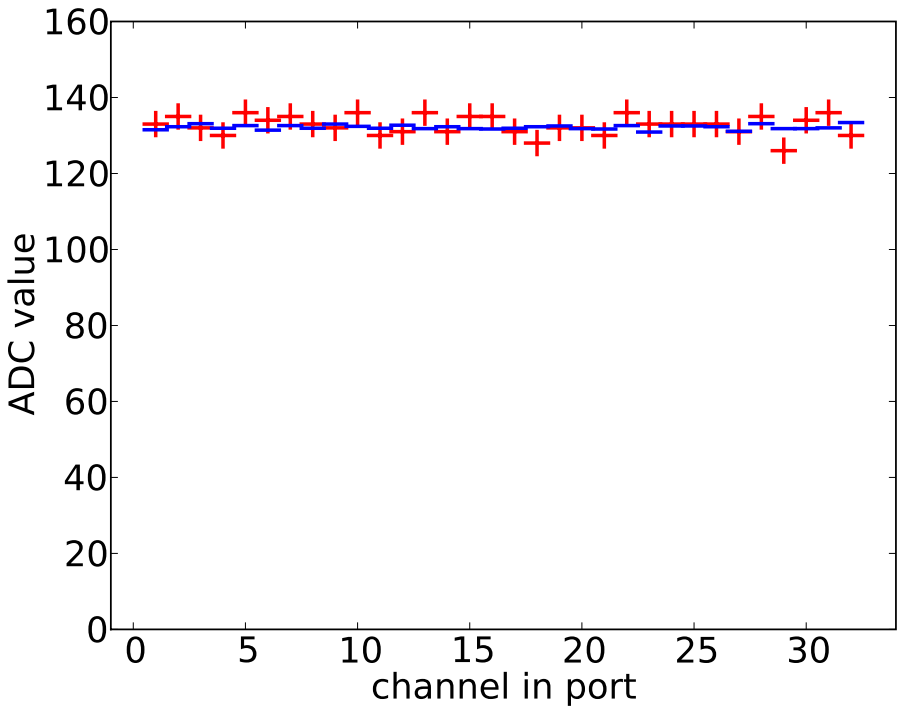


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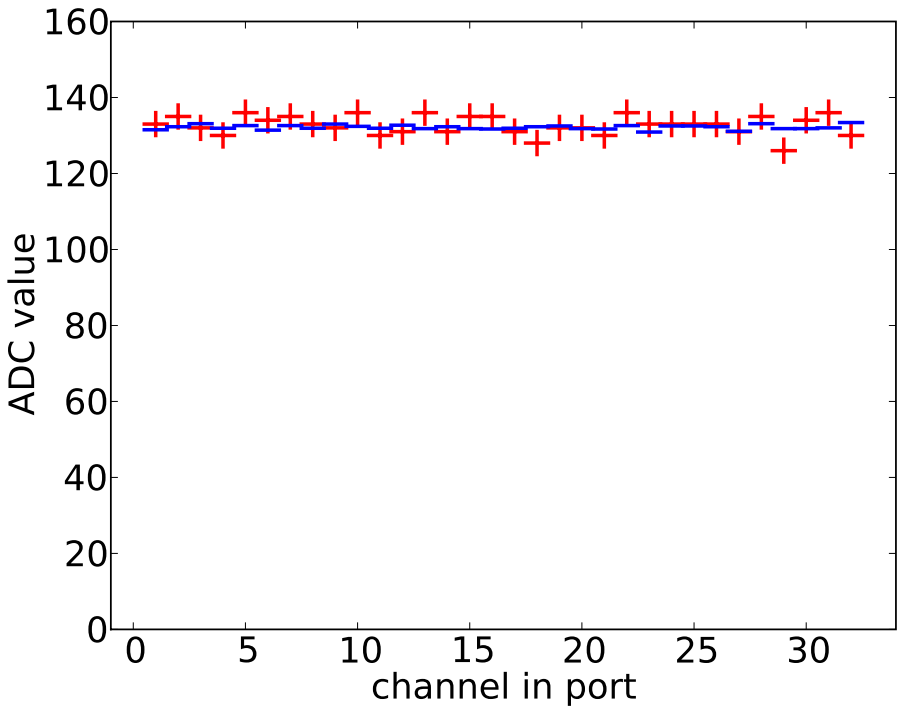


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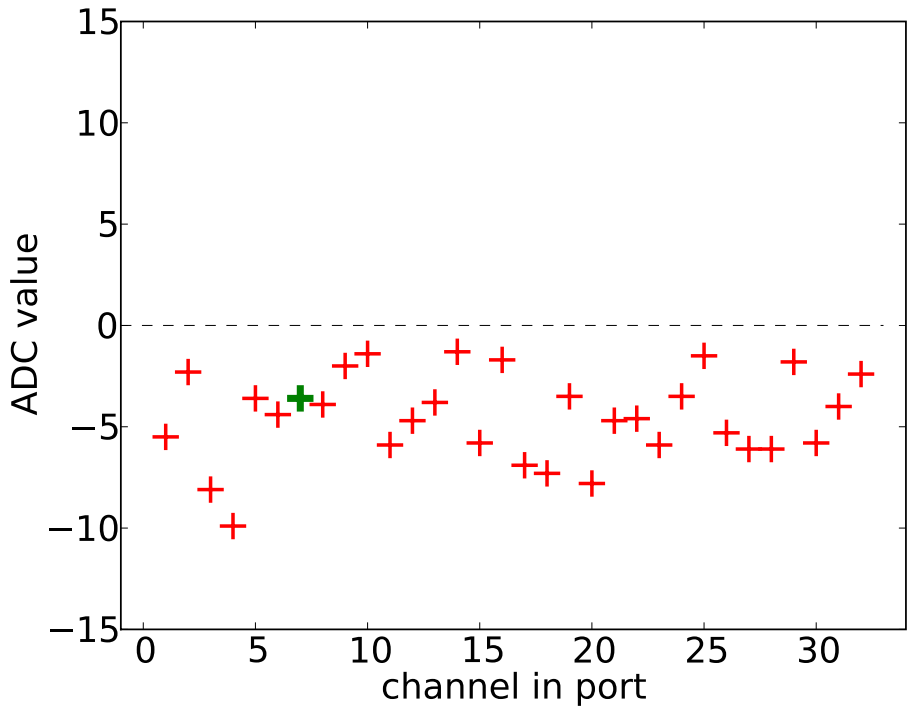


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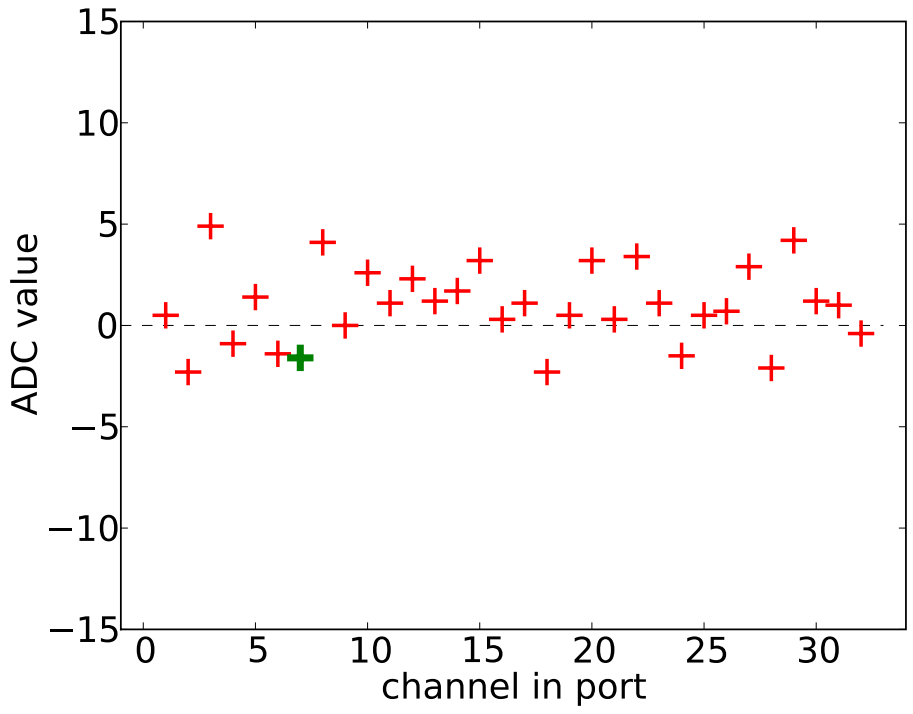


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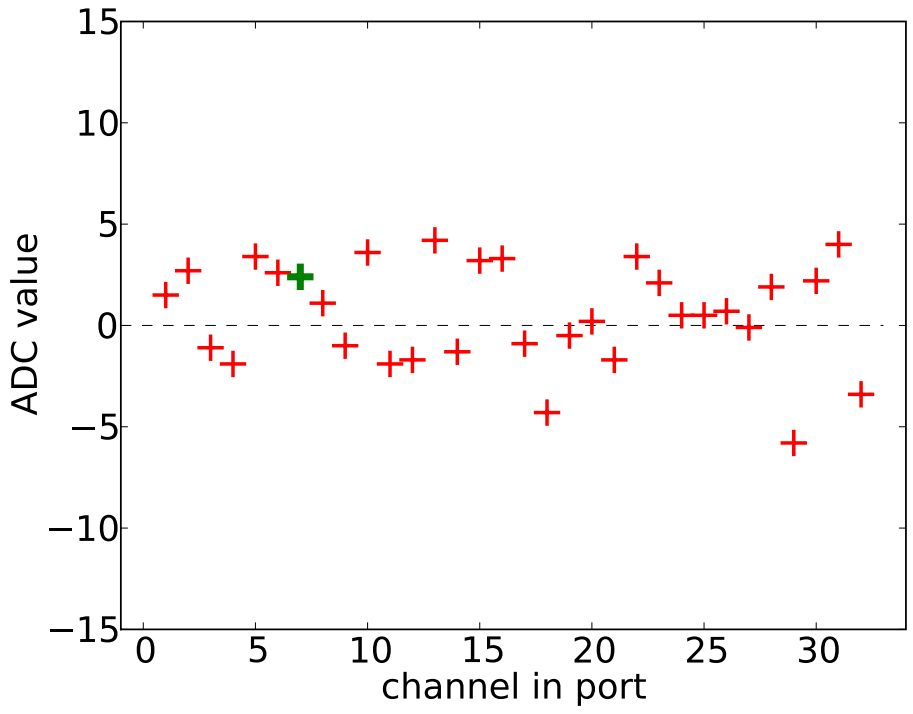


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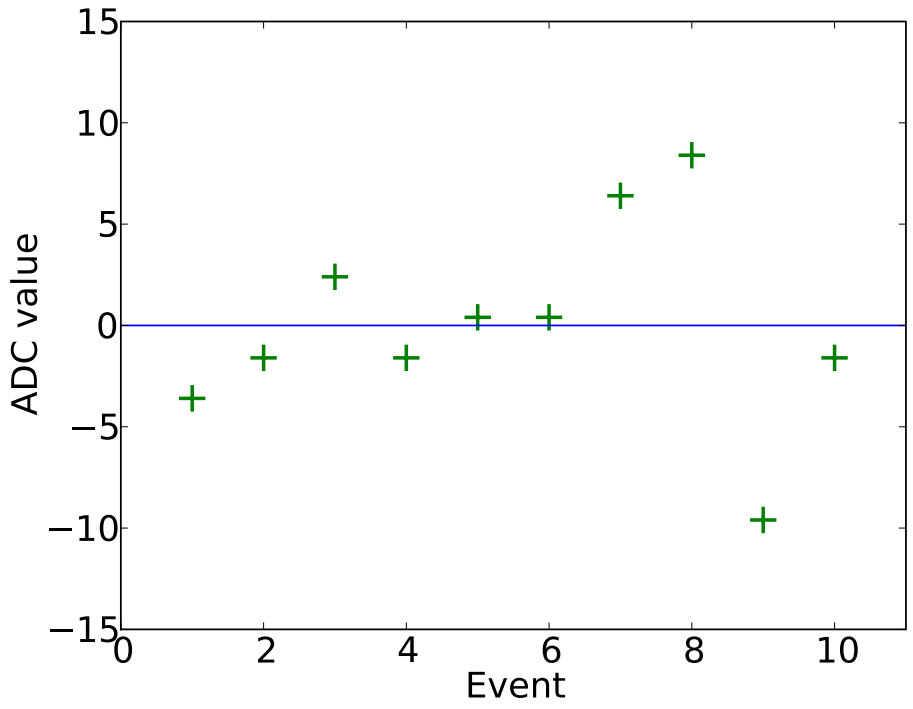


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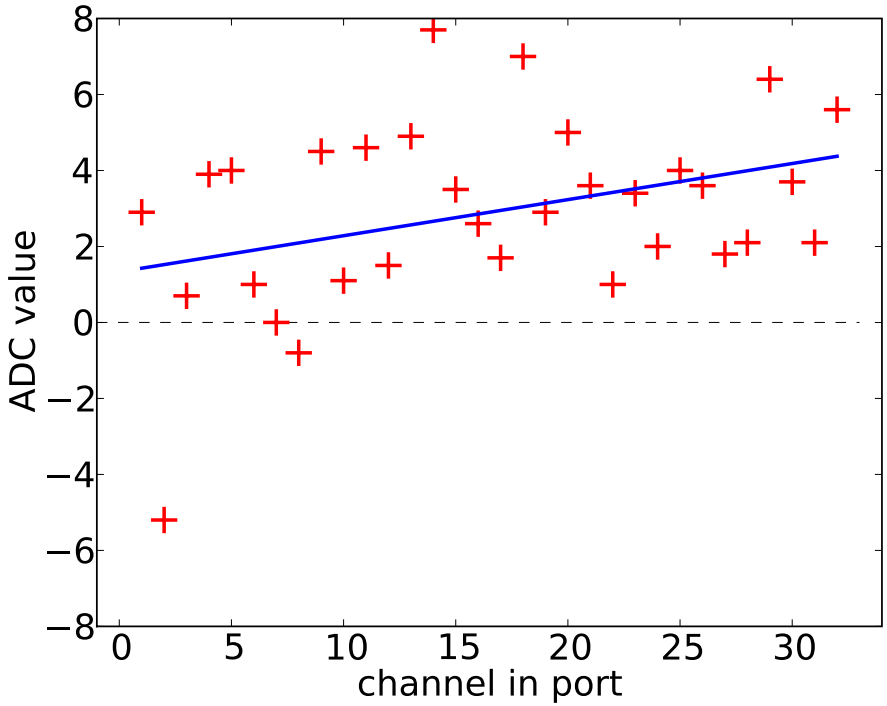
# Common Mode Subtracted (CMS) Noise




- after subtracting pedestal
- common mode:
  - linear effect on all channels
  - different for each event
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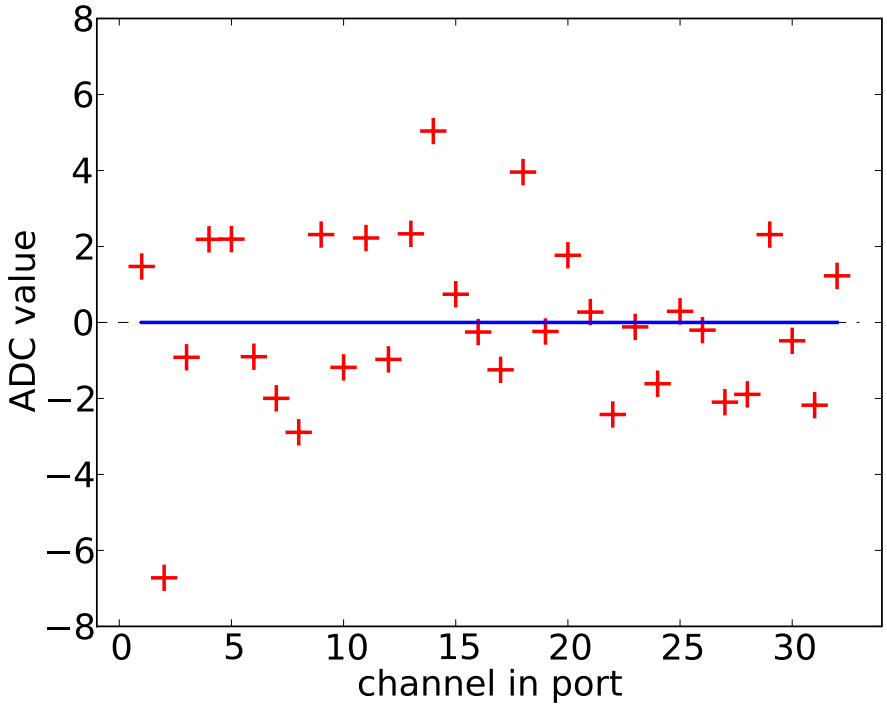


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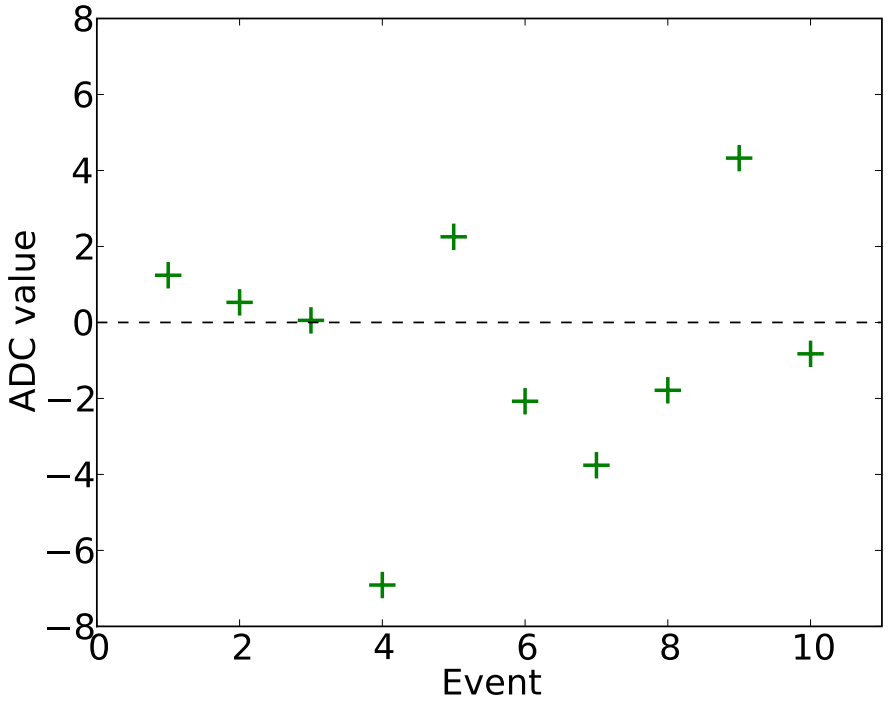


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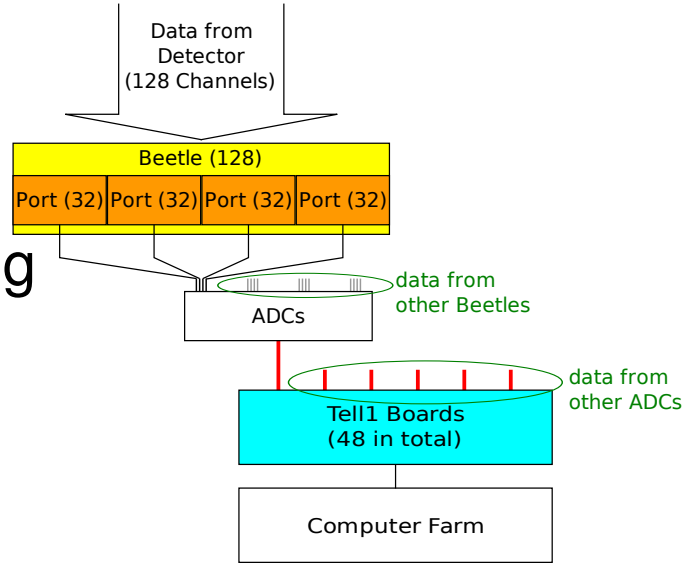
# Comparing Algorithms

## Common Mode calculation

- done on the Tell1 boards
- additionally implemented for monitoring




## Studied configurations

- 3 different algorithms
- 7 different implementations
- many different parameters
  (e.g. pedestal calculation, hit detection)

## Selected results presented below.

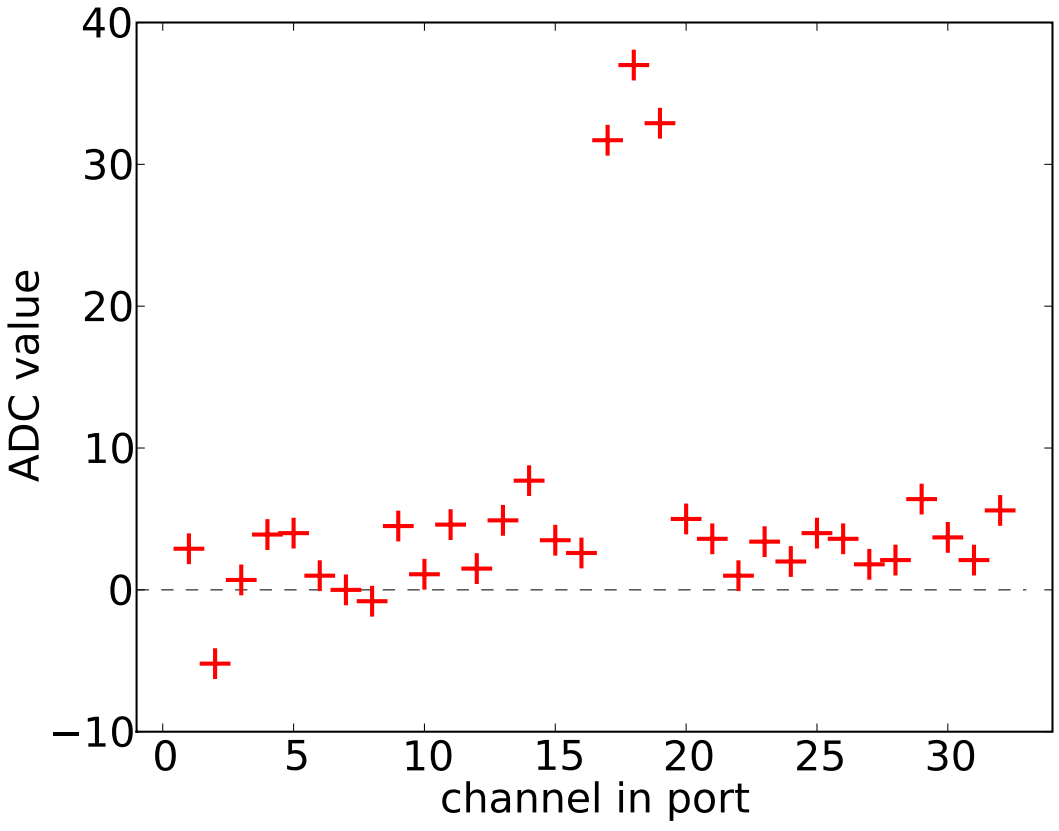
# Looking at Two Algorithms

1. explain the two algorithms
2. compare results for different numbers of hits

## ST algorithm

- implemented on Tell1 board at the moment
- strongly motivated by limitations on Tell1 boards
  - no floating point arithmetic
  - limited resources
  - only divisions by powers of 2

# ST Algorithm




1. calculate mean
2. subtract mean
3. detect hits
4. set hits and neighbours to zero
5. calculate new mean
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7. fit straight line (using least-squares)
8. subtract line

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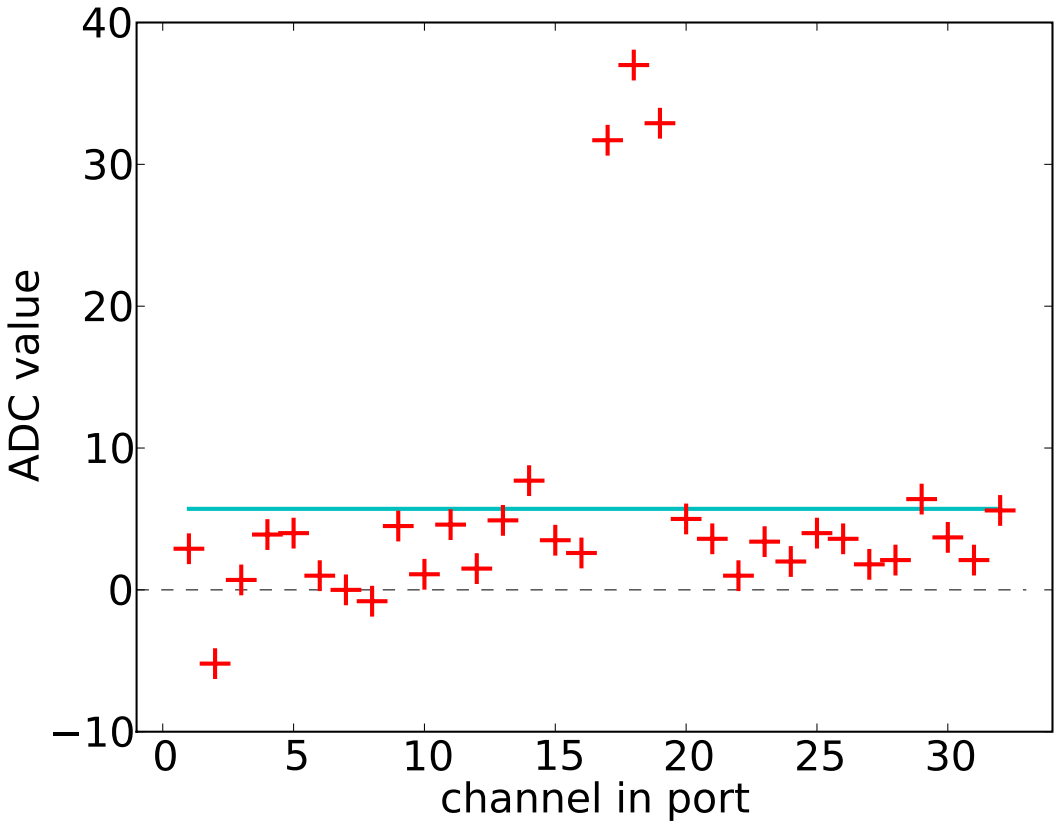


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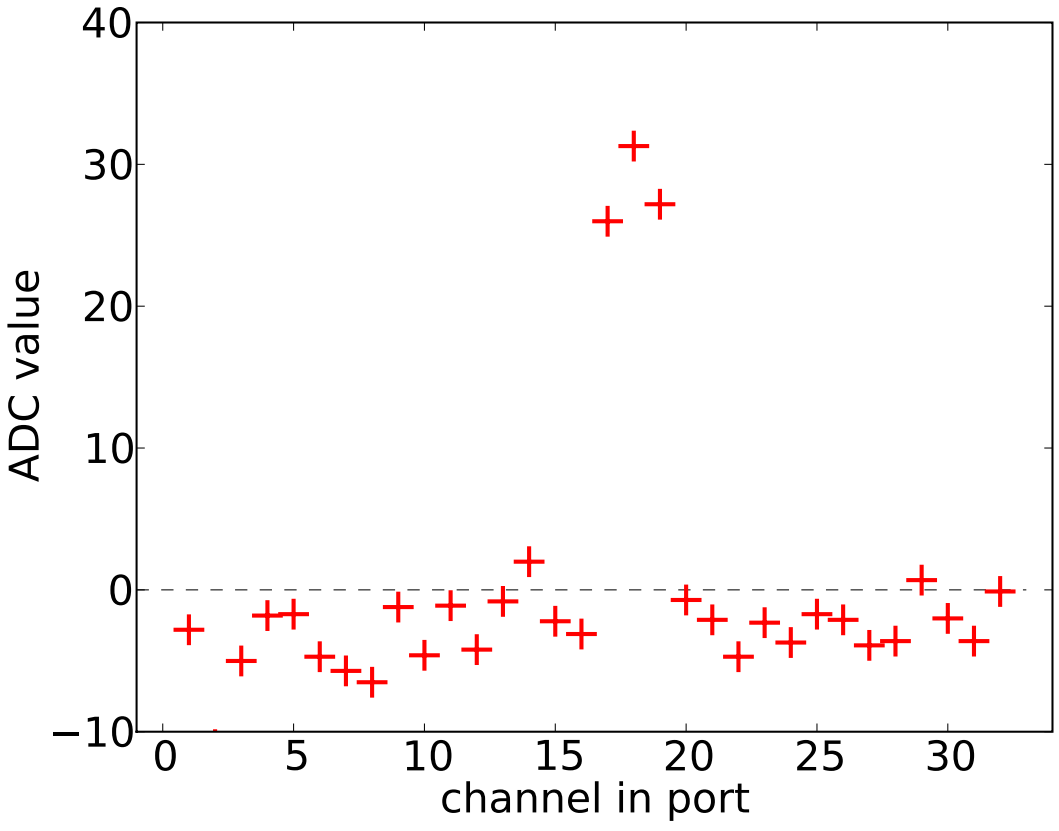


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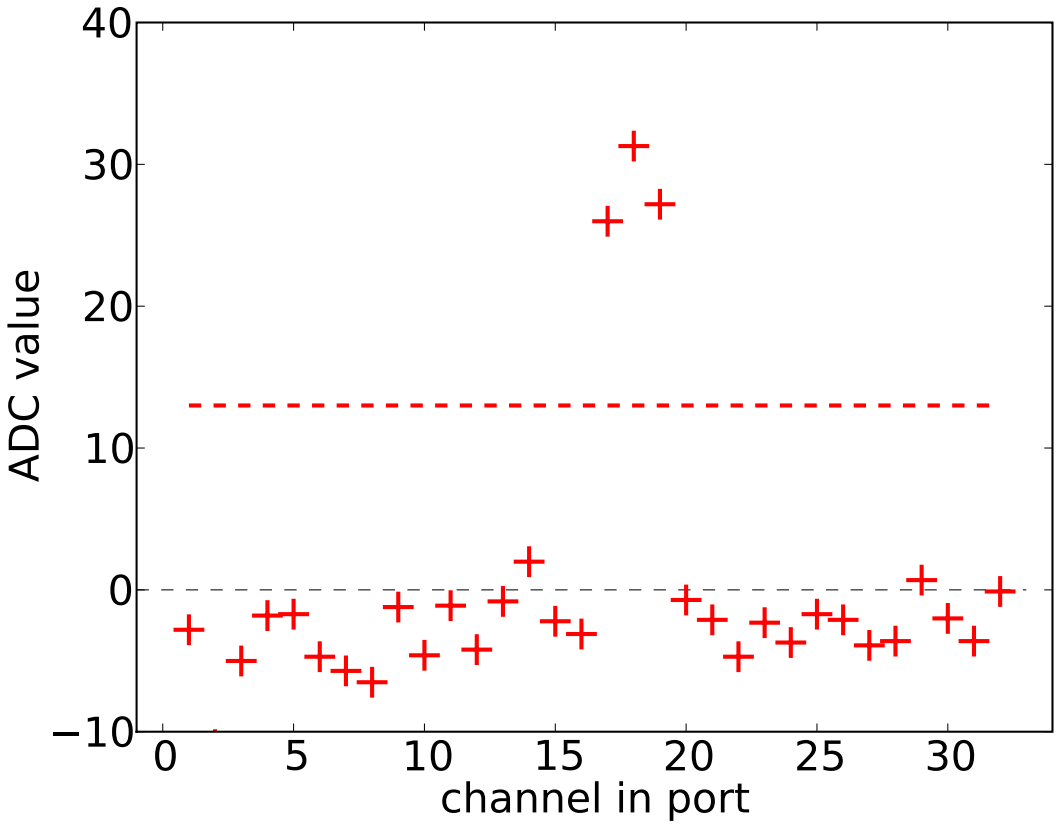


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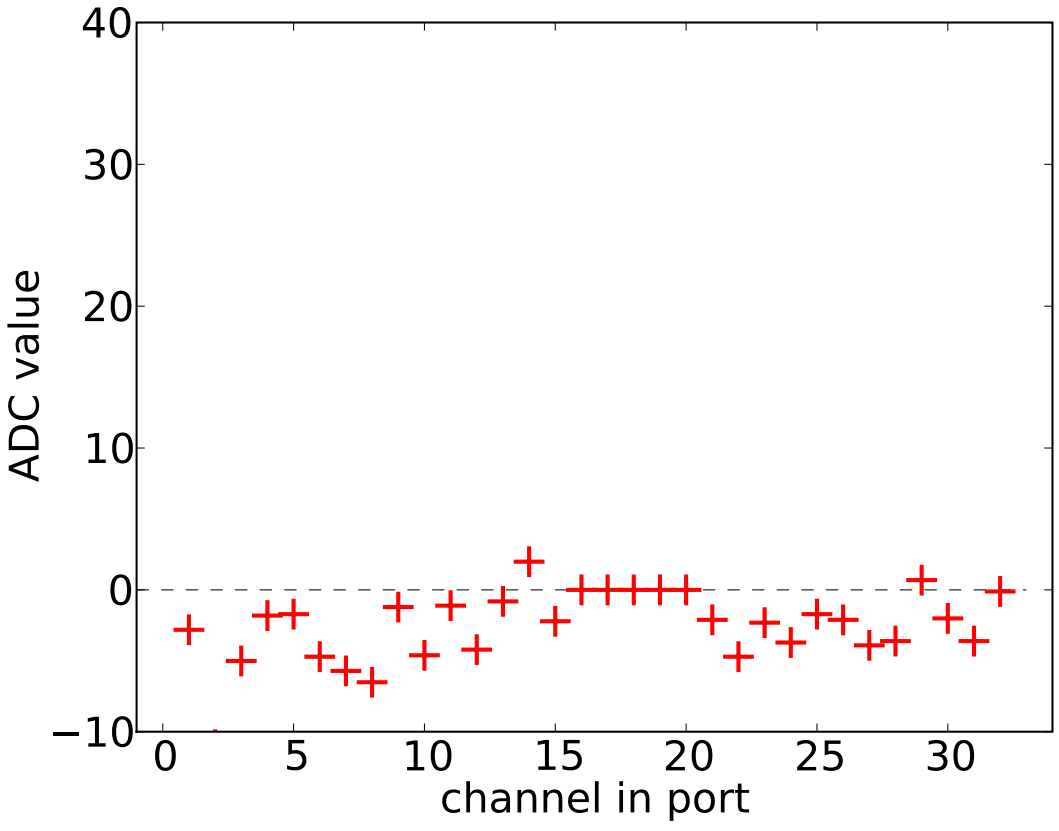


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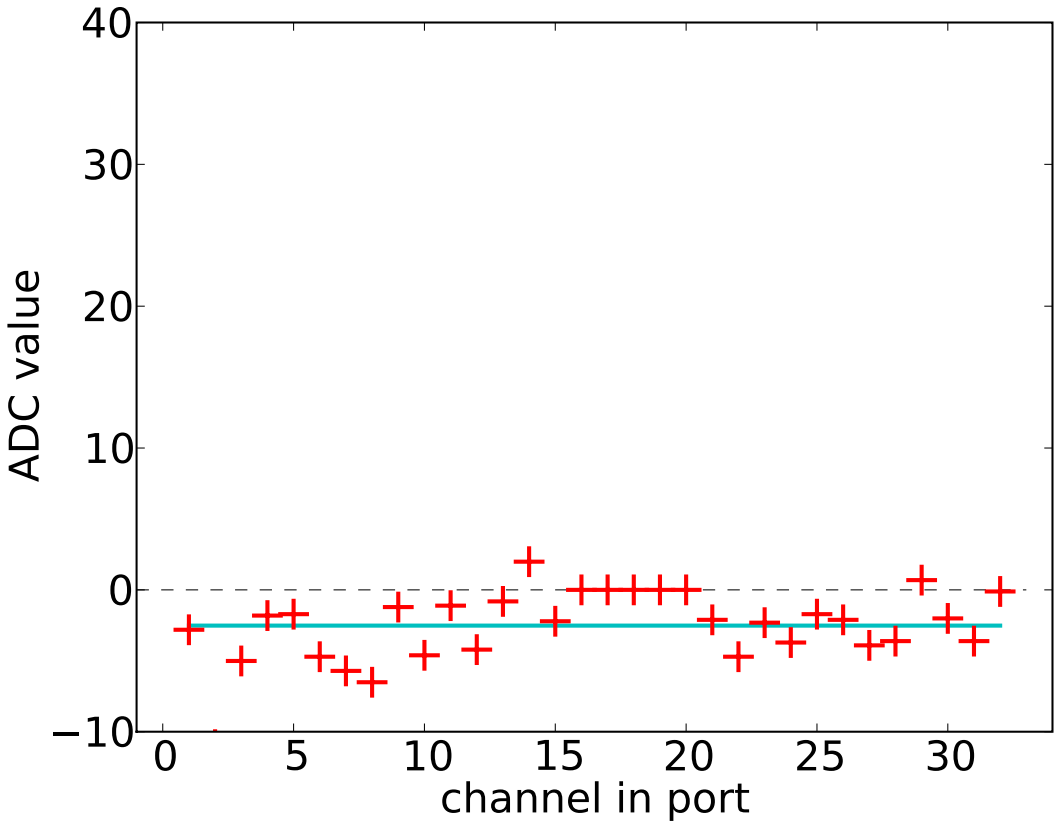


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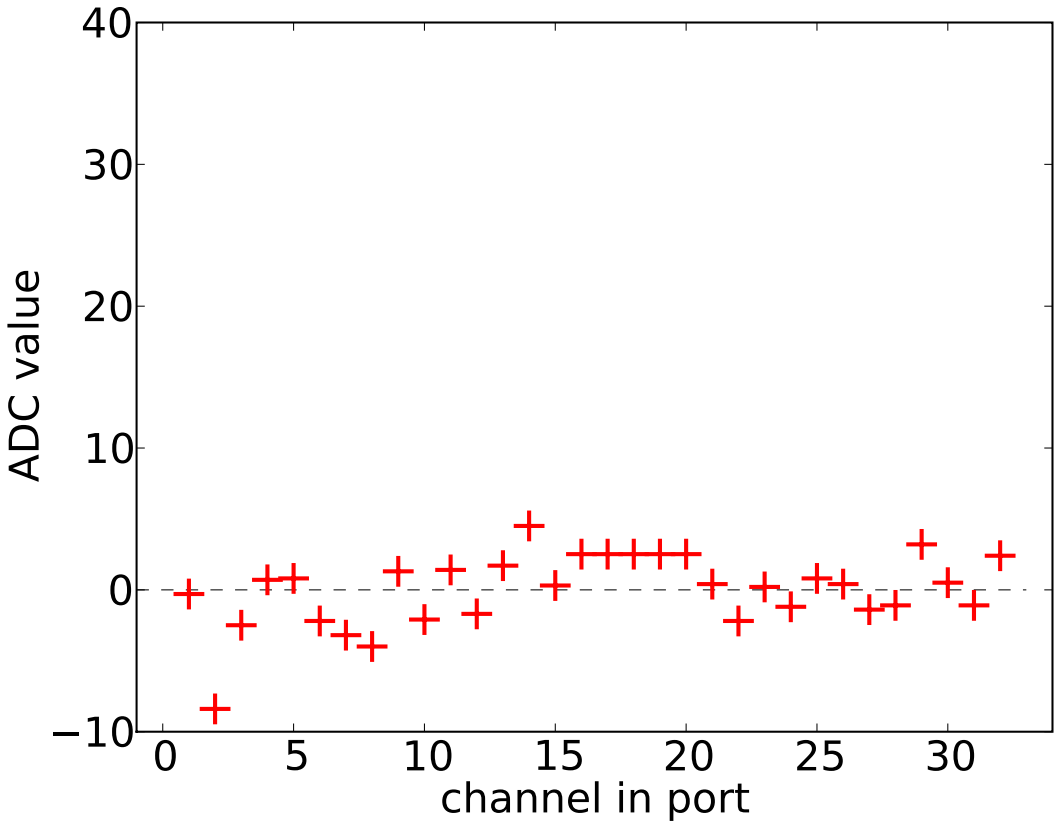


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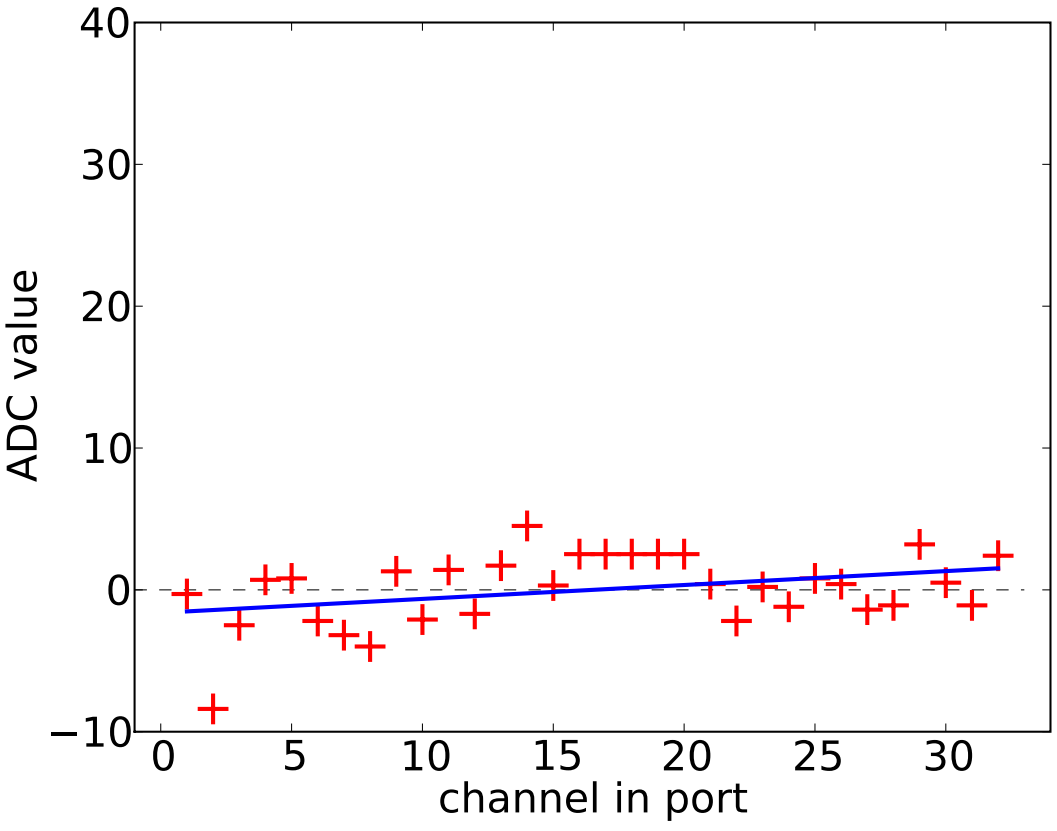


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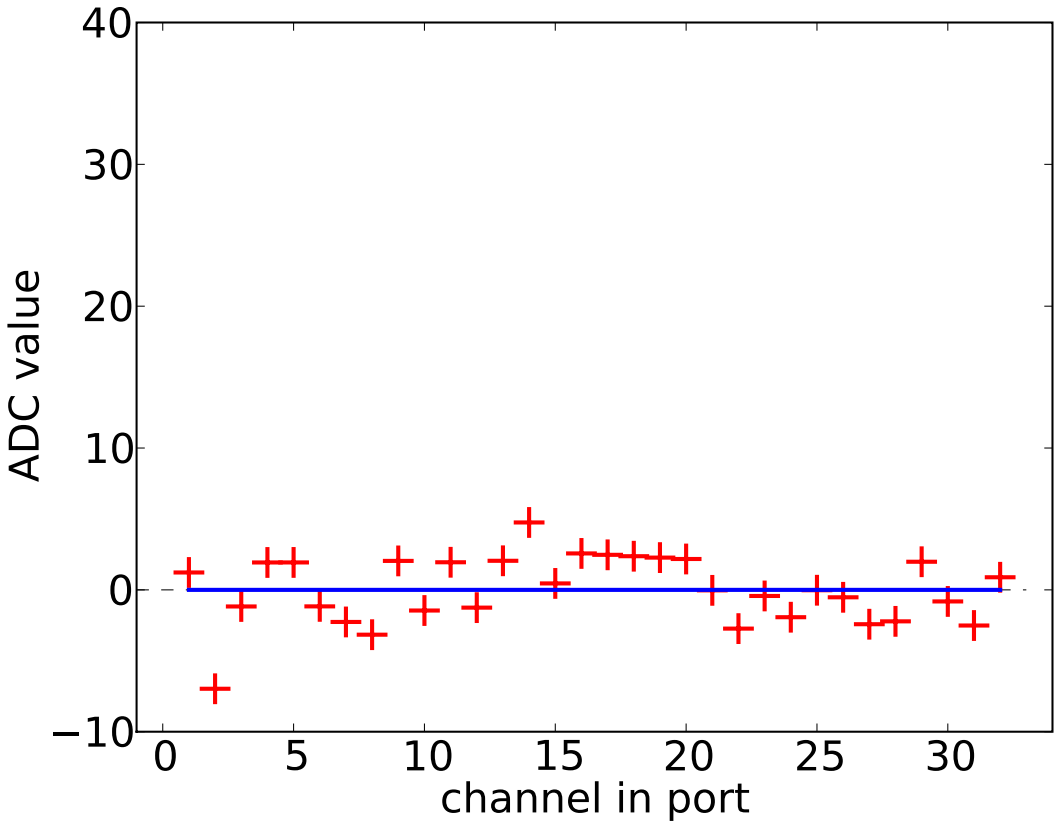
# ST Algorithm



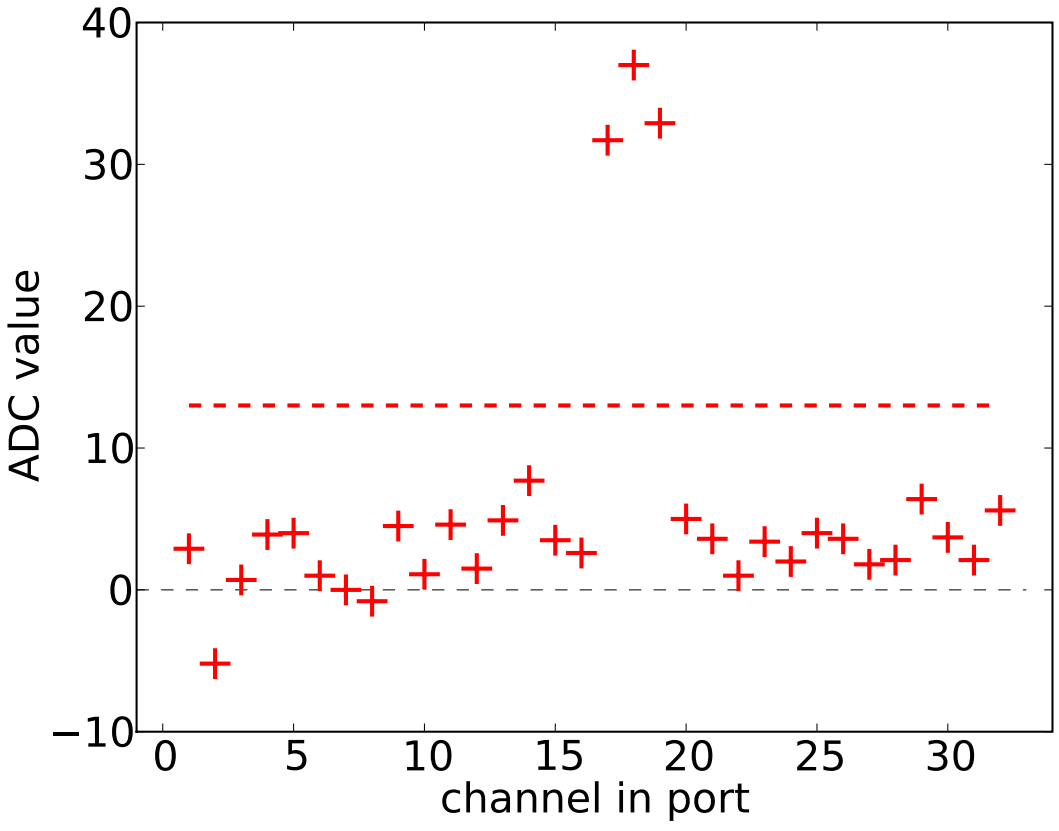

1. calculate mean
2. subtract mean
3. detect hits
4. set hits and neighbours to zero
5. calculate new mean
6. subtract new mean
7. fit straight line (using least-squares)
8. subtract line

# 2P Algorithm

## Why another algorithm?

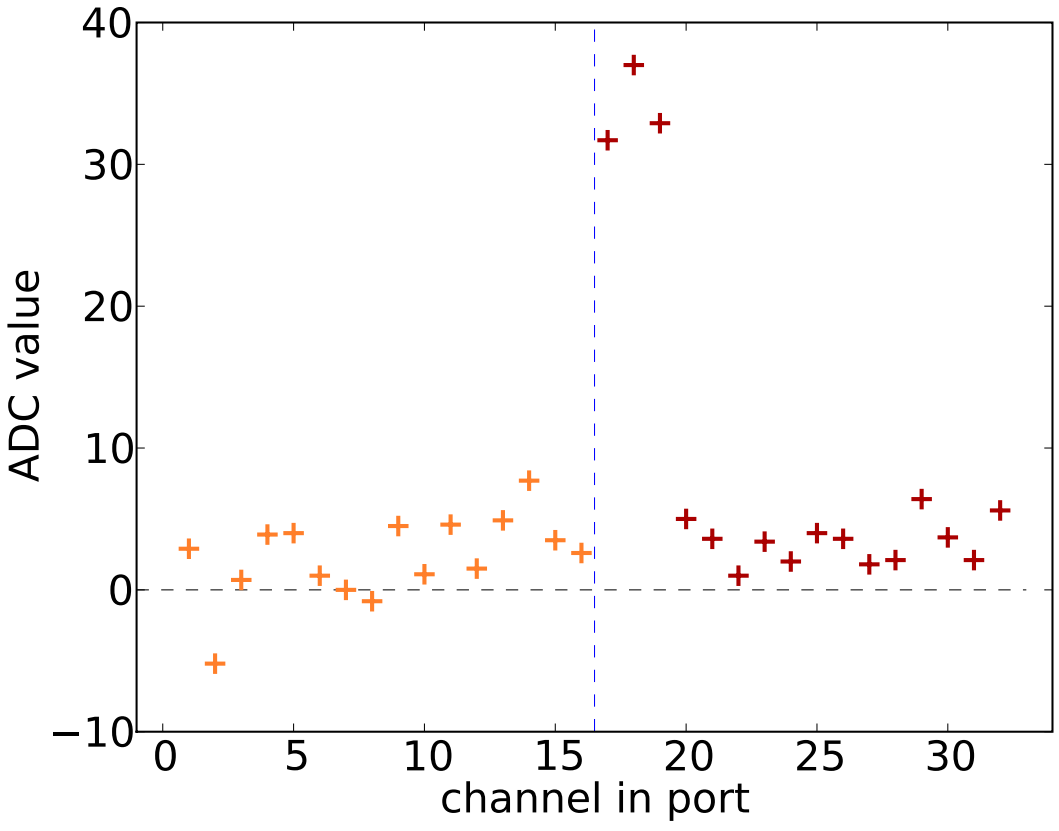
- avoid least-squares method
- look for simple algorithm for monitoring
- two point algorithm (2P)

# 2P Algorithm




1. detect hits
2. split channels in two sets (channels 1-16, 17-32)
3. calculate mean ADC and mean strip ignoring hits
4. calculate slope and offset of line through 2 points
5. subtract line

# 2P Algorithm

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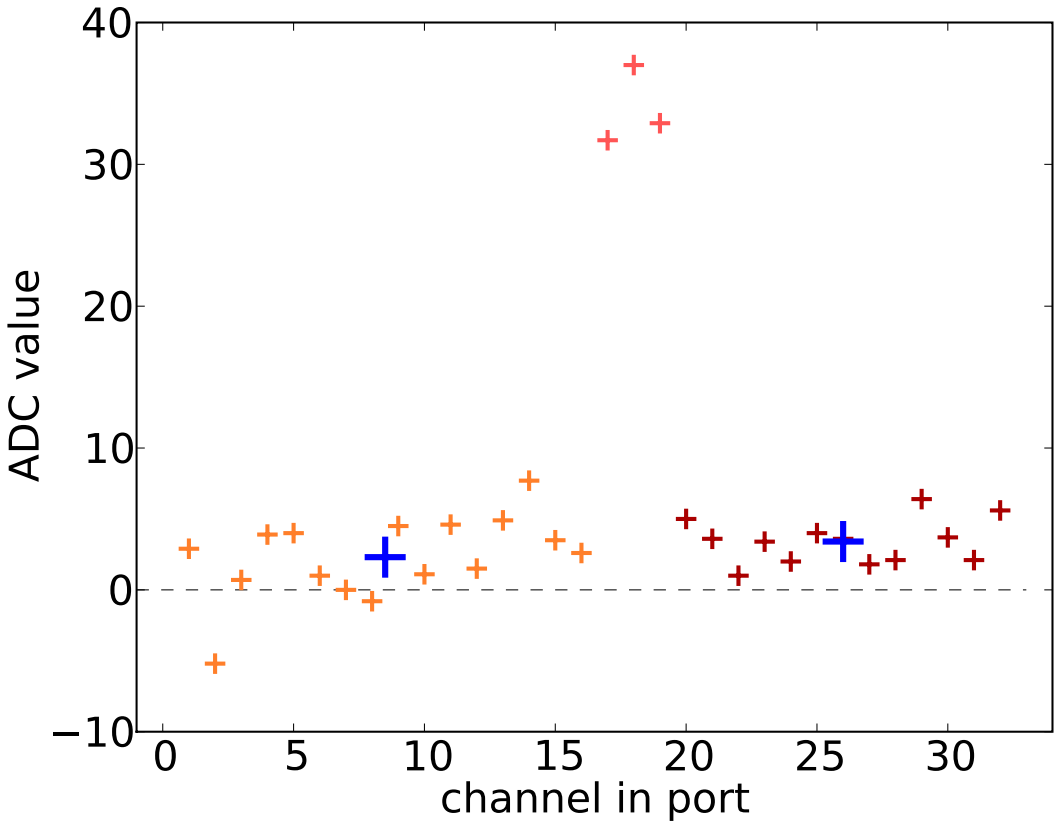


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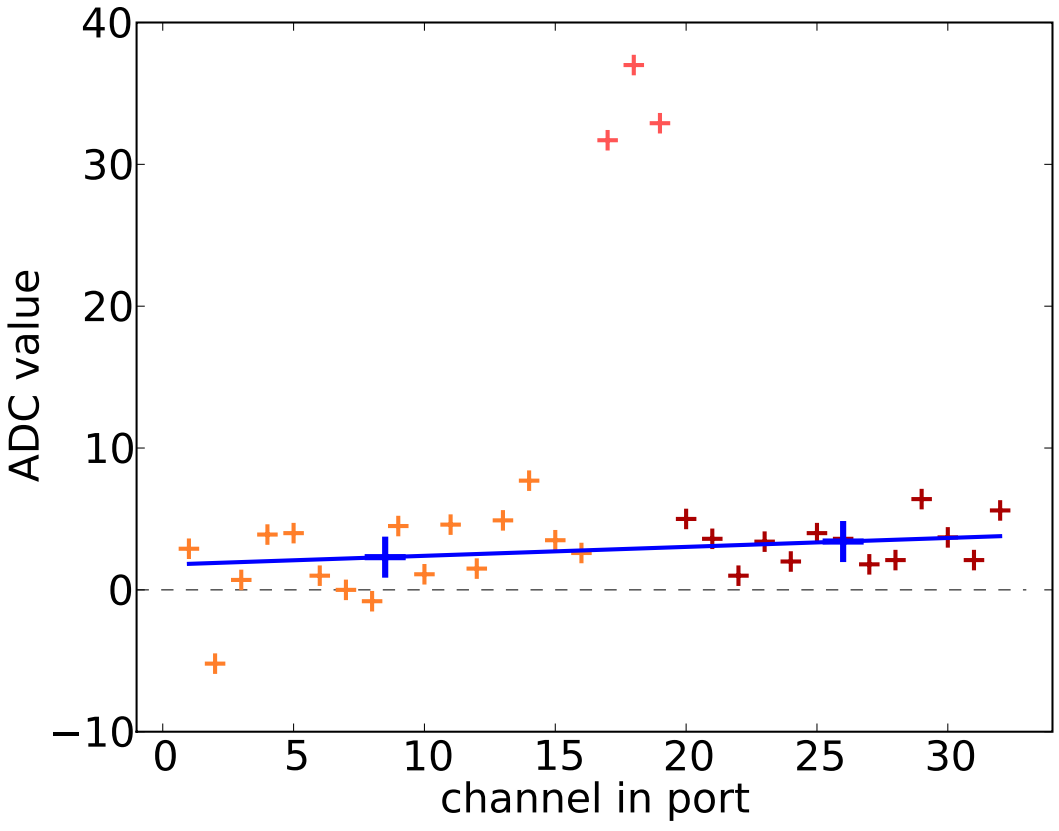
# 2P Algorithm

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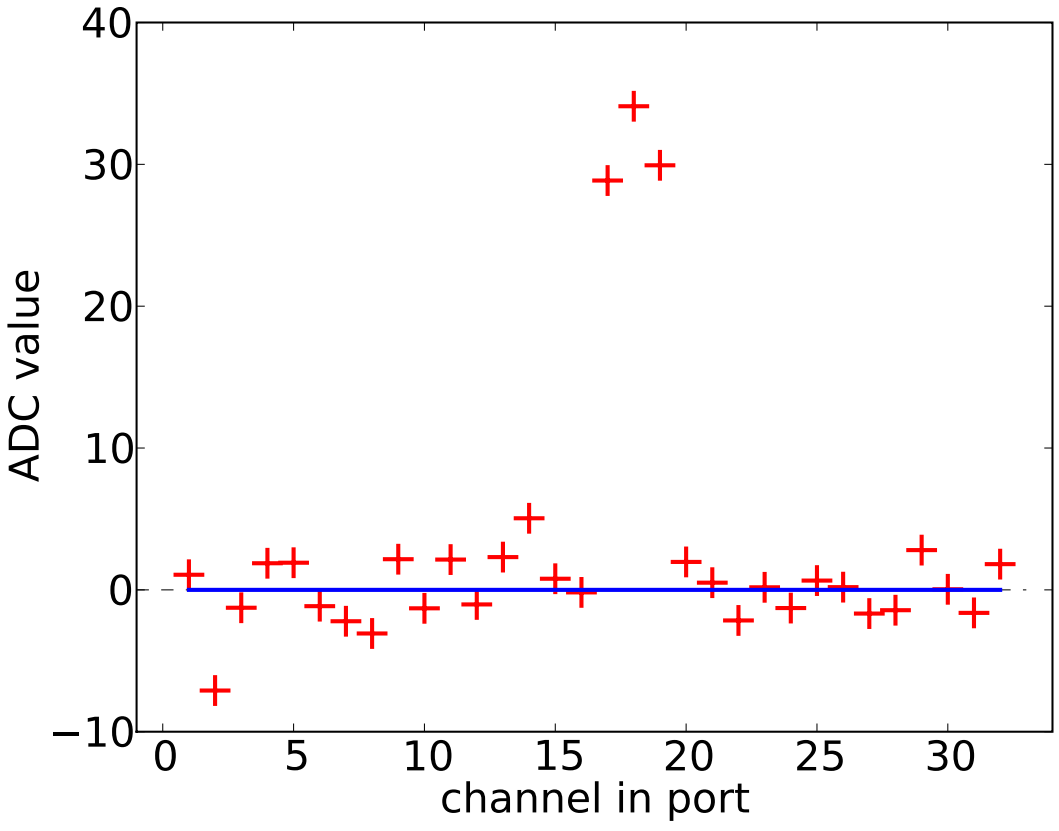
# 2P Algorithm




1. detect hits
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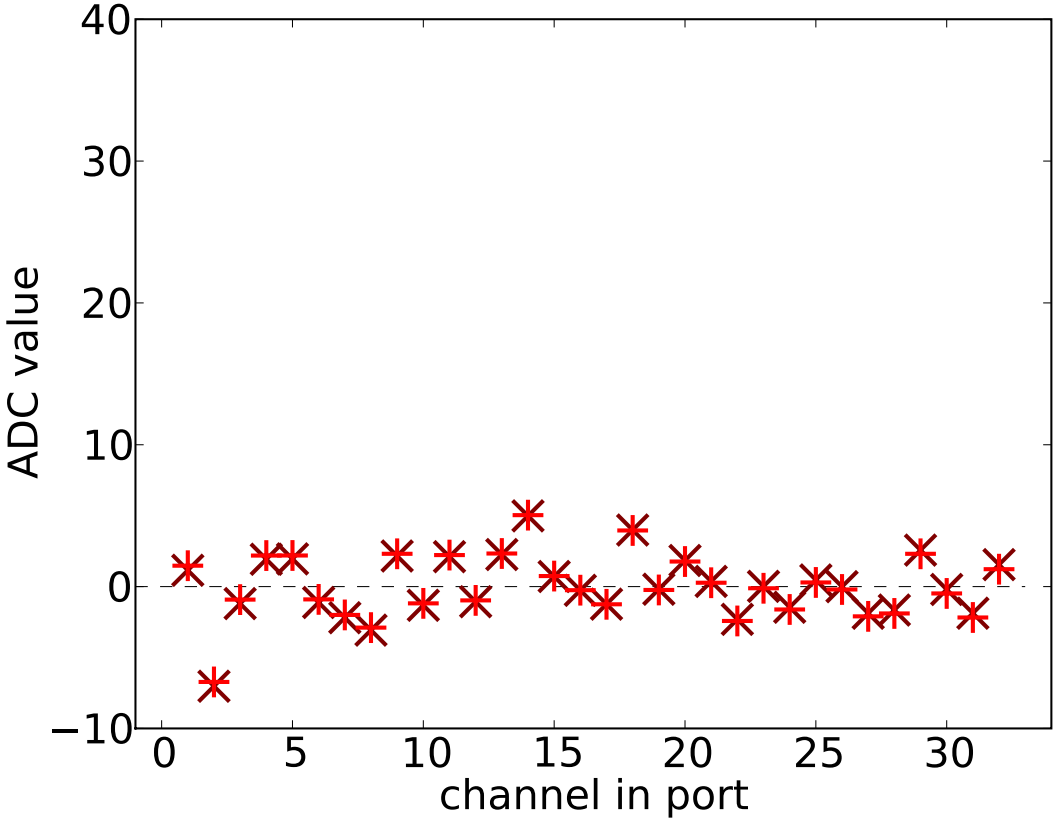
# Comparison of the Two Algorithms




**+ ST** **× 2P**

## Without hits

comparable results

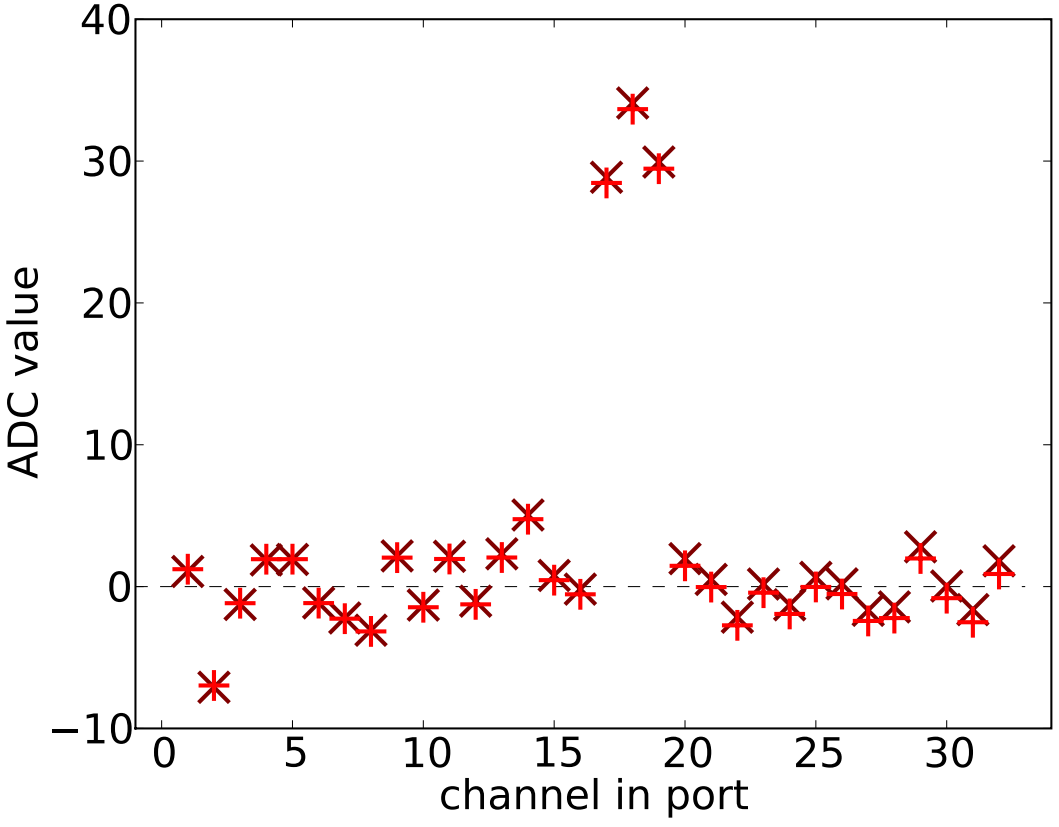
## Few hits

comparable results

## Many hits

ST algorithm gives wrong common mode

# Comparison of the Two Algorithms




**+ ST** **× 2P**

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comparable results

Many hits

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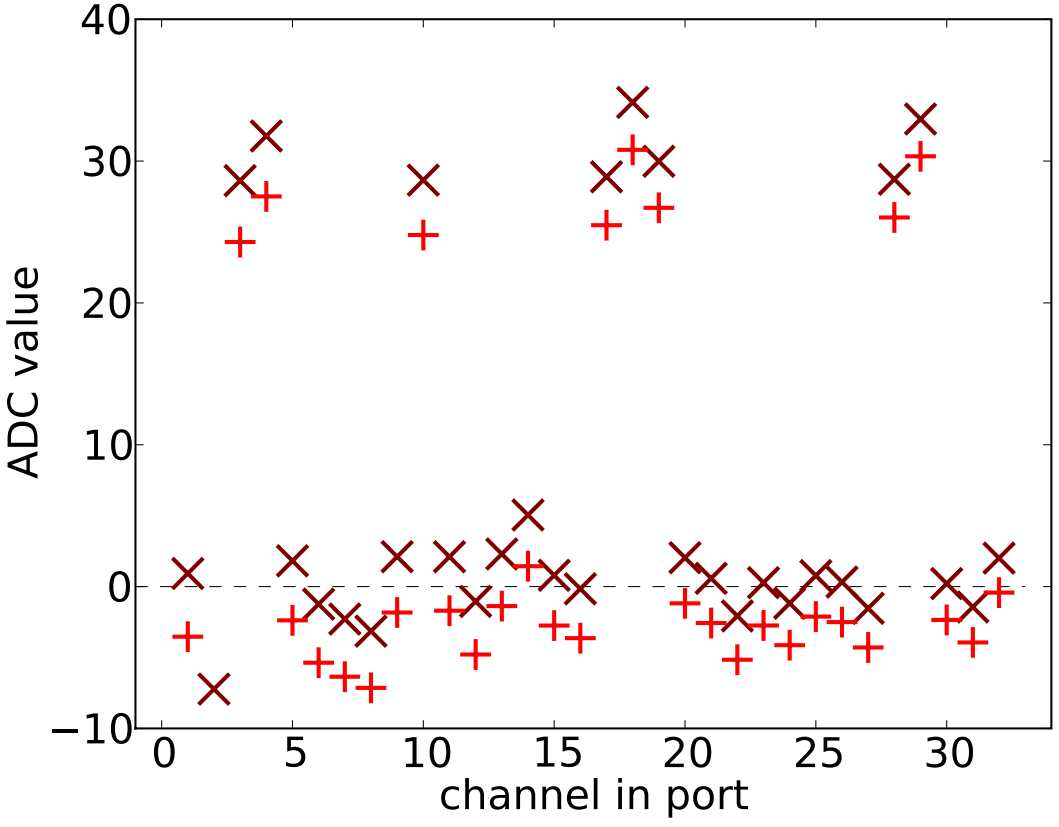
# Comparison of the Two Algorithms




**+ ST** **× 2P**

Without hits

comparable results

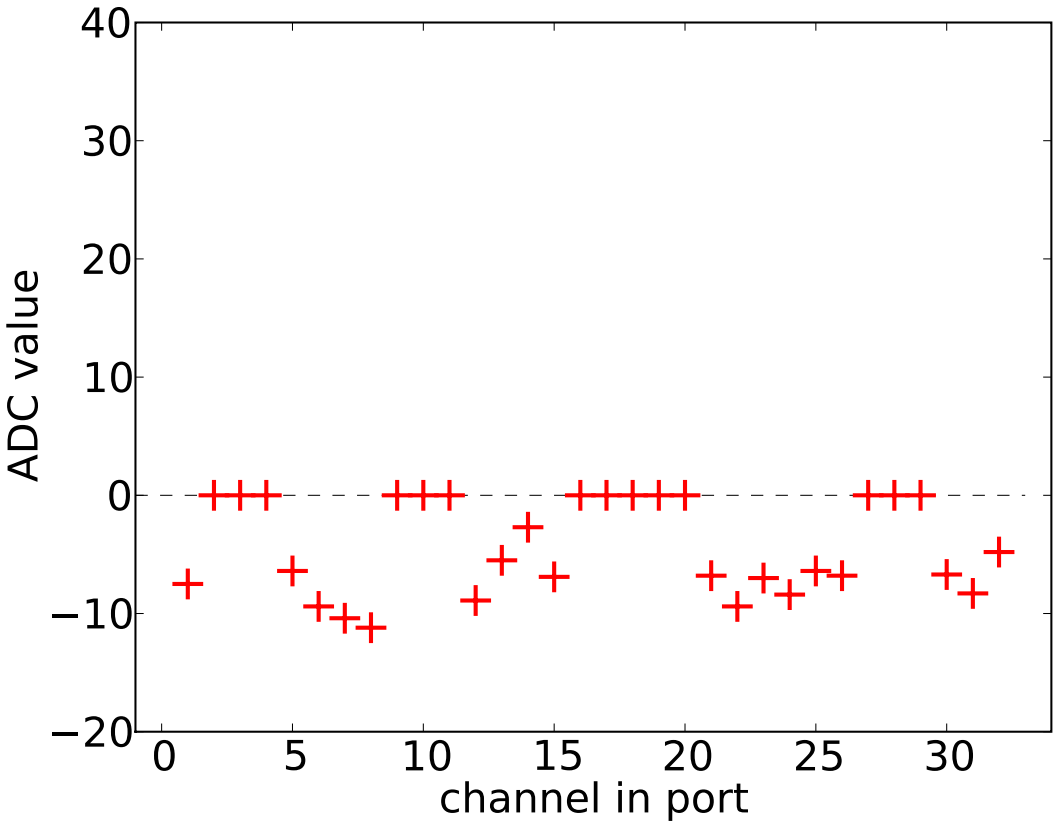
Few hits

comparable results

Many hits

ST algorithm gives wrong common mode

# Reason for Wrong Common Mode



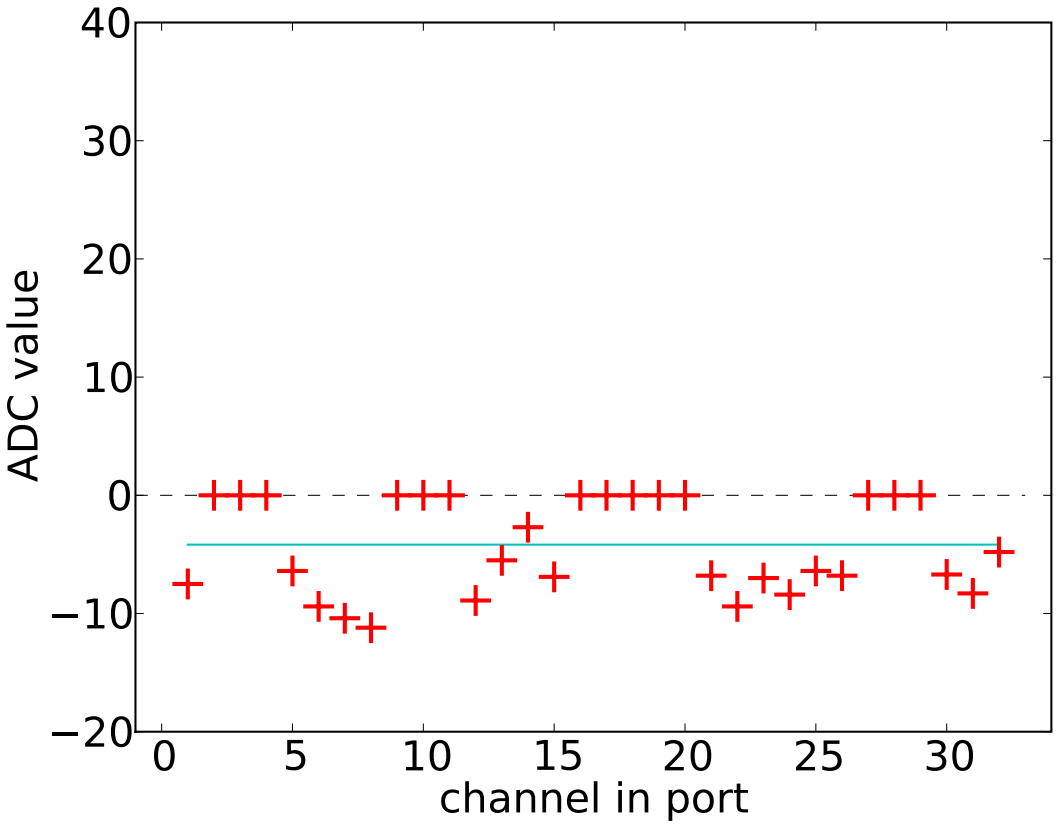

## Way hits are treated

- ST sets to zero
- 2P ignores completely

## Setting hits to zero

- zeros influence calculations
- $2^{nd}$ mean wrong
- common mode wrong

# Reason for Wrong Common Mode

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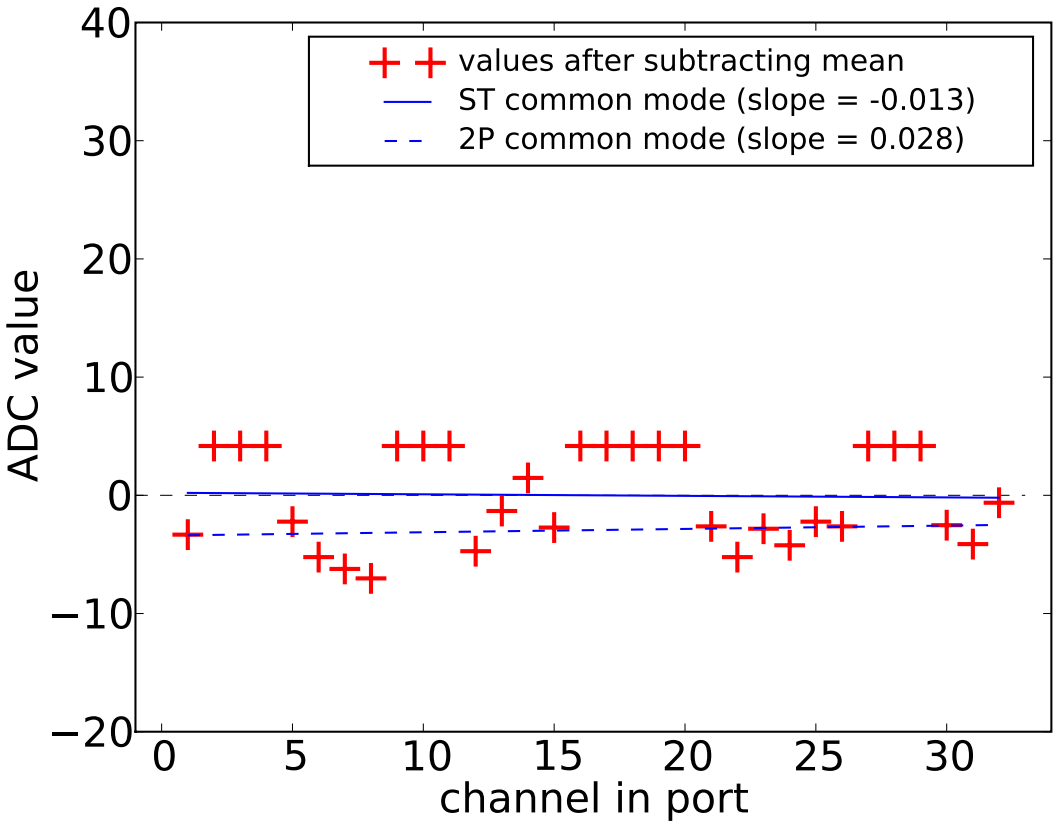



## Way hits are treated

- ST sets to zero
- 2P ignores completely

## Setting hits to zero

- zeros influence calculations
- $2^{nd}$ mean wrong
- common mode wrong

# What Did We Learn?

## Most important difference

- ST sets hits to zero
- 2P ignores hits completely

## Reason

- only divisions by powers of 2 on Tell1 boards
- 2P implemented without this constraint

## Result

- comparable without hits/with few hits
- ST algorithm wrong for many hits

# Summary

## Online Monitoring

- new pages and histograms added
- developed tool for management

## Common Mode subtraction algorithms

- treatment of hits is important
- ST algorithm: possible improvements?
- 2P algorithm: implementation on Tell1?

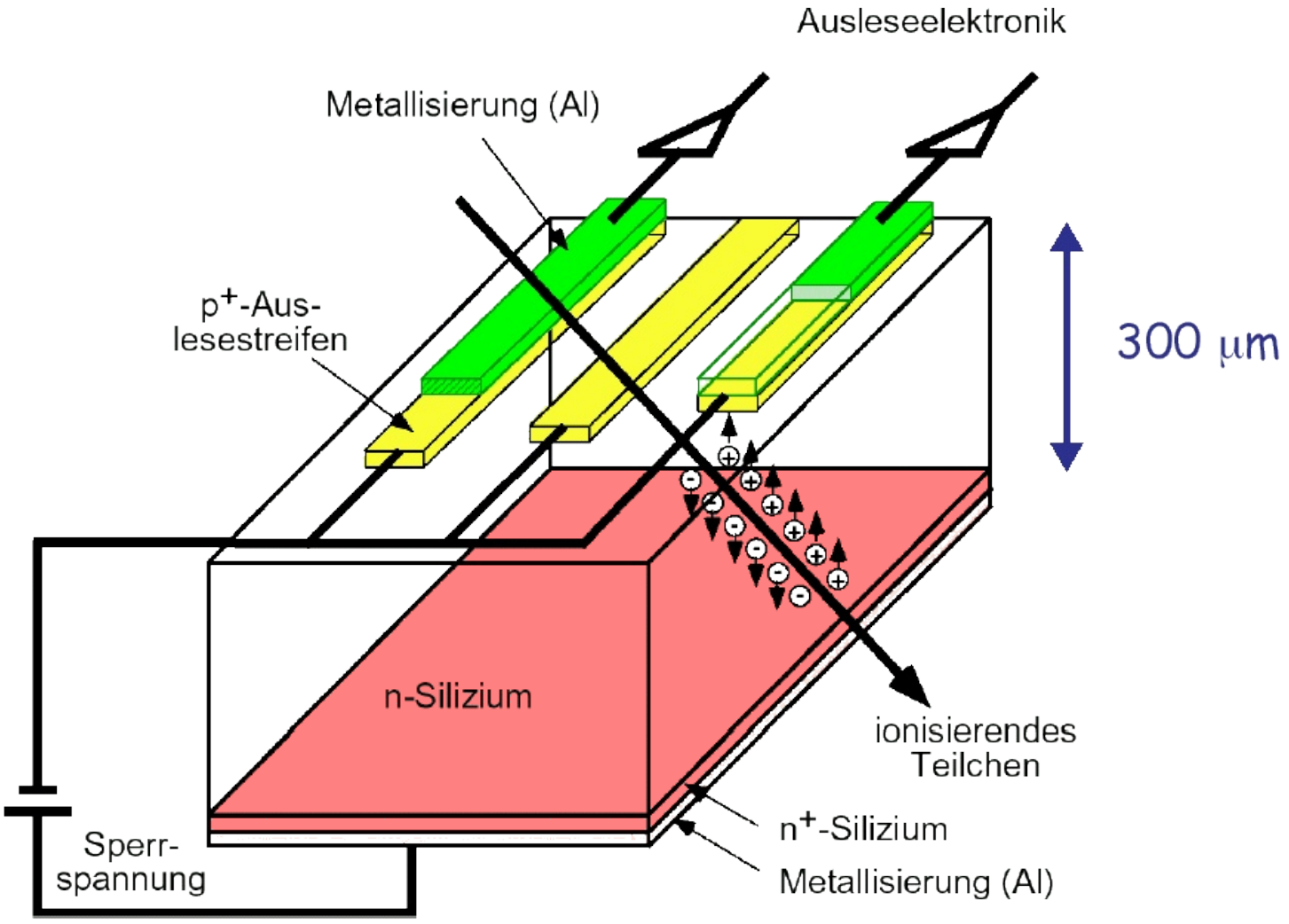
# Thank you for your attention

Questions?

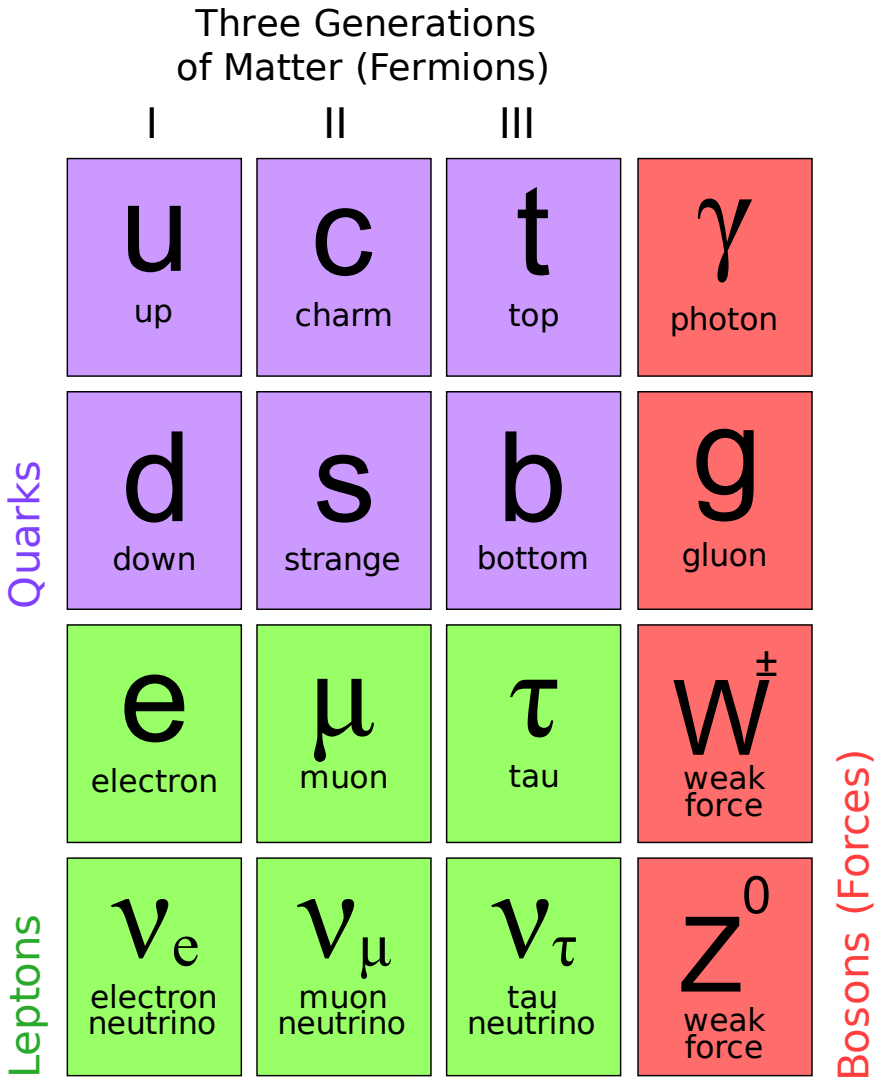
# Further Results

| Algorithm | ST | VELO | 2P |
|---|---|---|---|
| integers | $+0.03$ | n/a | n/a |
| PCN-pedestals | $+0.02$ (- Xtalk) | similar to ST algorithm | similar to ST algorithm |
| CMS no hits | reference | $-0.01$ | $-0.01$ (+ at Ends) |
| CMS 1% occ. | $< 0.01$ | $+0.08$ (hit detection) | $< 0.01$ |
| CMS 10% occ. | $+0.08$ | n/a | $-0.1$ |

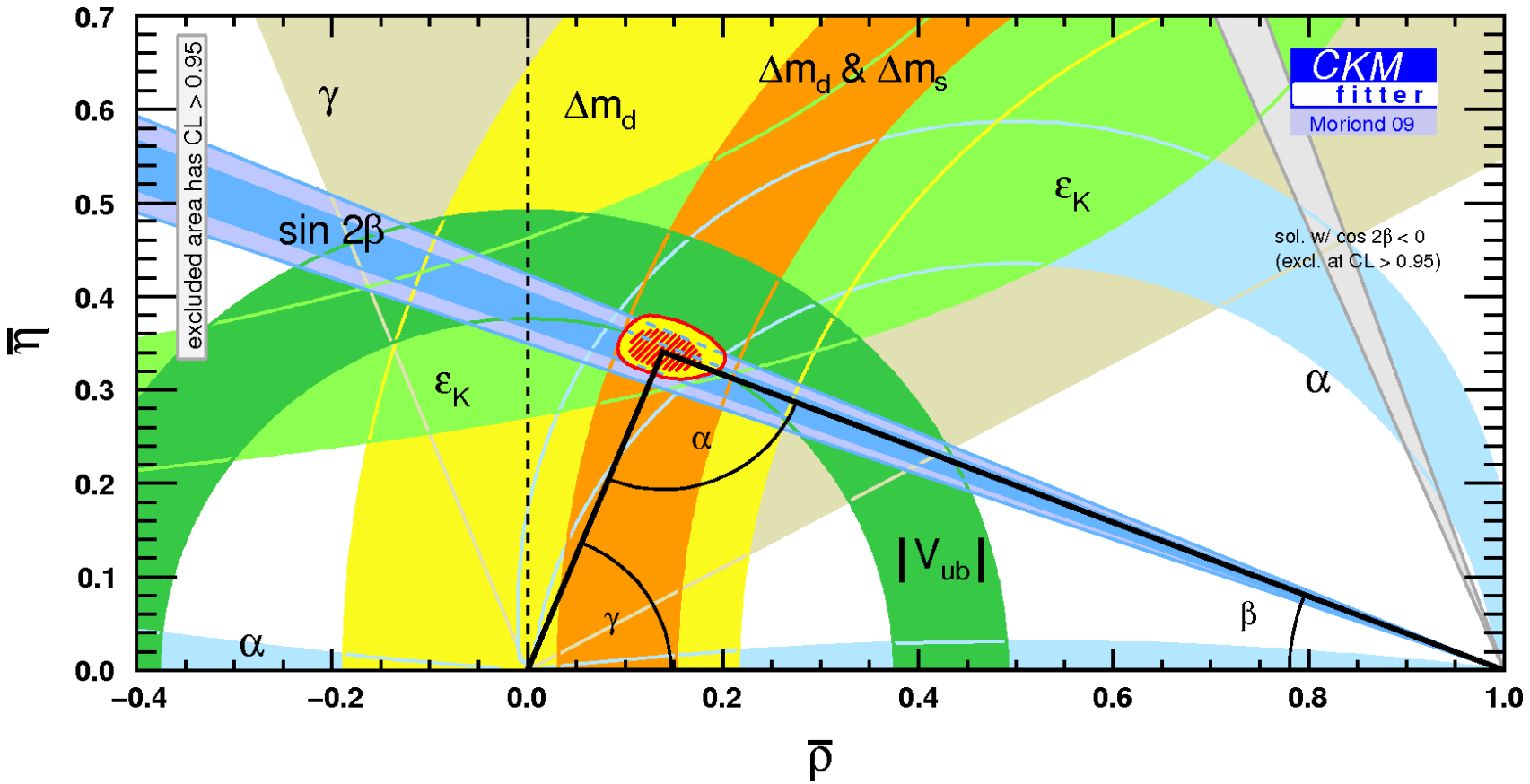
# How do Silicon Sensors Work?



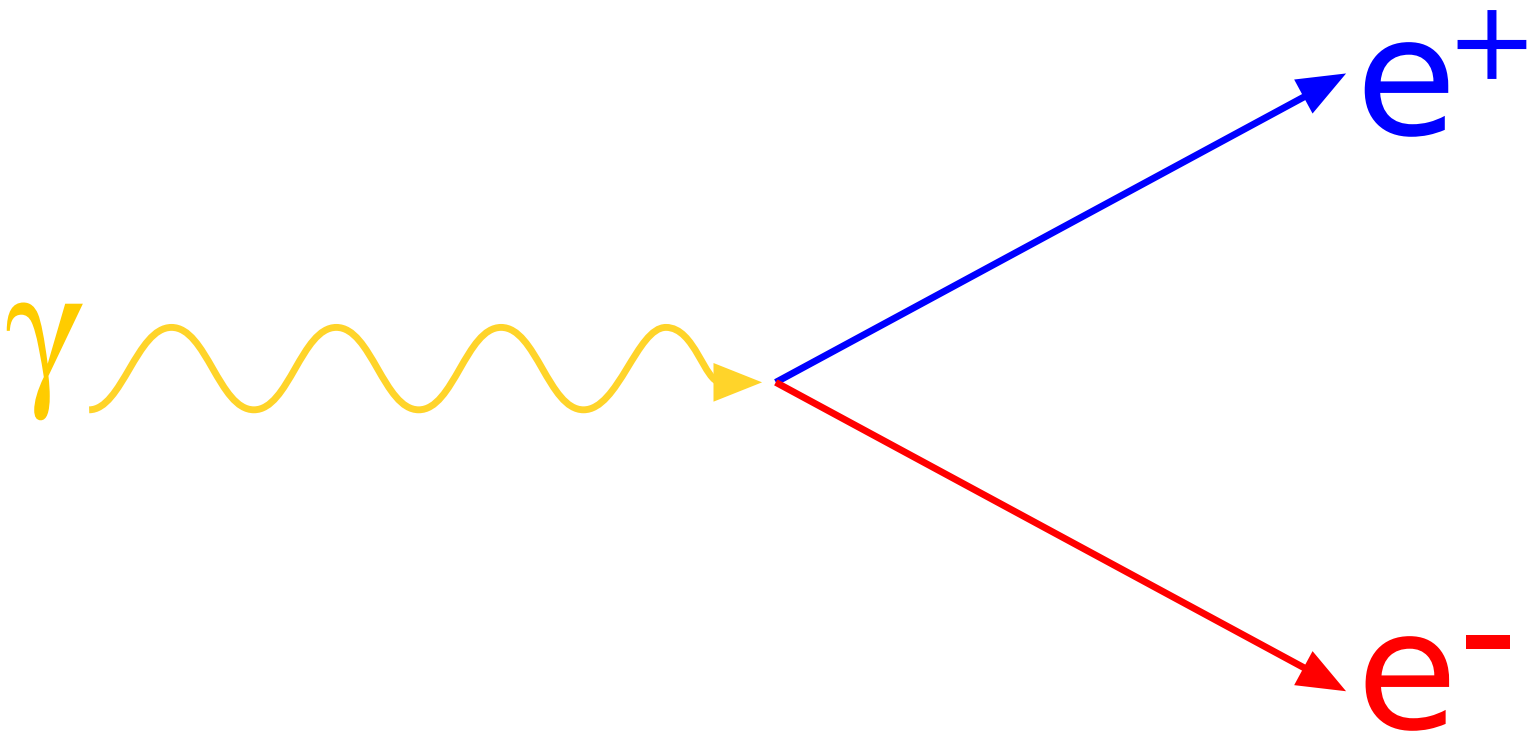
# Particles in the Standardmodel



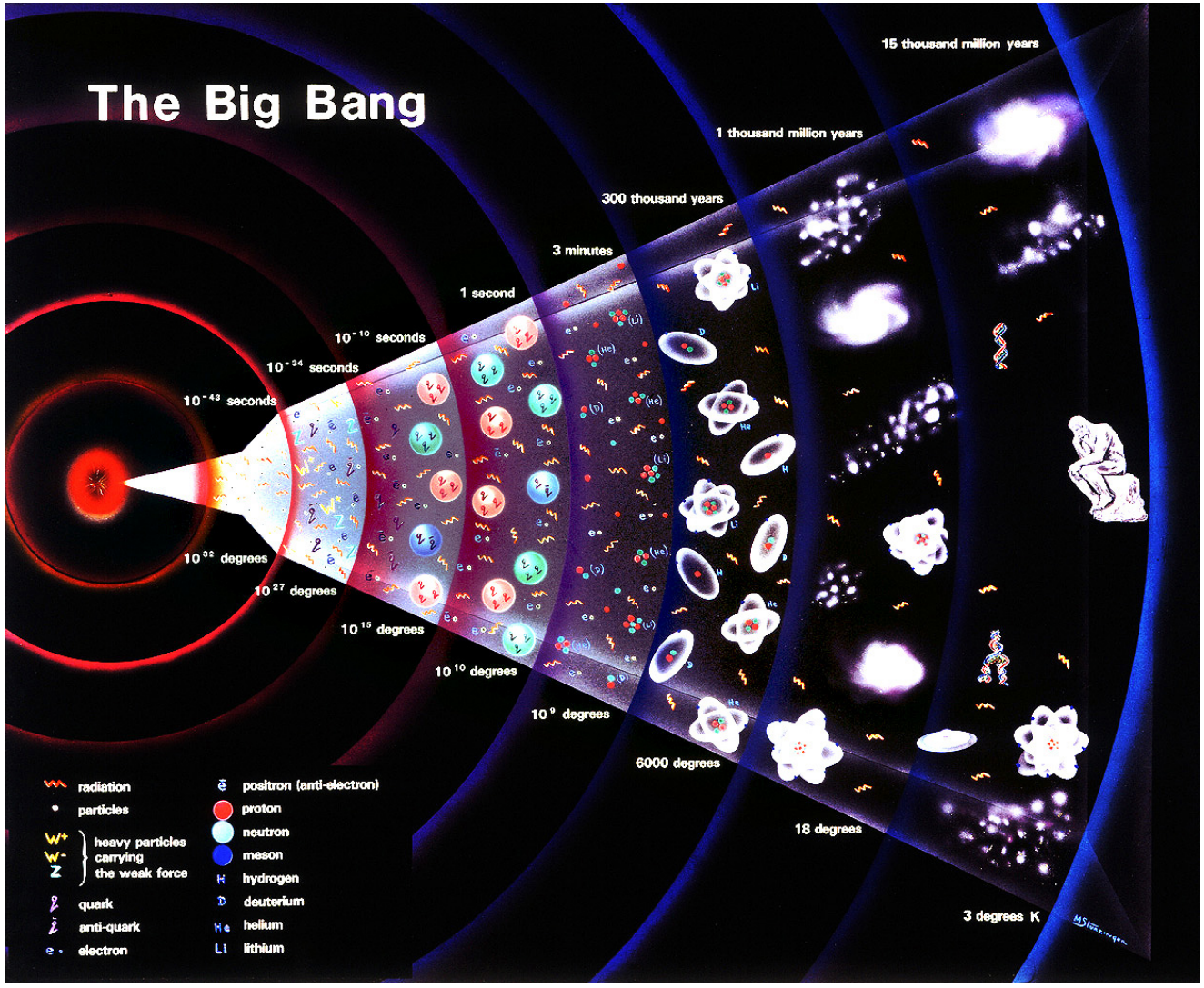
# Unitarity Triangle



# Pair Production



# Big Bang


The Big Bang
15 thousand million years
1 thousand million years
300 thousand years
3 minutes
1 second
10⁻¹⁰ seconds
10⁻³⁴ seconds
10⁻⁴³ seconds
10³² degrees
10²⁷ degrees
10¹⁵ degrees
10¹⁰ degrees
10⁹ degrees
6000 degrees
18 degrees
3 degrees K
radiation
particles
heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
hydrogen
deuterium
helium
lithium