Neuer analoger Summentrigger für die MAGIC Teleskope

Entwicklung und Simulation

D. Haefner, T. Schweizer, F. Dazzi,
D. Corti, D. Fink, R. Mirzoyan, M. Teshima

Max-Planck-Institut für Physik, München
Istituto Nazionale di Fisica Nucleare, Padova, Italien

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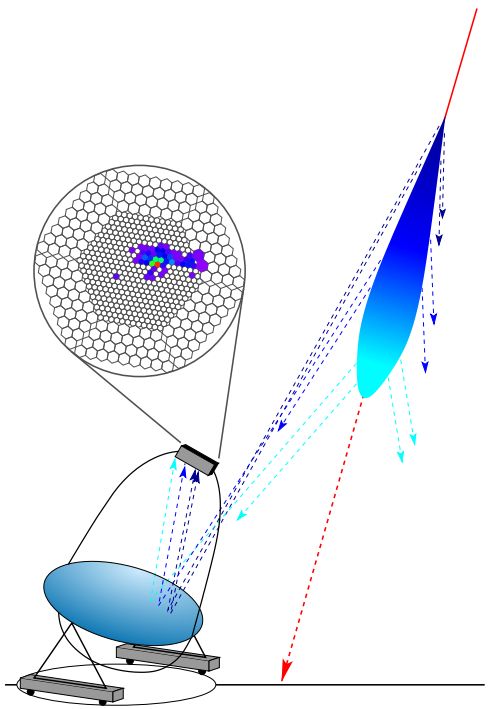
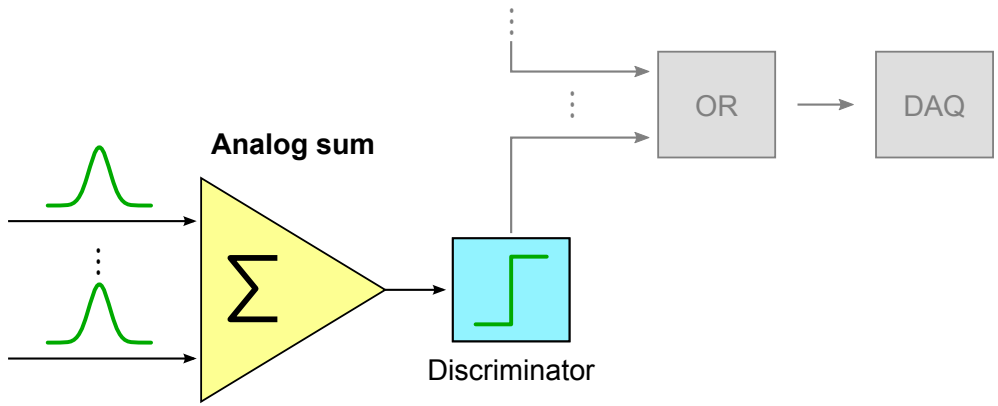
The MAGIC telescopes

- Located on the Canary Island La Palma at 2230m a.s.l.
- Detect faint Cherenkov flashes induced by cosmic particles
- Largest IACTs worldwide with two 17m reflectors
- High-resolution PMT cameras (2x 1039 pixels, after upgrade)
- Advantage: low detection energy threshold ($\geq$ 60 GeV)
- Sum-Trigger prototype (* 2008; † 2011) reduced threshold to 25 GeV
  $\rightarrow$ detection of pulsed γ-rays from Crab pulsar (SCIENCE publication)



Principle of the analog Sum-Trigger

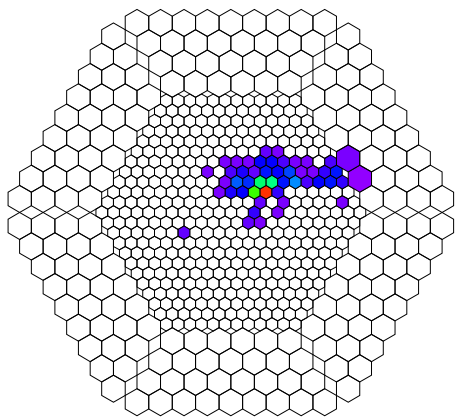
- Analog sum of the signals from adjacent pixels (patch) is produced
- Discriminator is applied to the summed analog signal



→ **Topological** and **timing** constraints:
- Cherenkov light cones produce **extended** images
- Duration of shower event on camera: **2 - 6 ns**

→ Takes into account **small signals** below the *single channel discriminator* threshold (standard trigger)

→ Charge integration of larger area (> 4NN) increases "signal to noise ratio" compared to standard trigger



Sum-Trigger II: Macrocell mapping

Inner part of camera is divided into 55 **patches** (macrocells) in which signals are **summed up**

- Sum-Trigger II: much **larger trigger region** than first Sum-Trigger

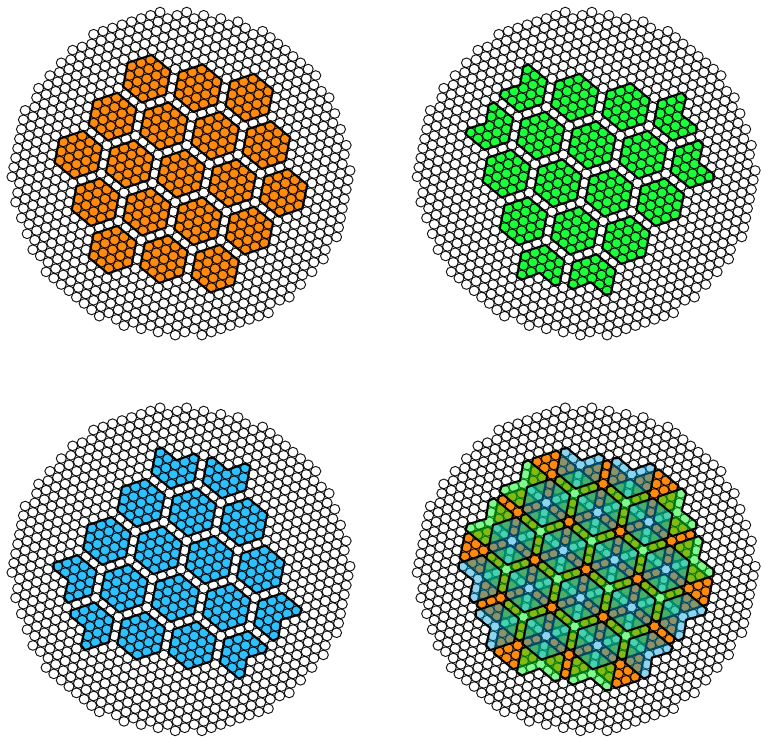
  → Enables *wobble mode*

  → Larger effective trigger area
- Macrocell size was optimized by Monte Carlo studies using γ-ray energies between 10 - 30 GeV
- Maintain circular symmetry

  → Hexagonal patches of **19 pixels**
- **3 layers**, overlapping

  → Cover full area of L0-trigger

  → No gaps

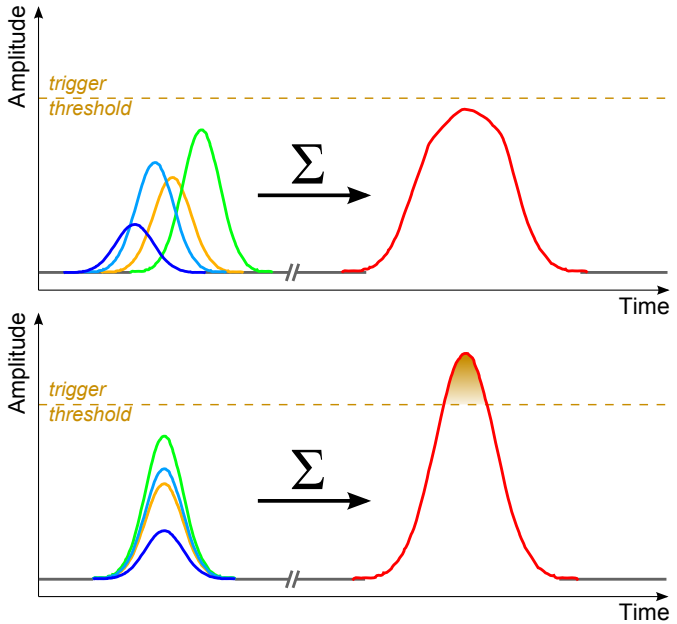


Sum-Trigger II: Idea of operation

Major challenge:

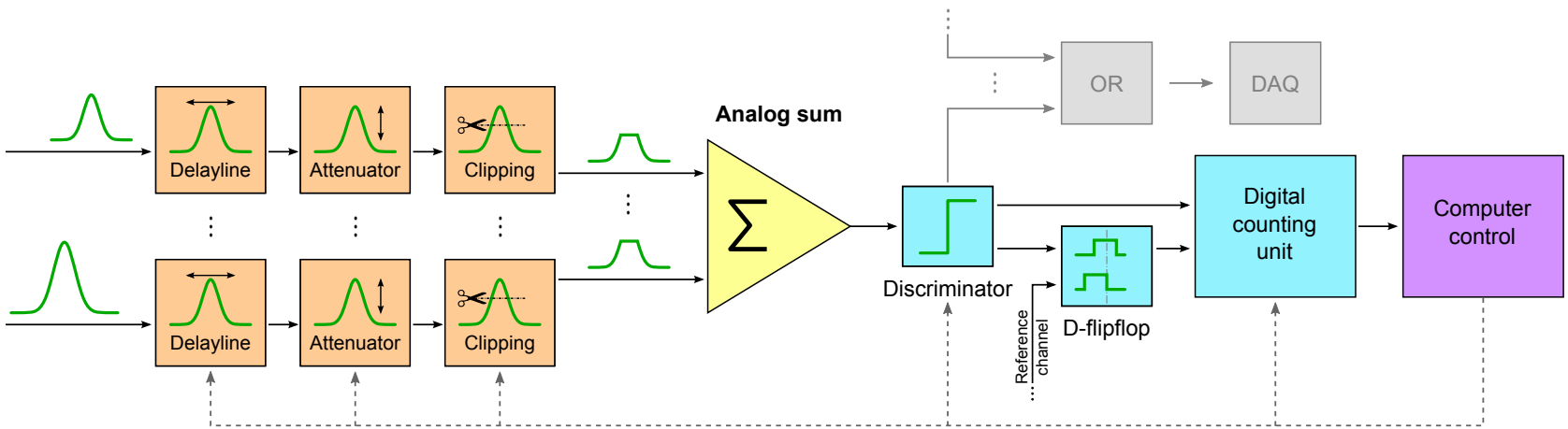
- Signal **transition times** inside the PMTs change when adjusting gain (flatfielding)
- Aging of PMTs **affects gain**
- For a correct "pile up" of signals in sum, **precise timing** is required

Old Sum-Trigger only manually adjustable
$\rightarrow$ intensive maintenance required

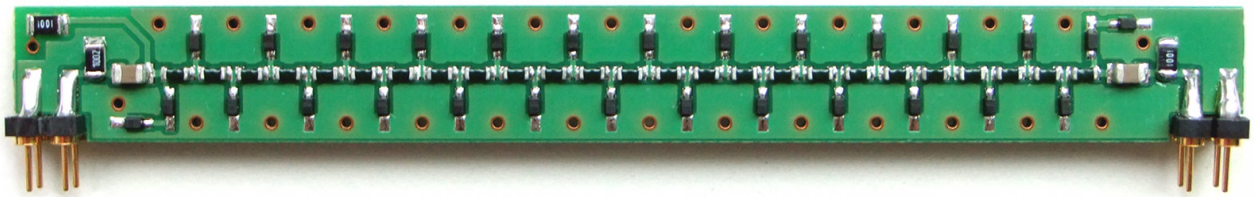


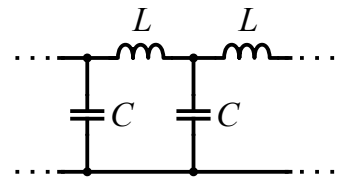
$\Longrightarrow$ Development of a ***New*** **Sum-Trigger** with completely **automated** **equalization** of **delay** and **gain** per channel

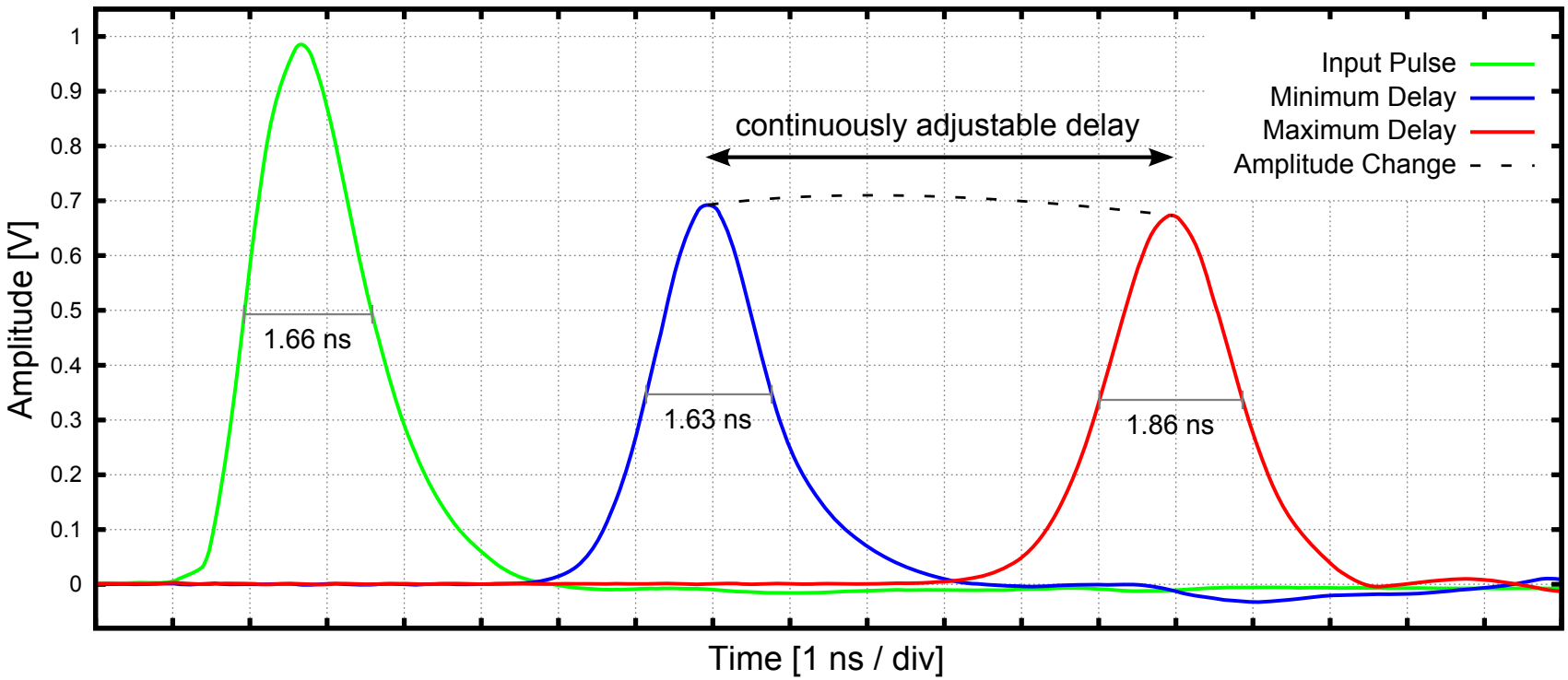
Basic principle:



Adjustable analog delay line prototype







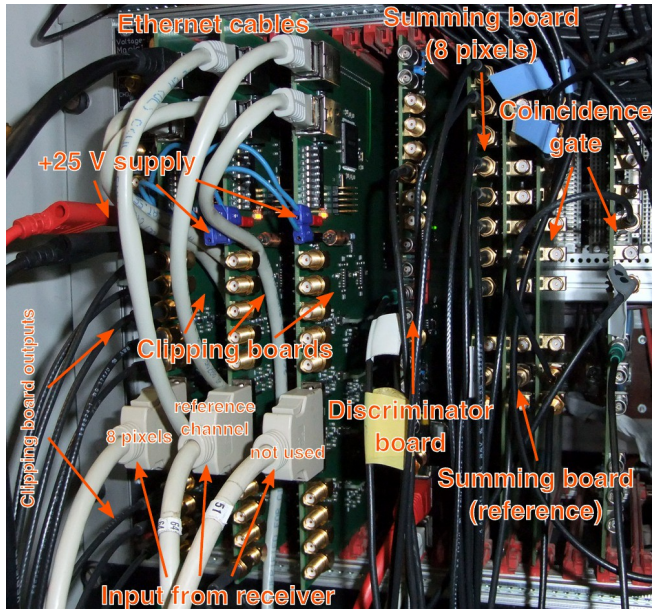
(Haefner et al., IEEE Transactions on Nuclear Science, Feb. 2012)

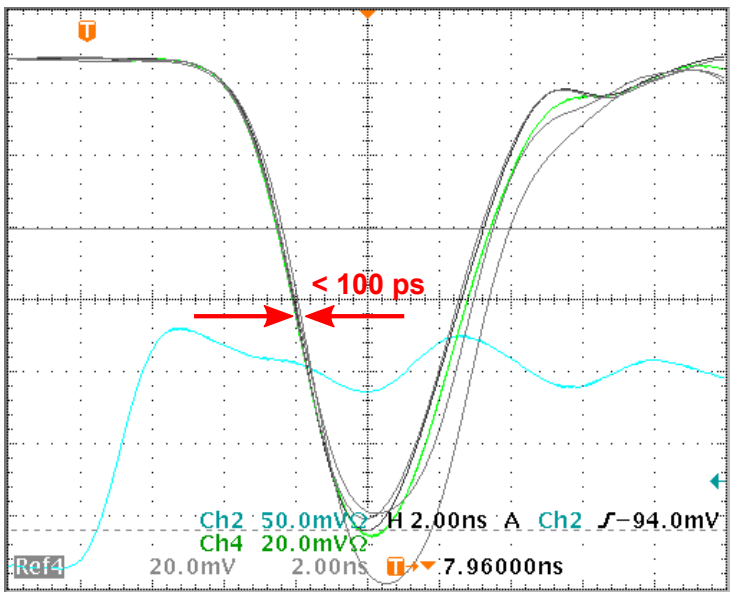
Sum-Trigger II: First tests

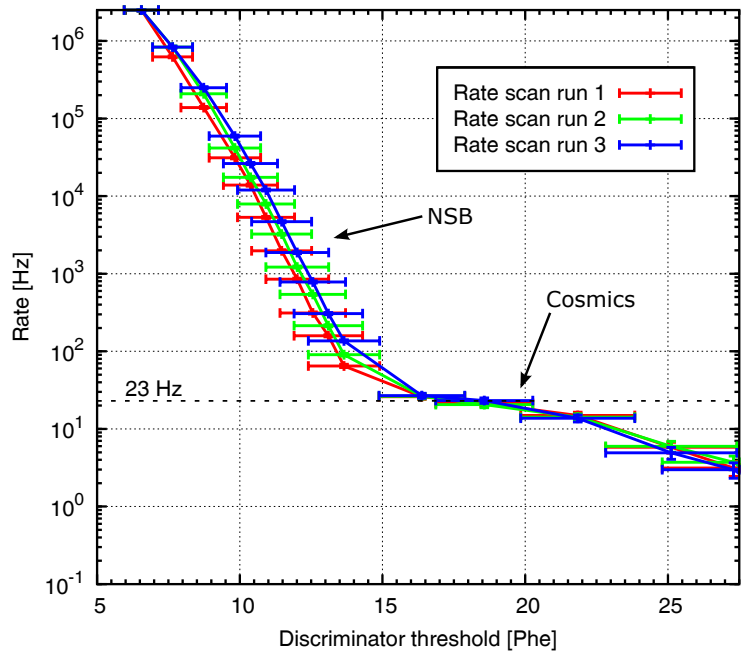
- **Fully functional test-setup** has been designed and built in 2010
- Setup was tested in August 2010, temporarily installed in MAGIC I

→ New concept of automatic calibration **works satisfactorily**

→ Roughly estimated trigger rate agrees with old Sum-Trigger

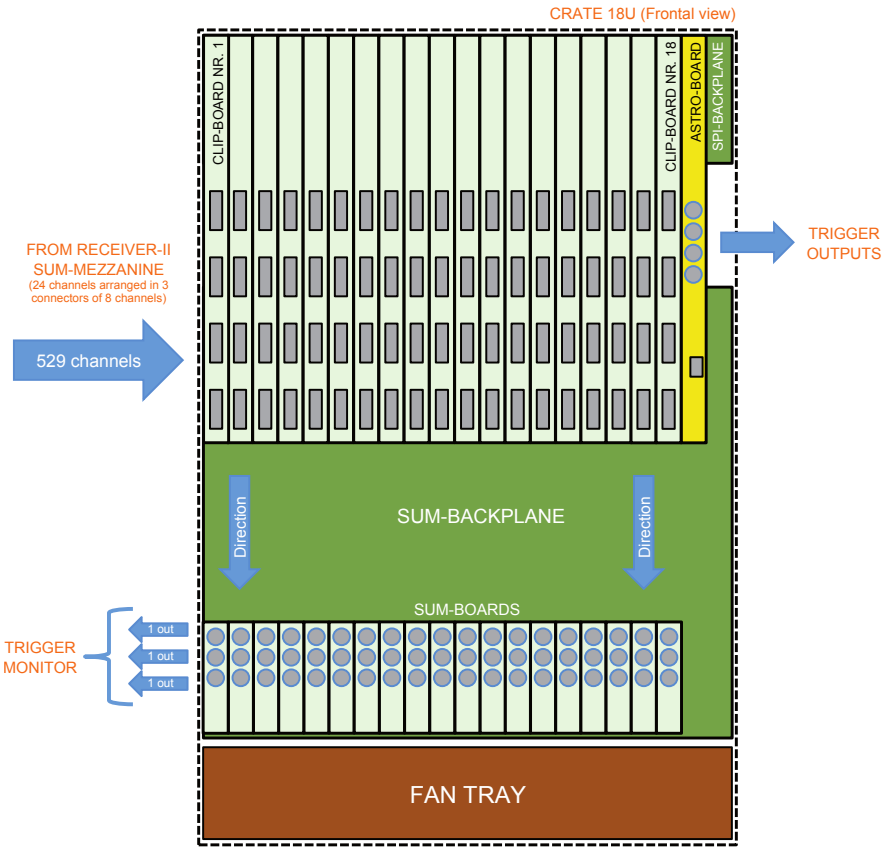


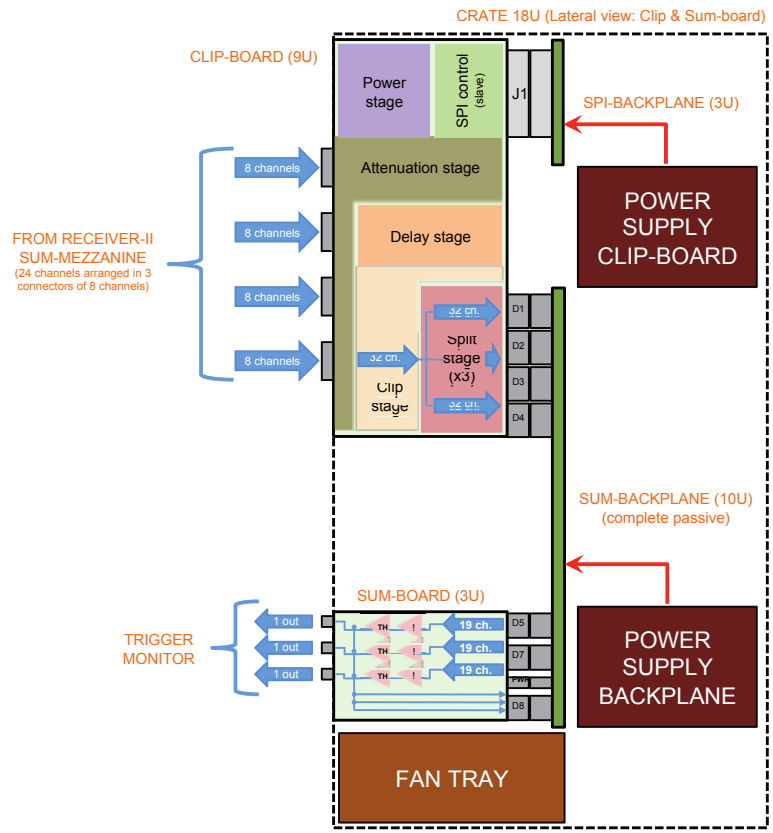




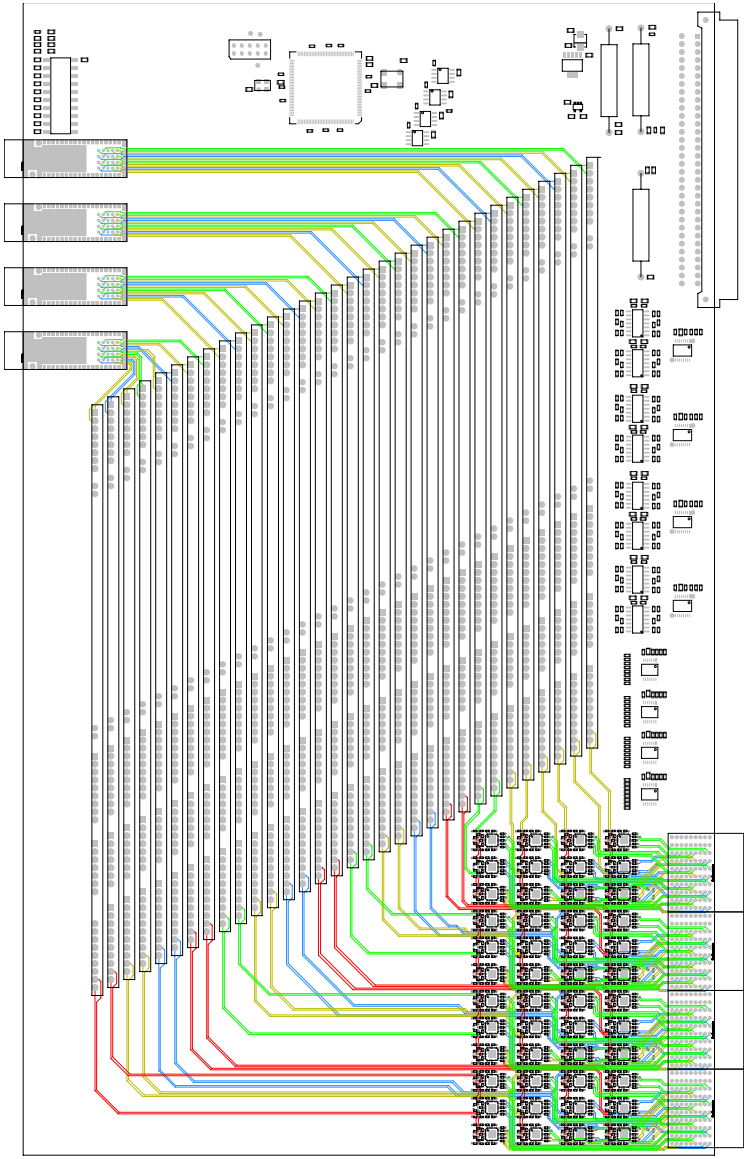
Final Design: Crate Layout

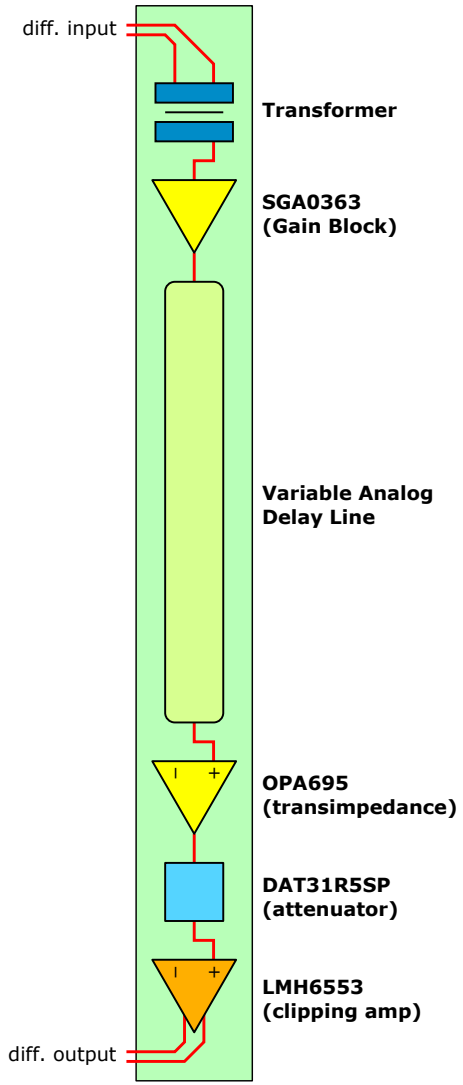
- One crate of 18 units size contains all circuit boards
- Modular concept
- Manages all 529 trigger channels
- Including splitting and patch-wise analog summation



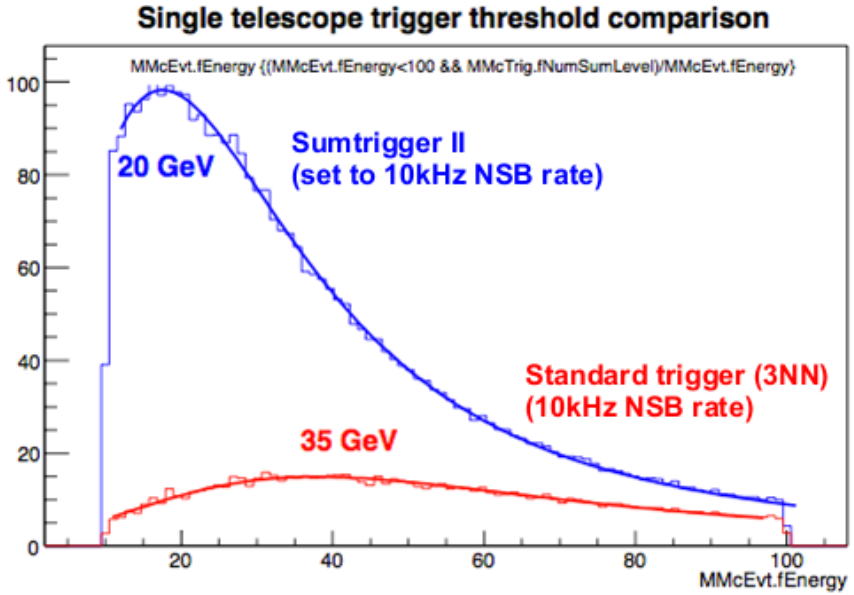


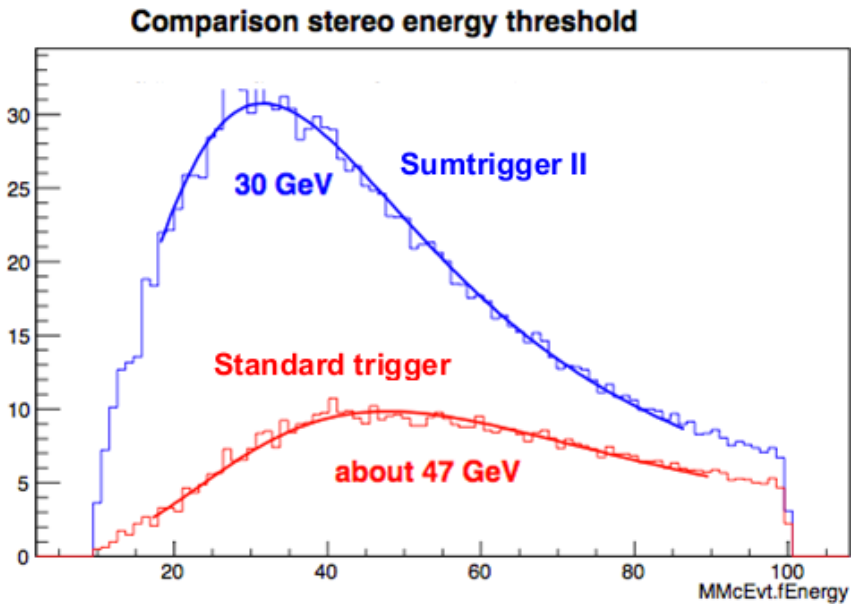
Final Design: Analog Clip-Board and Modules





Sum-Trigger II: Monte Carlo studies

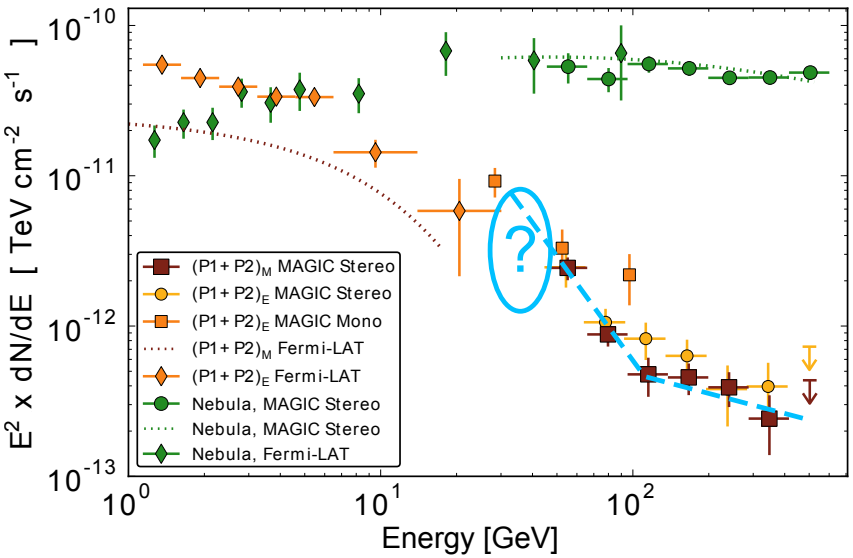




- Old Sum-Trigger: 25 GeV, old camera, MAGIC I only
- Sum-Trigger II: 20 GeV, single telescope mode
- In stereo: 30 GeV possible
- Very optimistic MCs even predict 10 GeV for mono and 17 GeV for stereo
- Also standard trigger (3NN) improves after MAGIC I camera upgrade and new electronics

Conclusion and Outlook

- Low threshold → essential for **pulsars**, distant **GRBs**, high-redshift **AGNs**
- Fully automated; high stability; larger and homogeneous trigger area
- Installation in both telescopes → **stereo** → better γ-Hadron separation



- Can further reduce energy threshold to **20 GeV** (30 GeV in stereo mode)
- May **close gap** between MAGIC stereo and Fermi-LAT data → **kink in spectrum?**
- Observation of **Geminga** pulsar

- Outlook for next generation Cherenkov Telescope Array (CTA)
  - Sum-Trigger ideal for Large Size Telescopes
  - lowest trigger threshold possible
  - low power consumption and low heat emission (compared to high-speed digital trigger)