Summary of the Hardware/Upgrade Session, Pt. 1

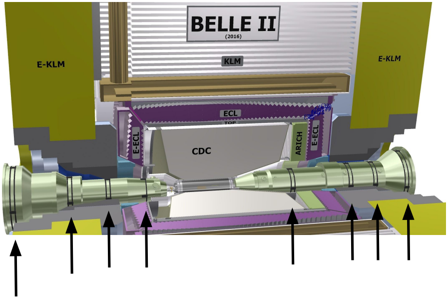
Dima Levit, Felix Meggendorfer

CLAWS for Beam Abort Performance and Prospects

The CLAWS System

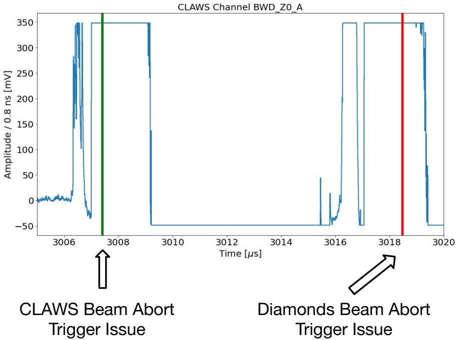
S**c**intillator **L**ight **a**nd **W**aveform **S**ensors:

- Hamamatsu silicon photomultipliers mounted on 3x3 cm^2 plastic scintillators, primarily sensitive to penetrating charged particles ("MIP"s)
- 32 sensors, 16 on forward and backward side of the Belle 2 detector, mounted on the QCS with varying z and ϕ positions



CLAWS Abort Trigger Scheme

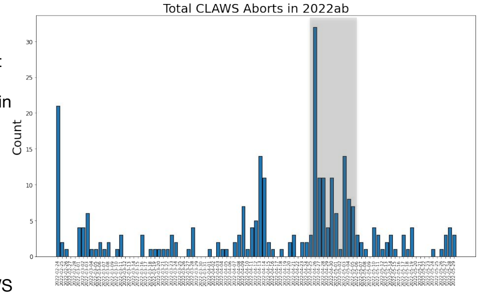
- Typical MIP signals observed by CLAWS sensors have **100-150mV** amplitude and decay over **50-70ns**
- In typical beam abort events the amplitude stays above **250mV** for **a couple of us**
- An amplitude and duration based threshold exceeding 250 mV for at least 200 ns reacts **substantially earlier** than current existing systems



Performance in Run 2022ab

Time Frame: 2022/02/24 - 2022/06/22:

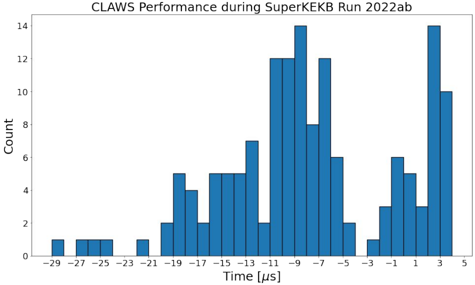
- **126** Aborts with High Beam Current
  - On average 30% less High Beam Current aborts per day in comparison to Run 2021c
- **154** Aborts during MR operation start-up
  - All in sync with injections
  - Solution: **increase veto duration**
    - New Veto Window: **[-16us : +300us]**
    - Total downtime of CLAWS abort signal - **1.58% of total runtime**



Performance in Run 2022ab

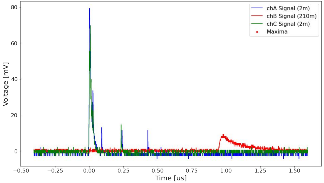
Time Frame: 2022/02/24 - 2022/06/22:

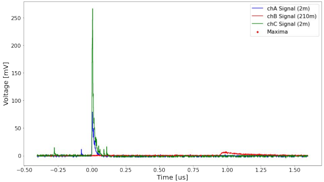
- **151** CLAWS aborts with more than 1 abort source and >1mA stored in both rings
    - CLAWS was the first system to issue abort for **119**
    - Newly installed beam loss monitors are able to provide better abort timing than CLAWS for events with beam loss originating in certain collimator heads
    - On average **7.6us** faster than next fastest abort source



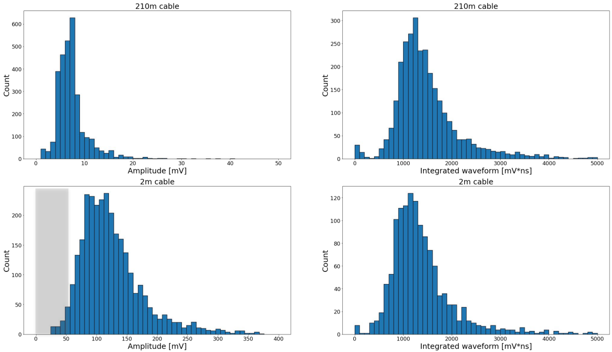
popov@mpp.mpg.de

CLAWS Expansion



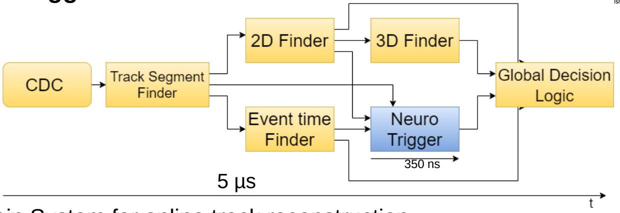


CLAWS Expansion



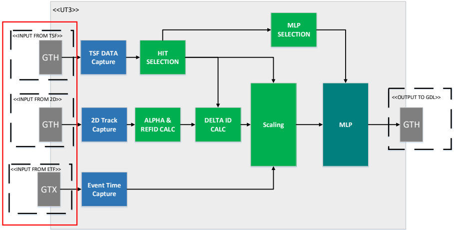
FPGA implementation of the Neurotrigger

CDC Trigger

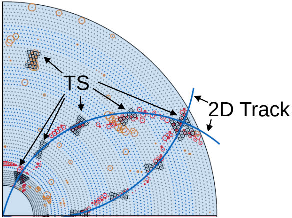


- Main System for online track reconstruction
- The Track Trigger System works with reduced data (TS from 9 SL)
- FPGA based Trigger
- 5 µs for the L1 Trigger System
- 350 ns for the Neuro Trigger [real latency 300 ns]

z-vertex Track Trigger FPGA Architecture

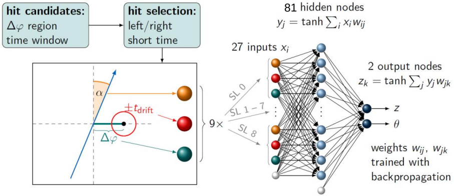


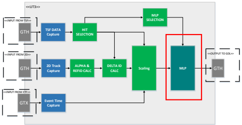
- Inputs:
  - 2D track from axial layers found via Hough transform
  - TS from stereo layer
  - Event time
- 4 Neuro Boards, one for each quadrant

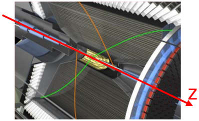


Multilayer Perceptron MLP

- Multilayer perceptron
  - 27 input neurons
  - 81 hidden layer neurons
  - 2 output neurons
- Determine z and Θ (polar scattering angle)
- Trained with full reco tracks
- Implemented pipelined in FPGA (Virtex 6)



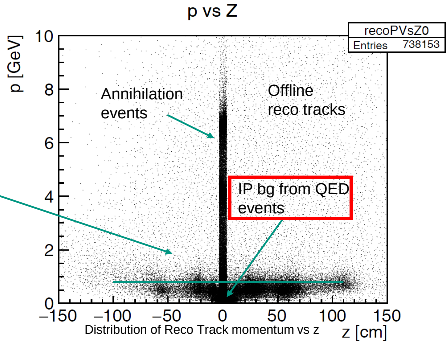




„STT“: a Minimum Bias Single Track Trigger

Momentum of particles outside of IP mostly below 1 GeV !!

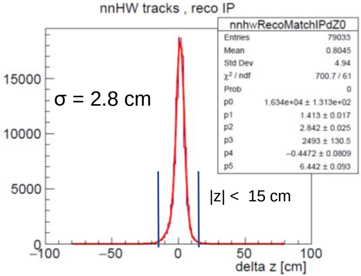
Collisions of electron with elements of the beam guide system, producing protons from nuclear spallation

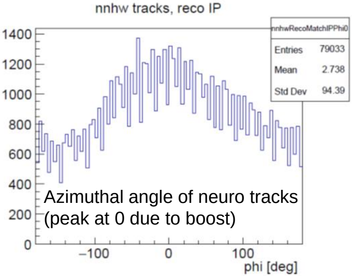


cut at $p > 0.7$ GeV
$|z| < 15$ cm

z Resolution for Tracks from IP

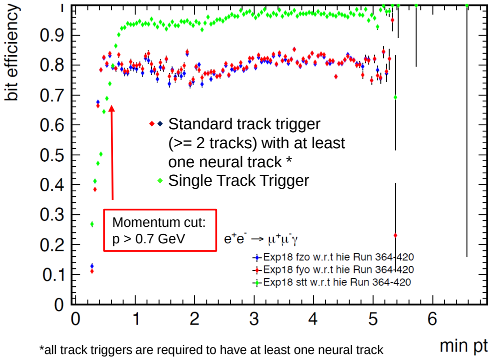
Results from new training





Data from 2022

Trigger Efficiencies

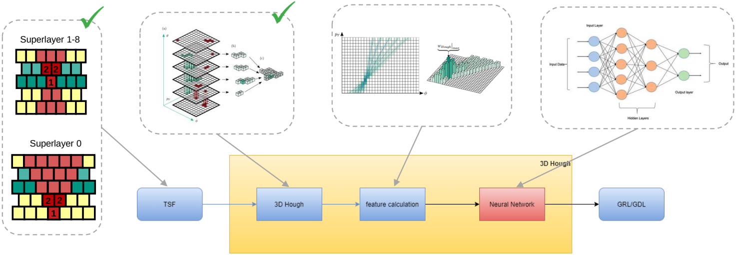


Michel Bertemes (HEPHY) + Petar Rados, Alberto Martini (DESY)

*all track triggers are required to have at least one neural track

3D Hough z-vertex Track Trigger

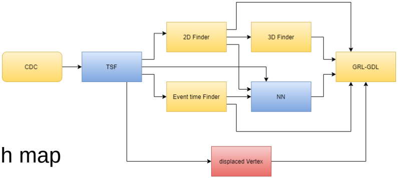
- 3D Hough Algorithm implemented in C/C++
  - Translated in VHDL over Vitis HLS
- Hopefully fewer differences between basf2 simulation and FPGA Hardware

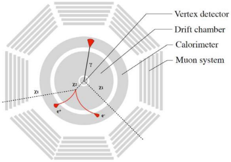


Karlsruhe Institute of Technology

Displaced Vertex Trigger

- A new type of CDC track trigger for finding displaced vertex Tracks
- Uses parallel Hough transformation with a hypothetical vertex
- Calculate track feature from the Hough map
- Use neural network to estimate true track origin
- Get the displacement from two-track vertex
- **Goal: Finding decays of long-lived particles not triggered by present L1 trigger**





All Layer DMAPS Vertex Detector Upgrade for Belle II

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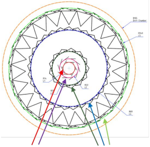
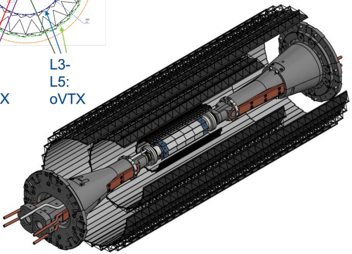
CMOS DMAPS VTX Proposal

- **5 layer pixel detector** with CMOS sensors
- **Same sensor chip for all layers**
  → Unique control and powering system
- **Low material budget**
  L(1-2|3-4|5): (0.1|0.3|0.8)% X_0
- **Power dissipation** ~100-200 mW/cm²
- **Direct connection** to standard Belle II **DAQ** and high level & level 1 **trigger inputs**
- Keep (or change slightly if required) current **machine-detector interface boundaries**

→ Development of new pixel sensor **OBELIX** by VTX collaboration

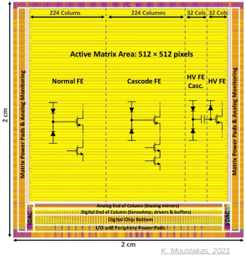




TJ-Monopix2: Design

- **Chip size** (2x2 cm²) with **pixel pitch** (33x33µm²)
- Improve FE to **lower noise and threshold**
  - Expected noise **<10 e⁻**, expected min. TH **<150 e⁻**
- **7 bit ToT** information
- 3 bit **in-pixel threshold tuning**
  - → More in-pixel logic at smaller pixel size
- **Triggerless readout**

- Command-based slow control from RD53B
- Four **LVDS lines for I/O** (additional 2 for debugging)
- **8b10b encoded data stream** with hit and register data



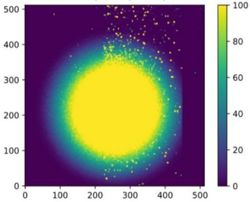
K. Moustakas, 2021

TJ-Monopix2: First Measurements

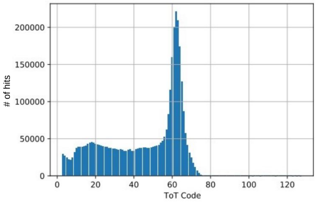
Successfully run source scan using **^{55}Fe source**

→ Chip works and detects radiation, detailed testing and characterization ongoing (see also upcoming talk by M. Schwickardi)

Occupancy map



Charge spectrum



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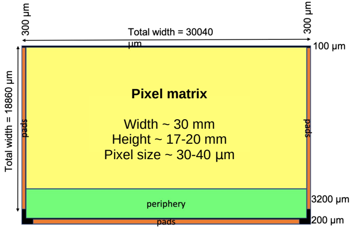
OBELIX

Based on TJ-Monopix2

- Increased **matrix size 3x2 cm²** with slightly larger **pixel pitch ~40 µm**
- **7bit ToT** information
- Fast **integration time**
  - 40 MHz clock
  - Consider 4 frames around trigger
- Integrate **trigger logic** and processing circuit
- Improve powering scheme for optimized power distribution across larger matrix

→ First **submission** aimed for **2022**

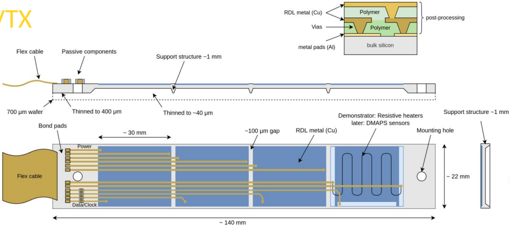

asterix.fandom.com



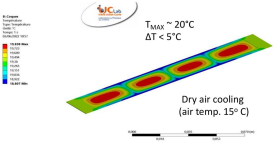
Inner VTX

All silicon ladder:

- Single piece of silicon
- 4 sensors per ladder
- **Active areas thinned** to ~40 µm
- Low power dissipation of pixel sensor makes **air cooling** viable
- Services only on backside



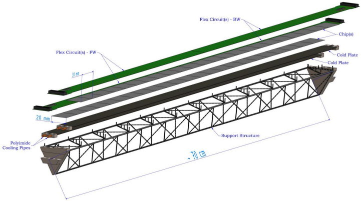
- First demonstrator with heater structures in progress
  - Order placed @ IZM (for Spring 2023)

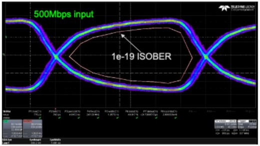


Outer VTX

Ladder concept:
- Evolution of **ALICE ITS2**
- Light carbon fiber support structure
- **Cold plate** including tubes
  - Leak-less water circulation for cooling
- Sensor glued to cold plate
- Flex print transmission lines

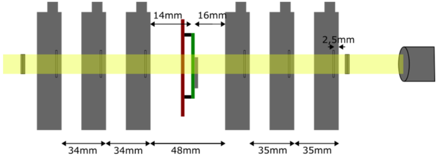
- First prototype available
  → Showed promising results

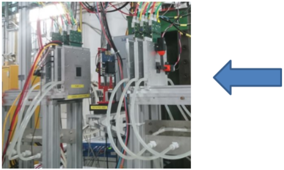




First test beam results with TJ-Monopix2

Test Beam Set-up Geometry





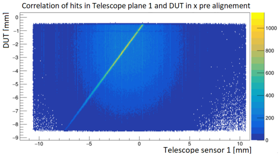
- TB22 (DESY) in June 2022.
- AIDA TLU and DURANTA telescope
- Scintillator triggering
- DUT on rotation-translation stages

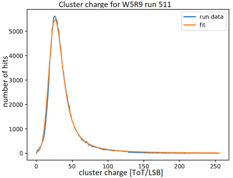
Measurements:

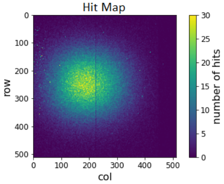
- First sanity checks: Correlation with telescope, pixel response, noise levels, cluster signal, full depletion depth
- Voltage scans
- Angular scans

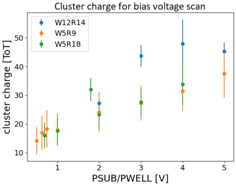
System Sanity Checks

- Geometrically aligned with beam spot
- Synchronization with telescope
- First bias voltage scans (depletion depth)
- Homogeneous response: Landau cluster charge distribution with $\mathcal{O}(10^{-1})$ masked pixels



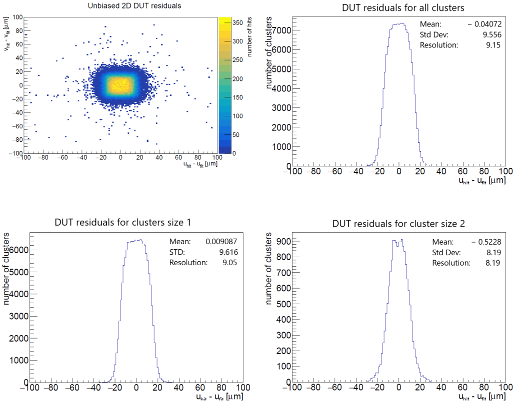






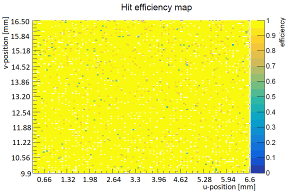
Residuals

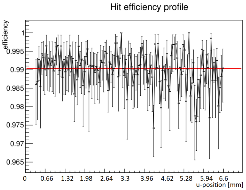
- W5R9: epi module
- Residuals at 3V PSUB/PWELL
- Uncertainty of telescope intersection at DUT plane ~3.5 µm
- Expected res. from pixel pitch: 9.54 µm
- **Resolution of 9.14 µm**



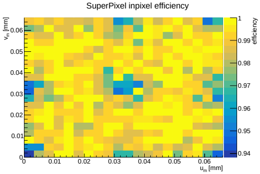
Efficiency

- 4 GeV, Perpendicular incidents
- Match DUT cluster hits in 100µm radius
- Hit efficiency $\epsilon = \frac{n_{matched}}{n_{tracks}}$
- Homogeneous overall and in pixel efficiency



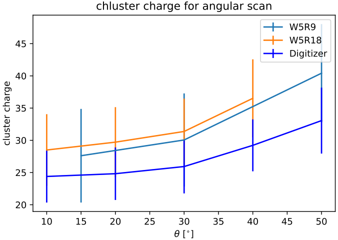


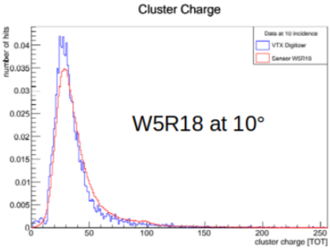
- ϵ at $\sim$500e threshold: 99.020 ± 0.004 %

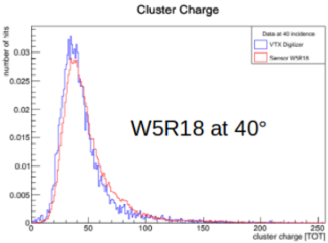


BASF2 Digitizer Validation

- Digitizer simulated for epi modules
- Pointing resolution, cluster size, and ToT from test beam spectra reasonably well described with specifics for epi modules







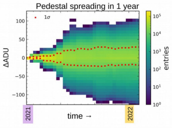
Belle II Germany Meeting

Hardware Session Pt. 2

- PXD2 Commissioning
- Influence of DCD Parameters →Pedestal Noise
- Introduction to ONSEN and ONSEN ROIs
- Update on Slow Pion Rescue with Machine Learning in the PXD

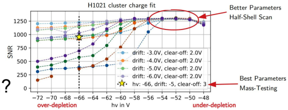
PXD2 Commissioning (Anselm Baur)

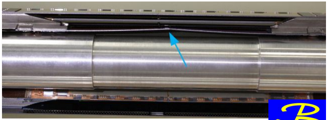
- Before LS1, PXD was only partially installed and the modules suffered from high instantaneous radiation doses, Pedestal aging and efficiency losses.
- Upgrade to full PXD is planned for LS1:
    - Modules and Half-Shells assembled at HLL and MPP
    - Complete Half-Shells tested at DESY
- Damage on 1st Half-Shell:
    - 2 broken (bended) inner ladders, kink height ~1.5mm
    - Cause of damage still under investigation
        - Screws to tight → no room for thermal expansion?
        - Thermal expansion of Al beam pipe?
        - Cooling broke down for a few seconds?
- 2nd Half-Shell commissioning on hold
- 2 good L1 replacement ladders available
- PXD2 will not be ready until October
- **BUT: PXD2 commissioning still planned for LS1**



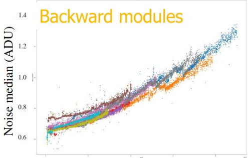
M. Konstantinova

$$SNR = \frac{\mathrm{MPV}}{\mathrm{noise}_{\mathrm{pedestal}}} \cdot \frac{\mathrm{area}}{1000}$$



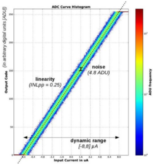


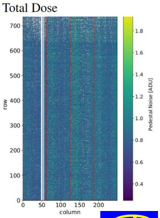
Influence of DCD Parameters on Pedestal Noise (Munira Khan)



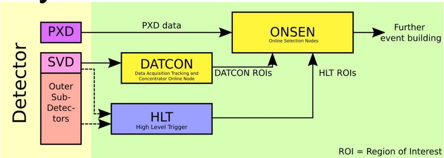
- Pedestal noise increased over time (almost doubled: 0.6ADU→1.2ADU)
- Corrections already in place: ACMC and offsets
- Past study: Irradiation of whole modules increased noise, Irradiation of only DCD had no influence

  →Study DCD parameters for possible noise reduction improvements:
  - DCD RefIn vs AmpLow: 0.12 ADU
  - IPSource-Middle: 0.07 ADU
  - IFBPBias: 0.08 ADU
  - IPSource vs IPSource2: ~0.2 ADU
  - Irradiated modules had higher pedestal noise
  - Operating under higher temperatures also yields higher pedestal noise
  - Noise is higher at one side of the DCD



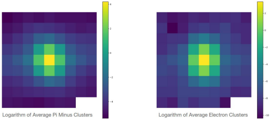


Introduction to ONSEN System and ROIs (Matthäus Krein)



- Data taking module for PXD
- Stable Operation during phase 3 (98.8% efficiency relative to B2DAQ)
- Runs on FPGA boards
- 8 Selector Carrier Boards get the ROI information simultaneously and distribute them to the selector cards (ANCs) (32 total)
- Currently, 4 ANCs are broken
- New development for CNBC (Compute Node Carrier Board):
  - Bigger FPGA, faster links
  - Compatible with current ONSEN system
- ONSEN system fulfills requirements for maximum luminosity (20Gbyte/s @ 3% occupancy and 30kHz trigger rate) → No need for replacement by PCIe40
- New idea: standalone slow pion rescue directly within PXD (studies ongoing in Gießen and Munich)

Update on Slow Pion Rescue with ML in the PXD (Johannes Bilk)



- Two approaches:
  - Feed reconstructed custers to Neural Network (Munich)
  - Feed 9x9 pixel images and position to NN (Gießen)
    → decision trees yield the best tradeoff between performance and speed
- Previous PXD based AI projects:
  - Search for magnetic monopoles with:
    MLP (good for high signal eff.),
    SOM and AE (both better for low signal eff.)
  - Search for slow pions vs. slow electrons with decision tree: precision 82%, sensitivity 80%, cluster charge is most significant information (97.6%)
  - Search for slow pions vs. electrons or background using SVMs and CNNs: precision 82%, sensitivity 81%
- New Study: Momentum estimation with neural network
  → it works, track creation possible