Impressions of the InGrid spark test at CERN SPS

November 9 – 14, 2016

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NIKHEF

LepCol meeting
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Overview

- Aim
  - Check for excessive sparking induced by high intensity hadron beam
  - High ionisation events expected from nuclear reactions
    - Gammas
    - Converting neutrons
    - ……

- Also unexpected phenomena observed
  - Limits in gain
  - Fast charging up of protection layer
  - Also charge signal current at inversed drift field

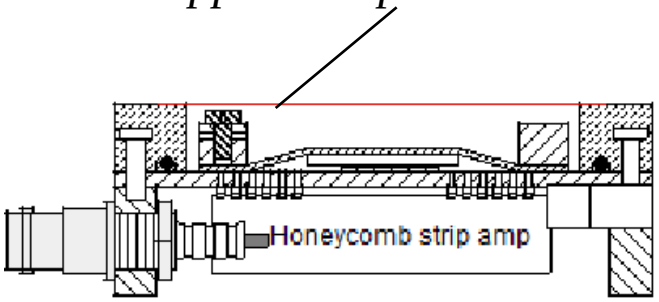
- Initially all grids showed gas amplification
  - One grid rapidly rising dark current at -650 V => useless

- **A lot of data waiting to be analysed**

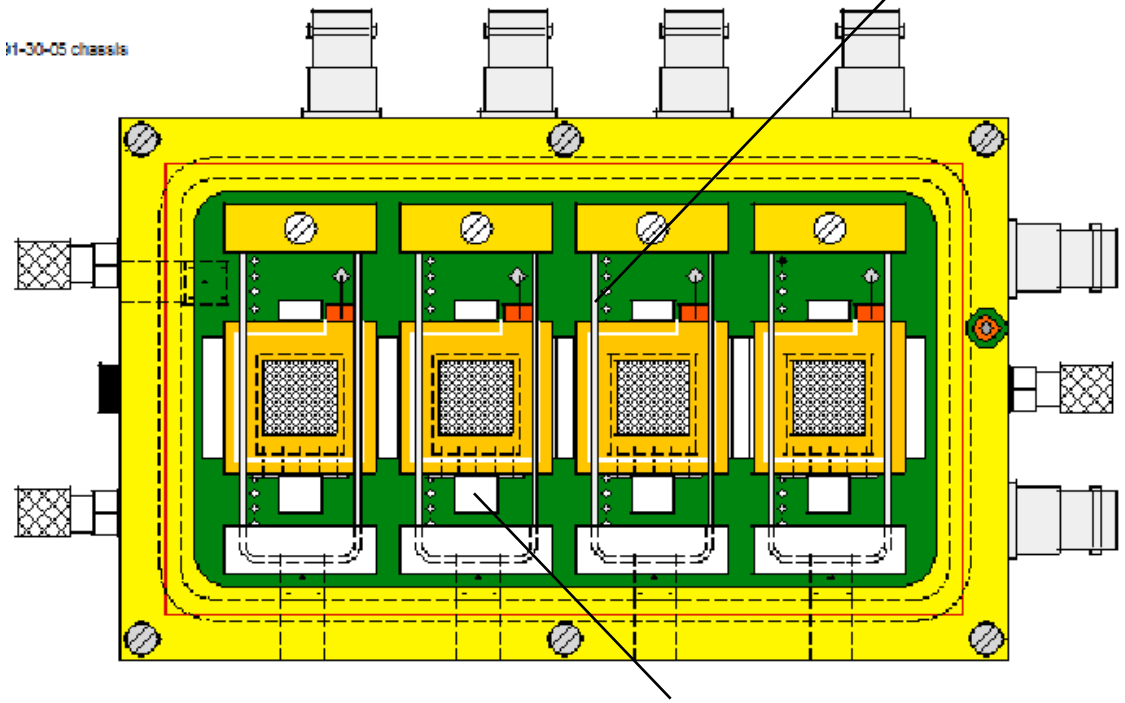
Protection layer test device

- 4 channels
- PCB sandwiched by insulating gas envelope and aluminium connector frame

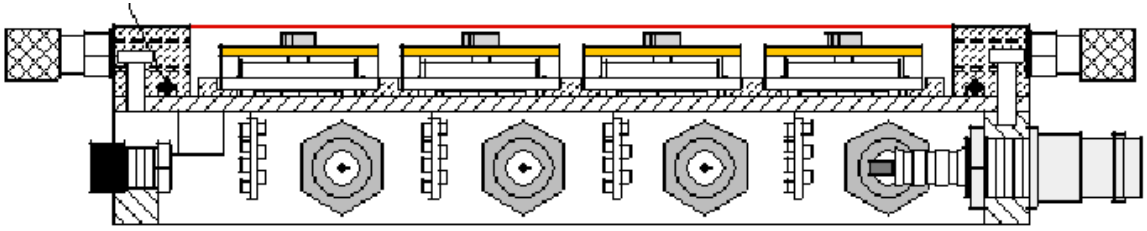
Coppered kapton cathode



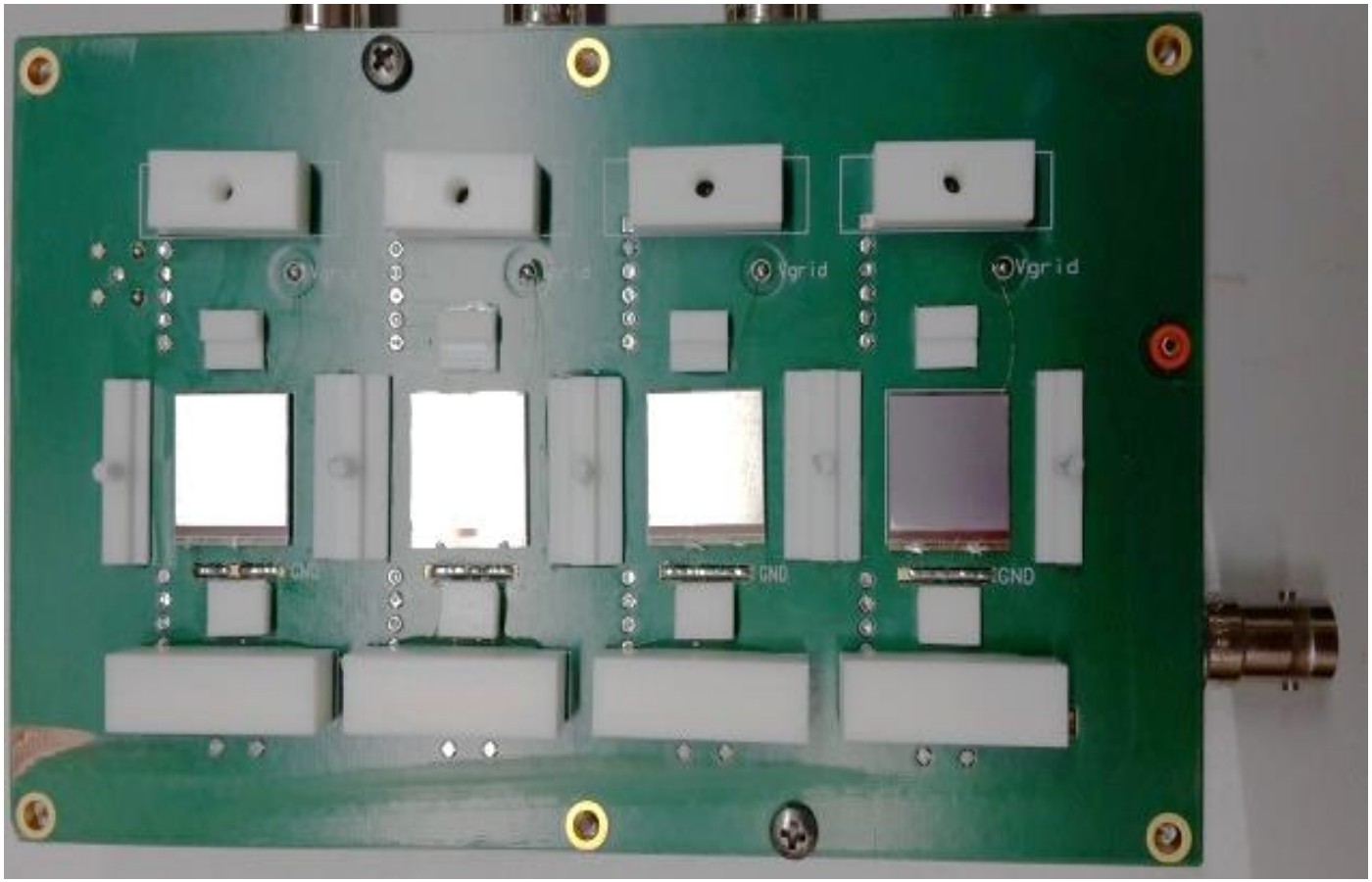
Silicon rubber wire

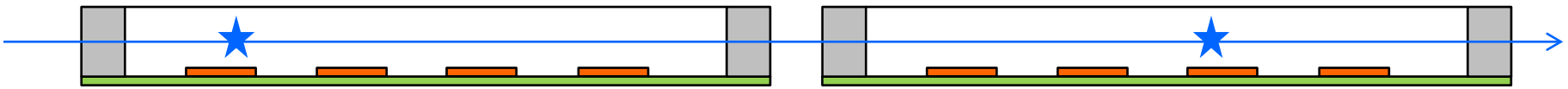


Plastic blocks to guide the Micromegas



Chips with Ingrid mounted instead



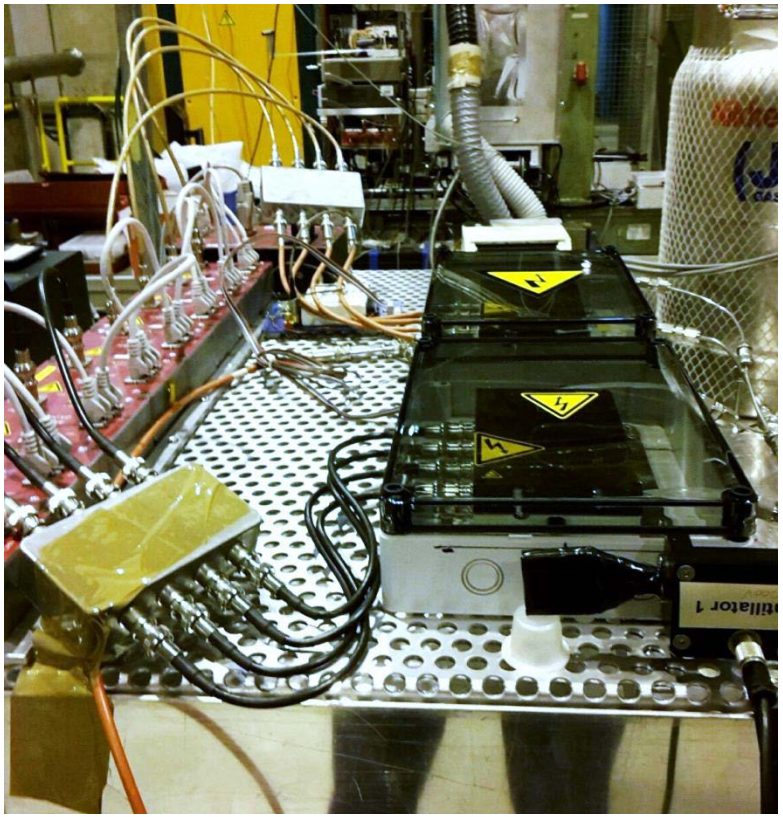


Setup

- 8 chips with InGrid tested simultaneously
  - 4 x TPX3 + 4 µm SixNy
  - 2 x TPX1 + 4 and 8 µm SixNy
  - 2 x silicon + 4 µm SixNy (dummies)
- All supplied by Yevgen at October 26

CH1	TPX3-4 um SixNy A6
CH2	TPX3-4 um SixNy M5
CH3	TPX3-4 um SixNy B7
CH4	TPX3-4 um SixNy A5
CH11	dummy 4 um SixNy-1
CH12	dummy 4 um SixNy-2
CH13	TPX1-8 um SixNy D2
CH14	TPX1-4 um SixNy H4

- Individually connected with MiniHV
  - Current measurement with 0.1 nA resolution
- Cathode at 10 mm height
  - No guard electrode
- Grids connected by 100 MΩ to HV
  - ~30 pF grid capacity
- Few tests at the end 1 nF capacitor added
  - => large sparking current



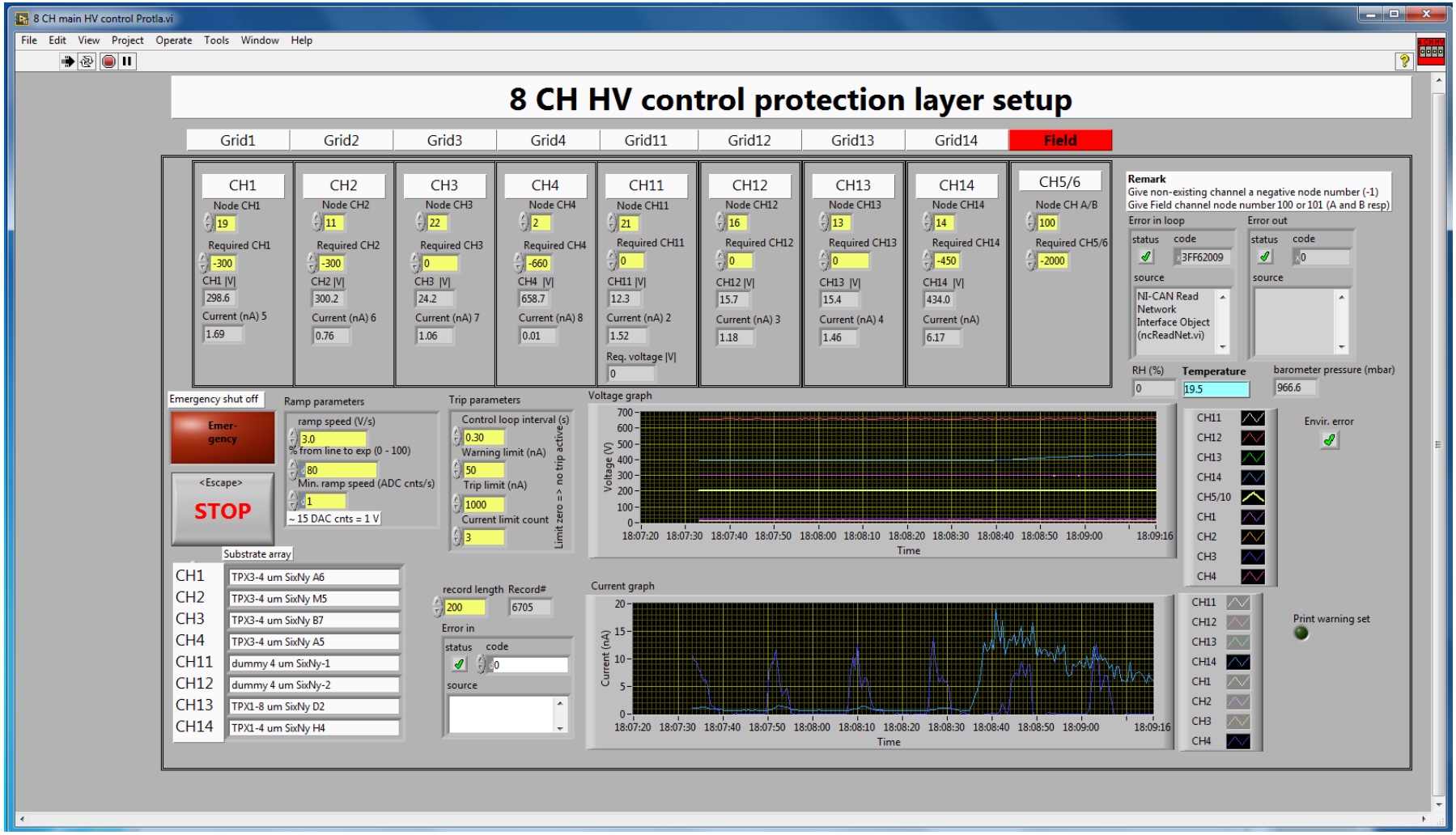
Setup (cntd)

- Gas
  - Starting with iC4H10/Ar/CF4 2.1/94.9/3.1 (T2K)
  - Vgrid normally 300 – 400 V
- Also tests with DME/CO2 50/50
  - Vgrid 600 – 780 V
- Beam SPS H8 200? GeV pions
  - ~1.5 x 10^6 pions /spill
  - Duration 5 s
  - Period 18 s
  - Profile: ellipse of ~ 8 x 12 mm
  - => rate ~ 300 kHz/cm^2 of parallel tracks

- Scintillator added to measure the beam flux
  - ~1.5 M per spill
  - Can be used to calculate the gas gain from the measured current

DAQ window

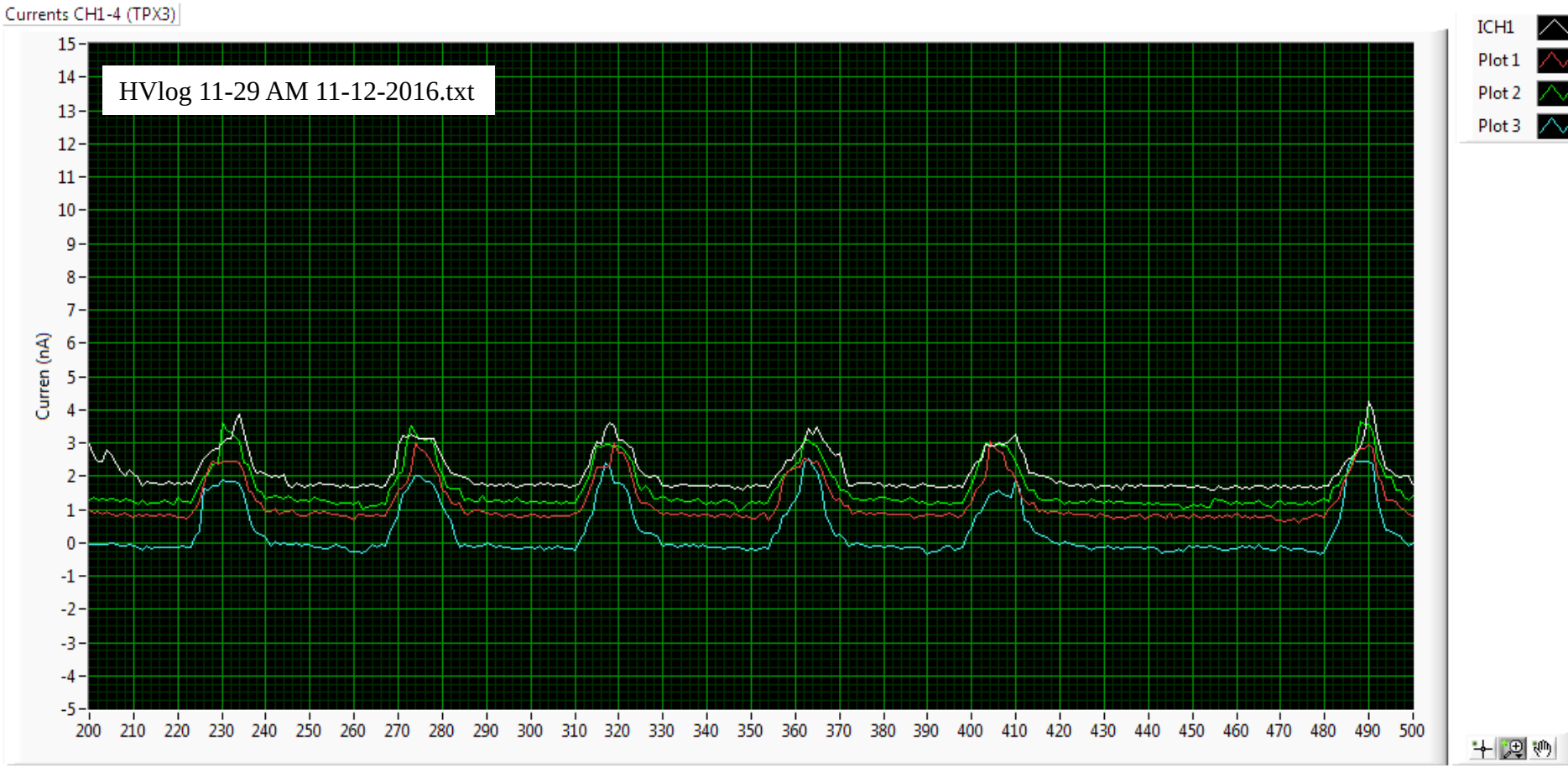
- Voltages, currents, chamber pressure, temperature permanently registered at 2.5 Hz



4 x TPX3

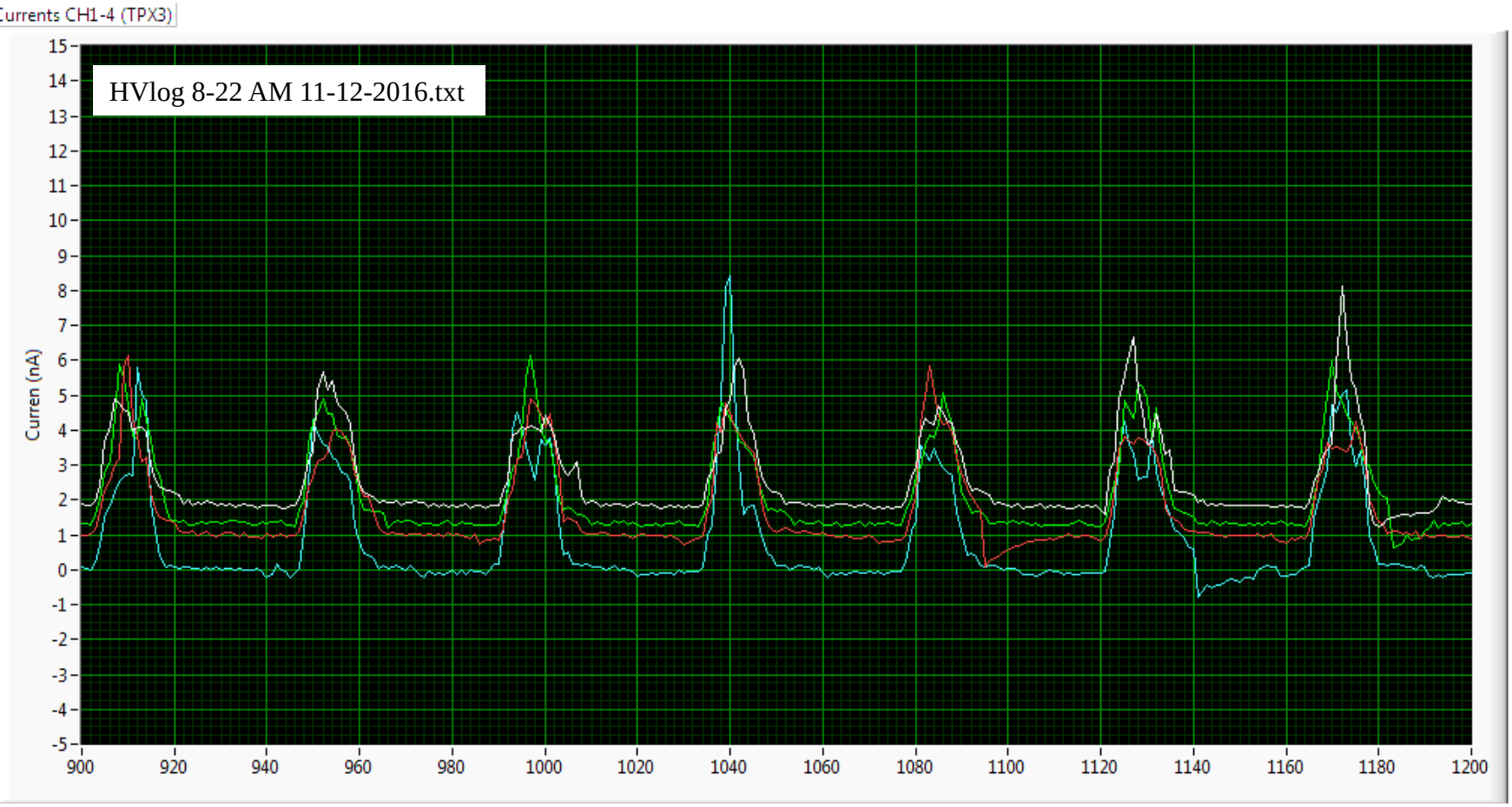
All potentials negative

- **All 310 V**
- Current induced by spill well visible (~2 nA)



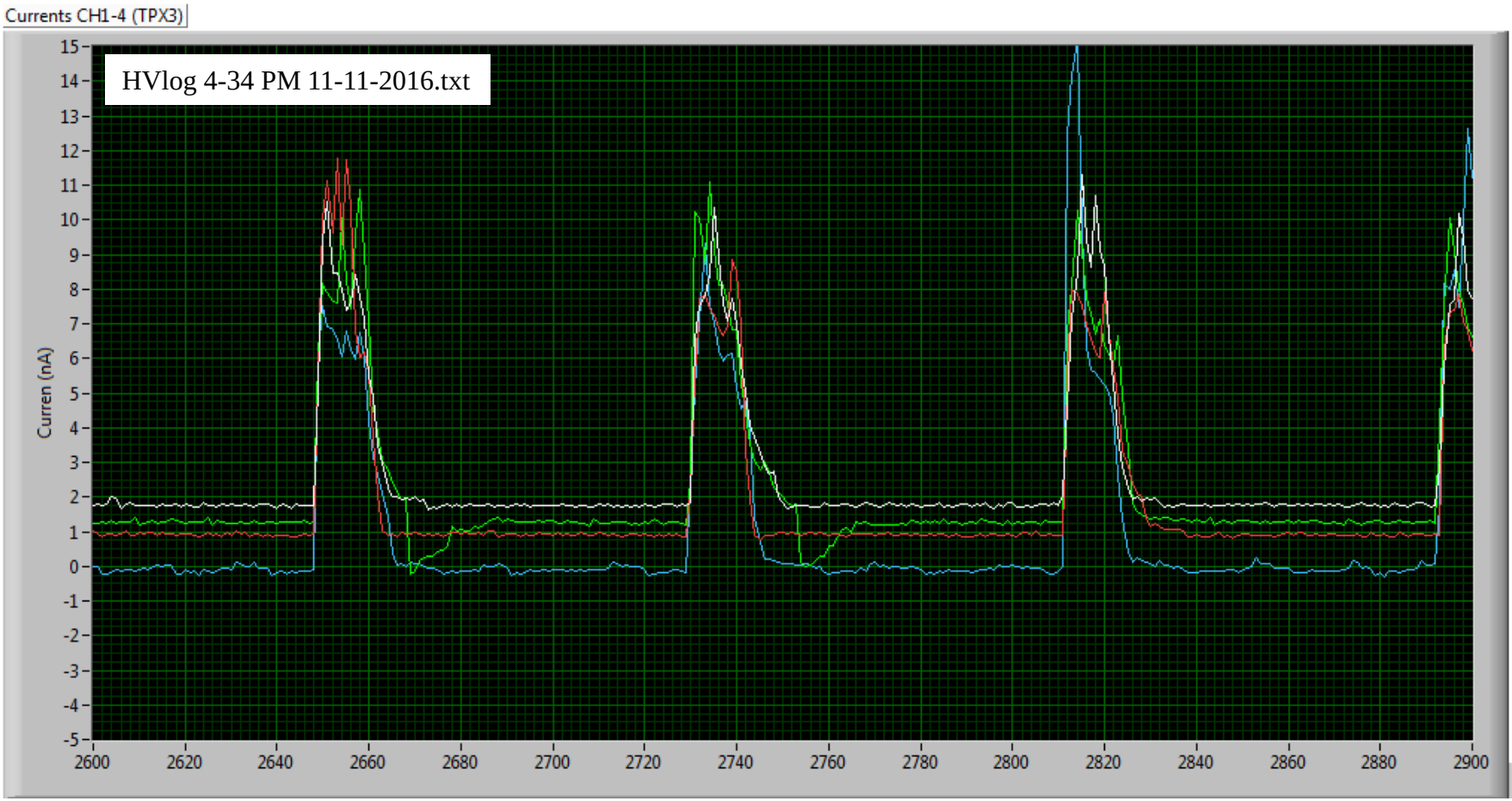
4 x TPX3

- **All 350 V**
- Current ~4 nA



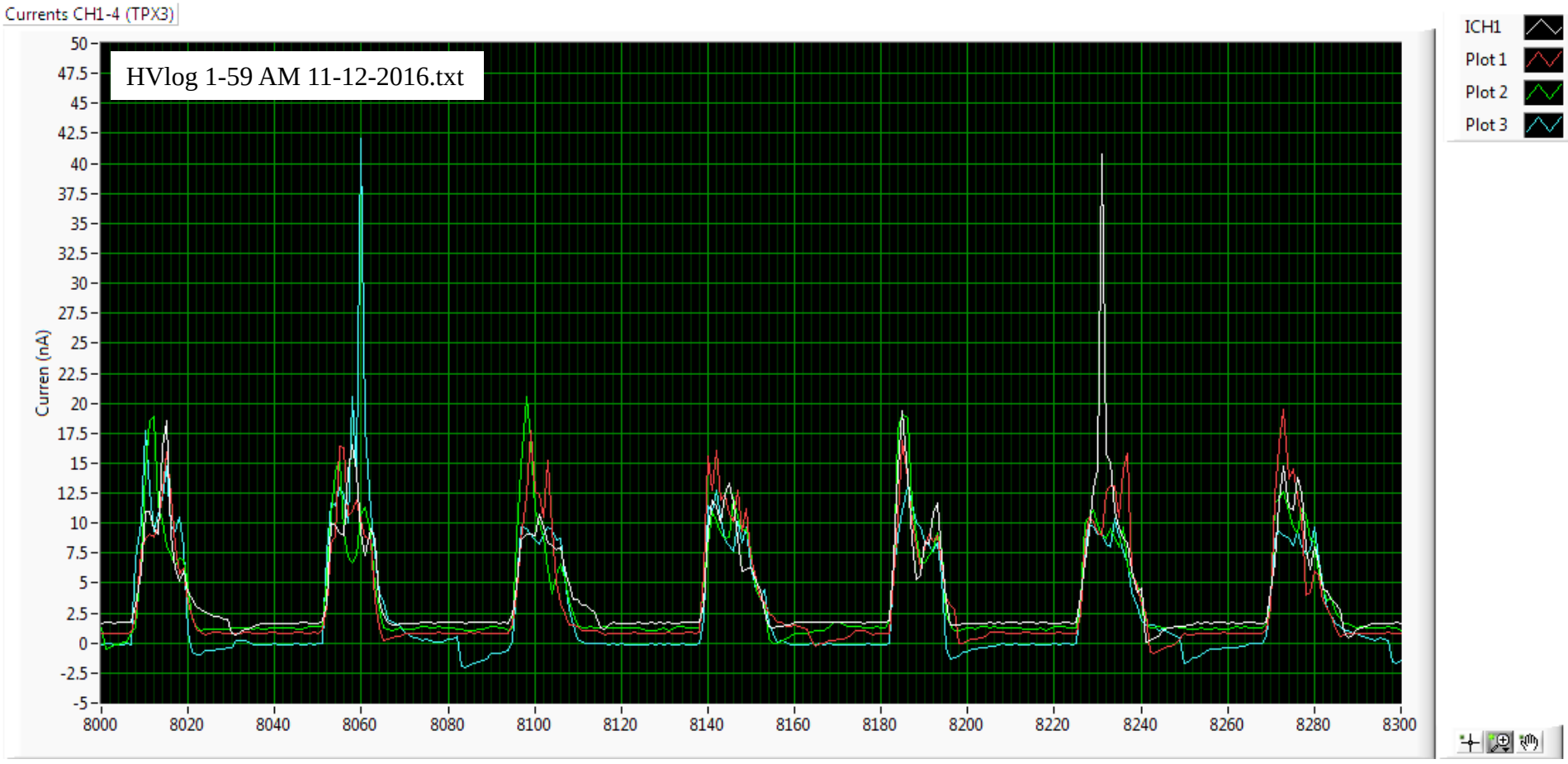
4x TPX3

- All 400 V
- Current ~ 8 nA



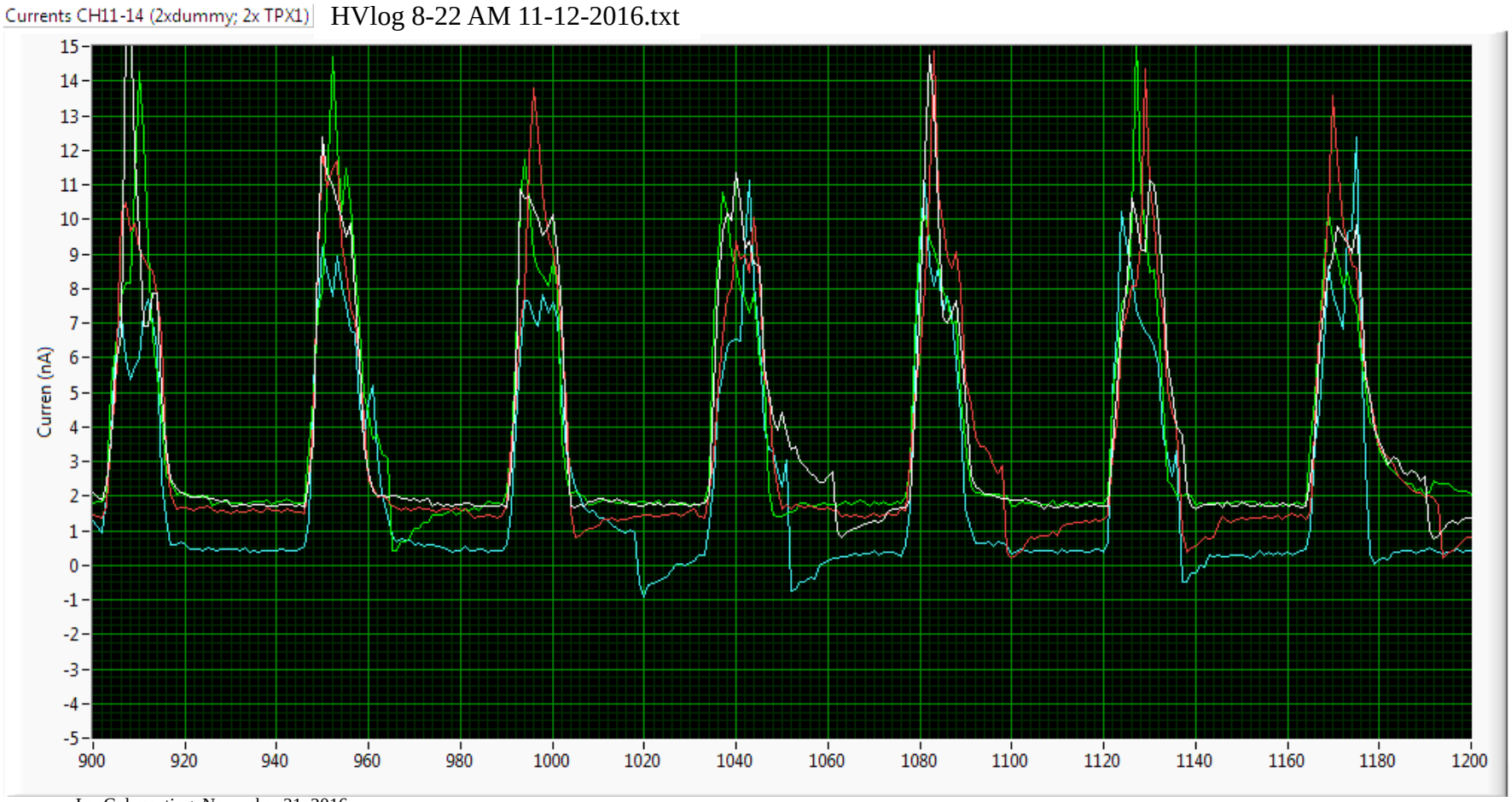
4x TPX3

- **All 450 V**
- Induced sparking
- Current ~10 nA: saturation



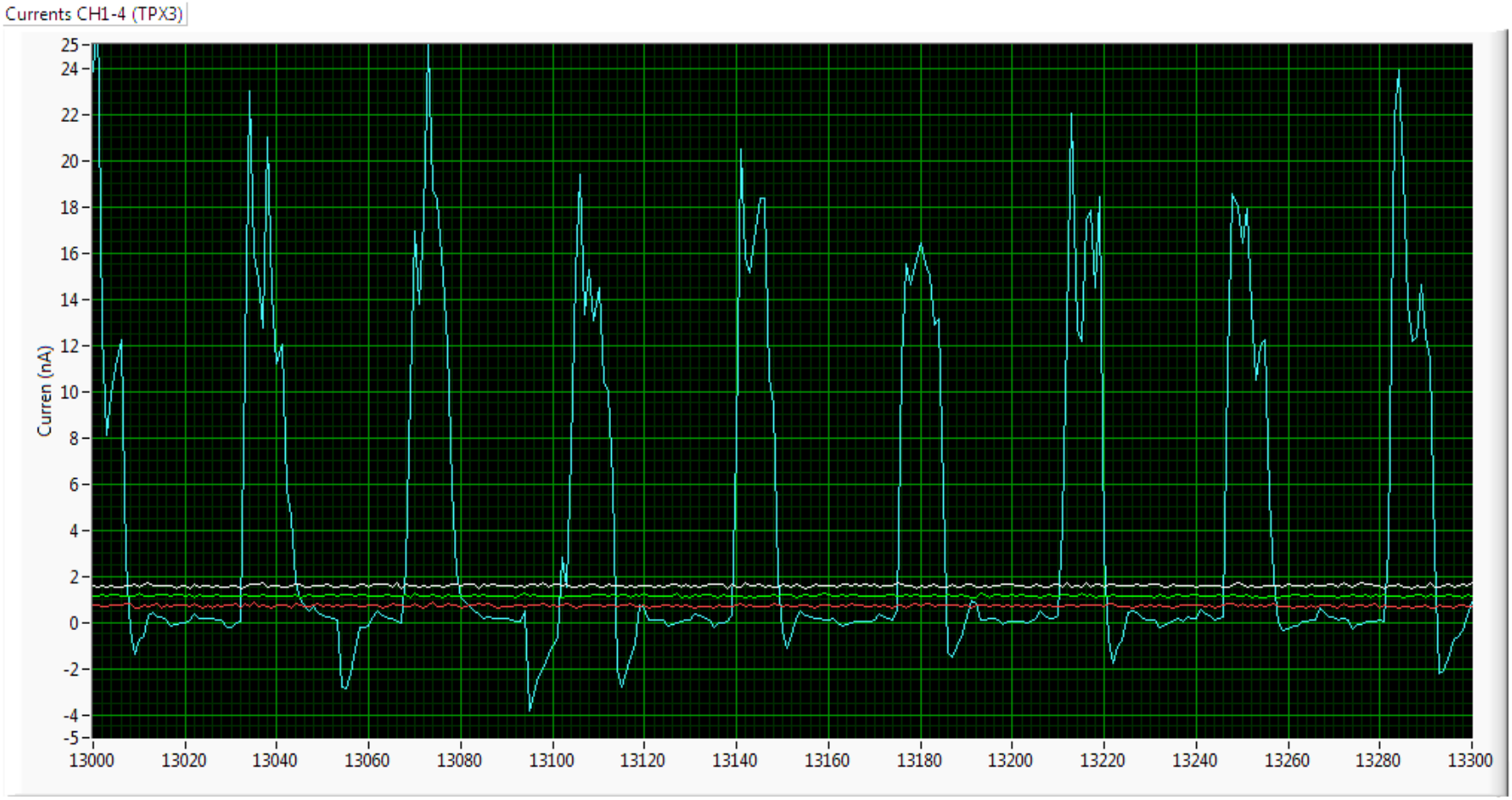
2x dummy; 2 x TPX1

- **Dummies: 300 V**
- **TPX1: 325 V**
- Same current at much lower grid voltage



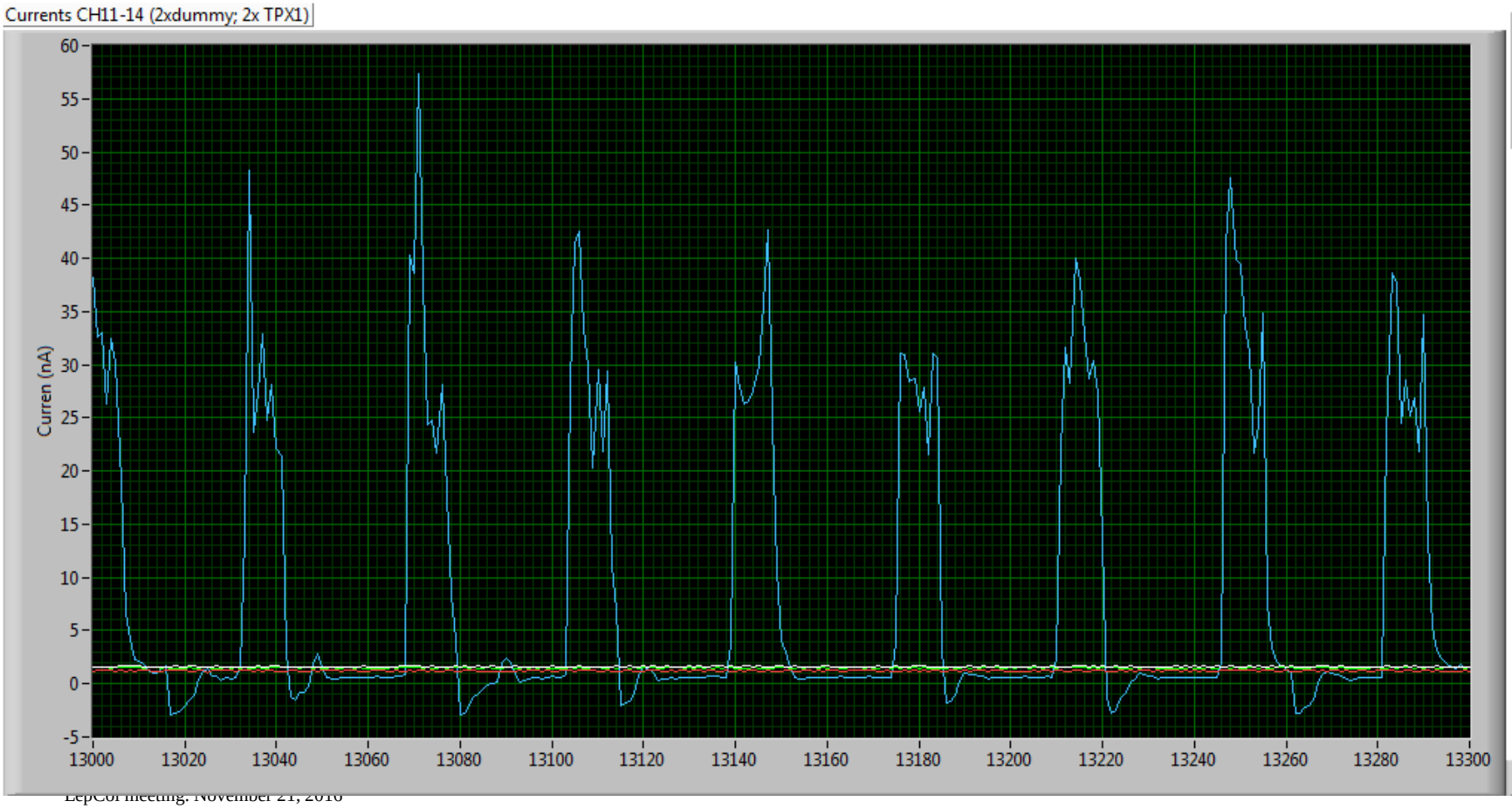
TPX3 (CH4) in DME/CO2

- **Vgrid = 780 V**
- ~15 nA at extreme grid voltage



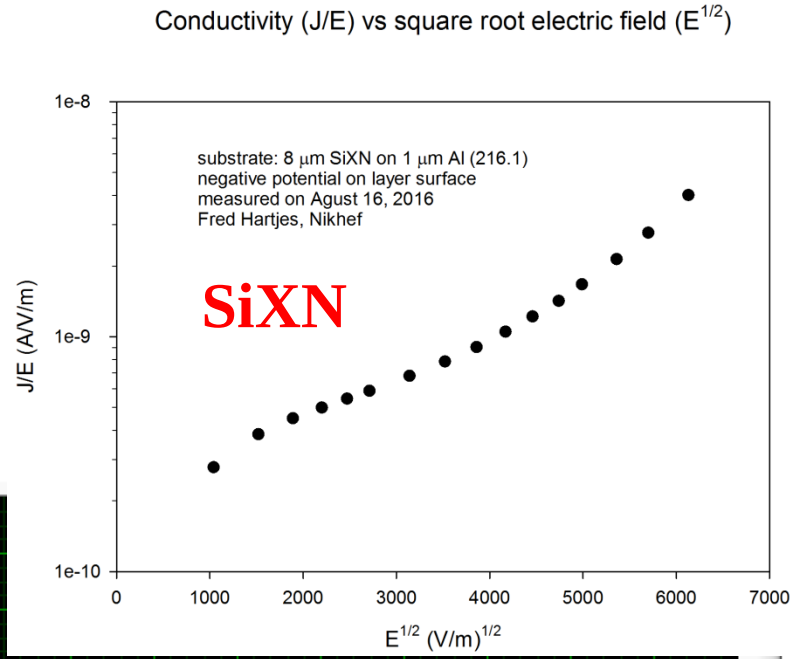
TPX1(CH14) in DME/CO2

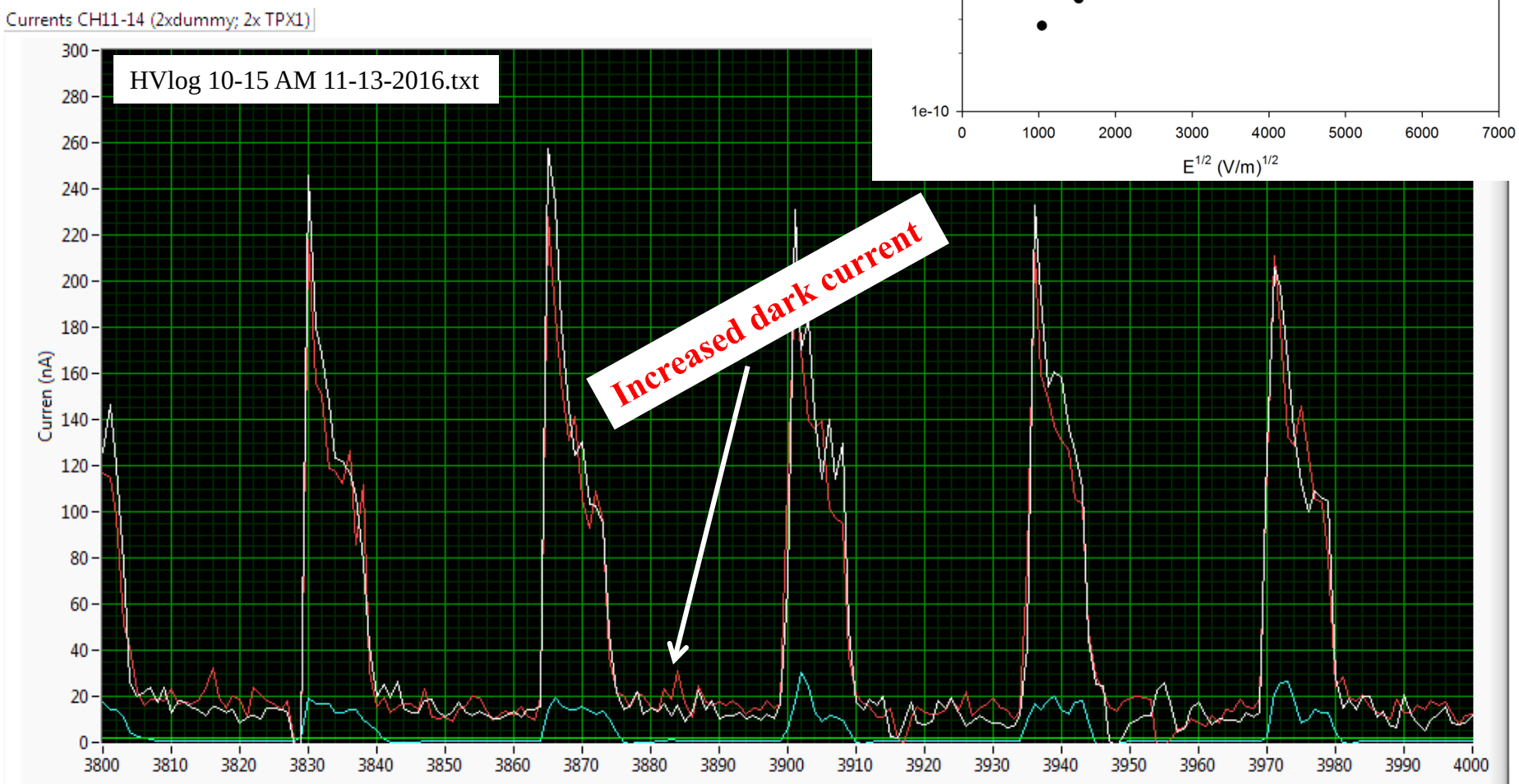
- **Vgrid = 680 V**
- Double current at 100 V lower grid voltage



CH11 and 12 (Dummies) in DME/CO2

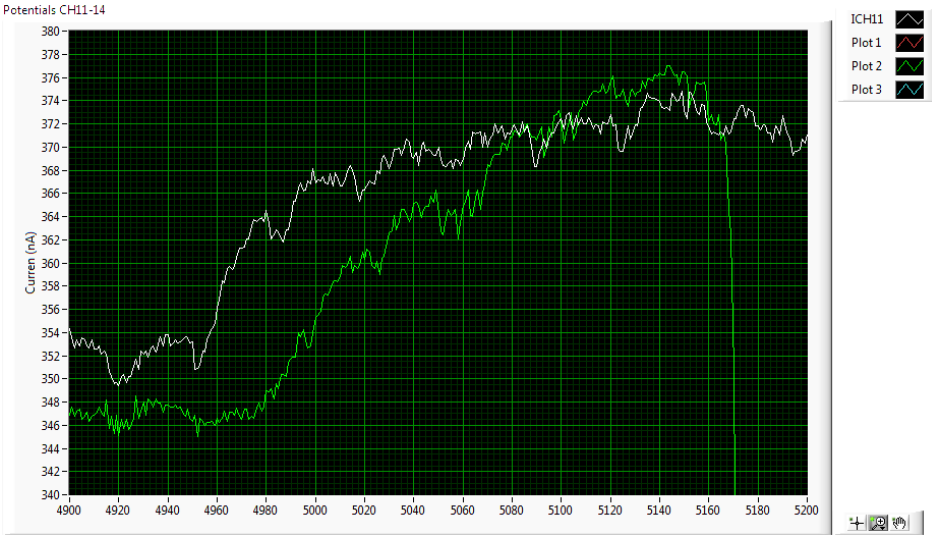
- **Vgrid = 710 V**
- Rapid charging up of protection layer
  - Low resistivity due to high potential difference across the layer
  - => small time constant

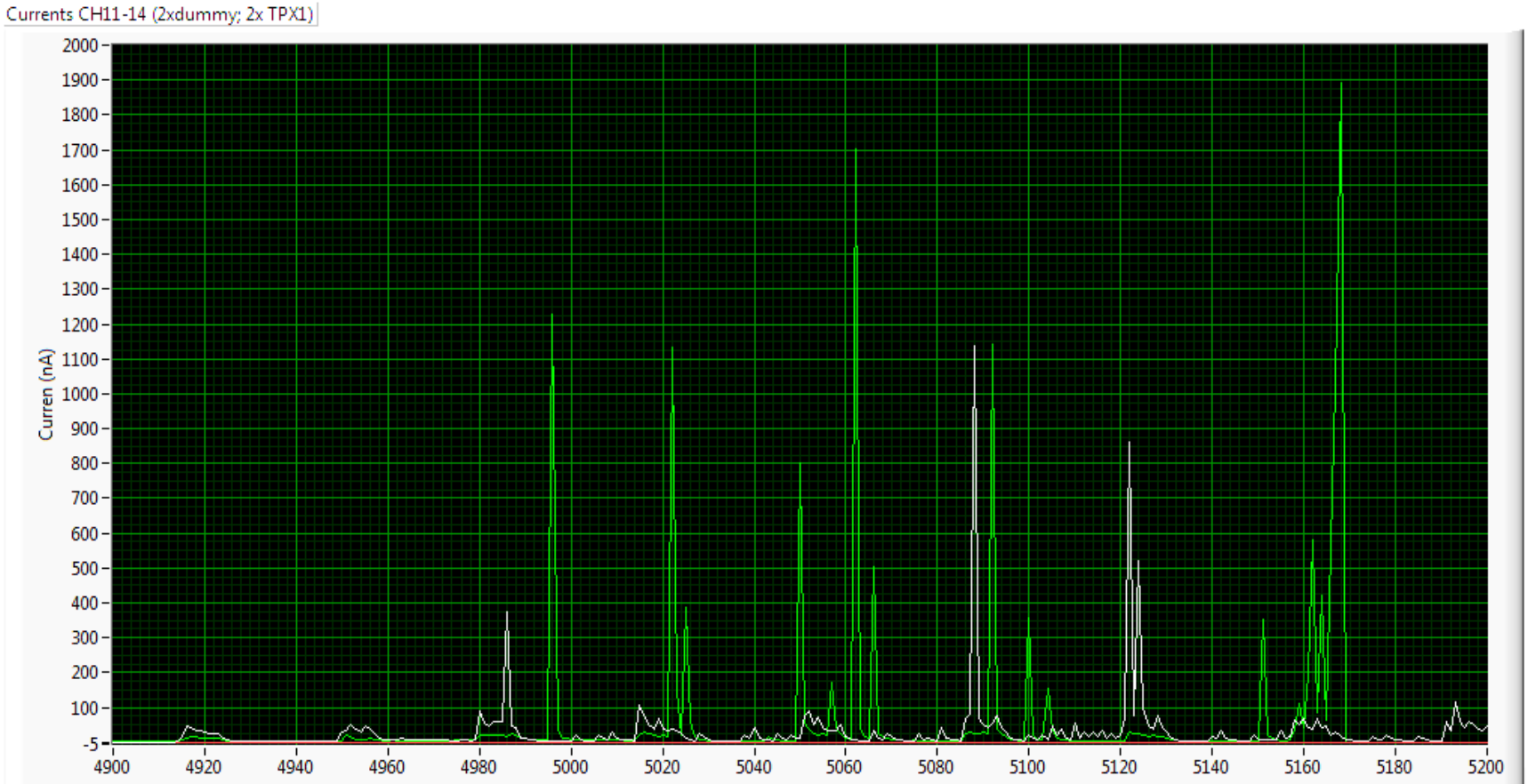




1 nF grid capacitor added

- **CH11 (dummy) and CH13 (8 um TPX1)**
- Ramping from 350 to 370 V
- => lethal sparking in µA region
- **CH13 tripped**
- Sparks easy to trace under the microscope





Conclusions so far

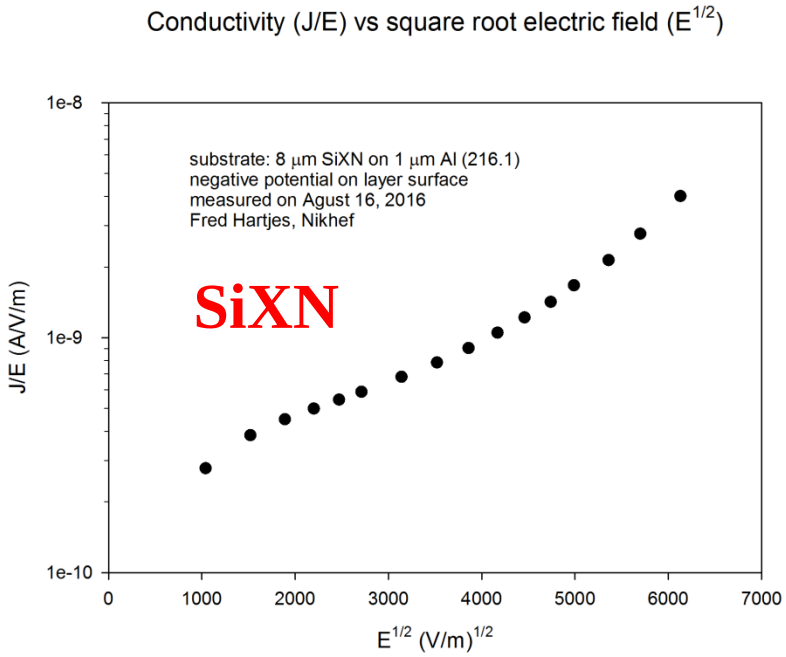
- During irradiation there is some increased sensitivity for sparking
  - But no excessive sparking at moderate gain observed
- Limited amplitude of sparking current
  - ~30 nA (T2K) or ~60 nA in DME/CO2
  - Possibly not lethal for chip
- High sparking amplitude (µA region) with 1 nF added
  - Lethal damage to chip

- Large dependence of induced current on surface of pads
  - Moderate current for TPX3 (10 nA), but probably sufficient gain (increased Vgrid needed) but very high grid voltages do not help
  - 2 x larger current for TPX1
  - Very large current possible for the dummies (up to 500 nA)
- Increased dark current for the dummies at high grid voltage
  - Spontaneous electron emission by the grid?

- At high grid currents 70% remained when the drift field was inversed
  - Not quite understood
  - High negative charges on PCB (no guard electrode)

Consequences for LepCol

- Also at much lower rate the observed effects may be present but in a smaller extend (gain reduced to 50 -70%)
  - Reduced conductivity at small voltage drop across protection layer
  - We will always see the first 10 - 15 V drop across the layer
- The observed effects can be easier and more accurately studied at Nikhef
  - Source with remotely controlled mechanical shutter



SPARE

Registering sparks

- Designed for dummy substrates with loose Micromegas
- **But can also be used for TPX3 chips with InGrid**
- 4 channels per assembly
  - Each channel has individual HV control
    - Nikhef miniHV
  - Currents measured in sub nA resolution
  - Currents registered at 5 Hz rate
  - Two alarm levels
    - **Warming: register discharge (presently 50 nA)**
    - **Trip: shut off HV (presently 3 x 1 µA in succession)**

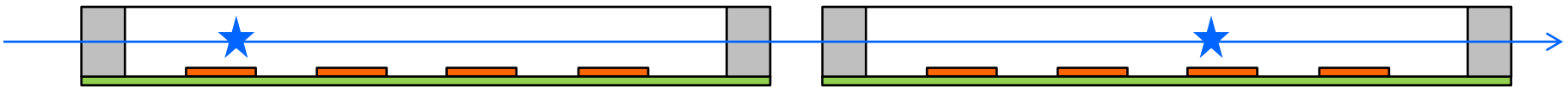
- Grid coupled to Honeycomb strip amplifier
- Normally currents and voltages are only logged once a minute
- At spark discharge (exceeding warning limit) currents of few minutes before and after discharge are stored

Testbeam at CERN

- High rate (> 1 MHz/cm2) hadron beam at SPS
- => many awkward high ionization phenomena
  - Showers
  - Converting gammas
  - Converting neutrons
- Raether limit (~ 10^7 e^-) frequently exceeded
  - Many sparks expected

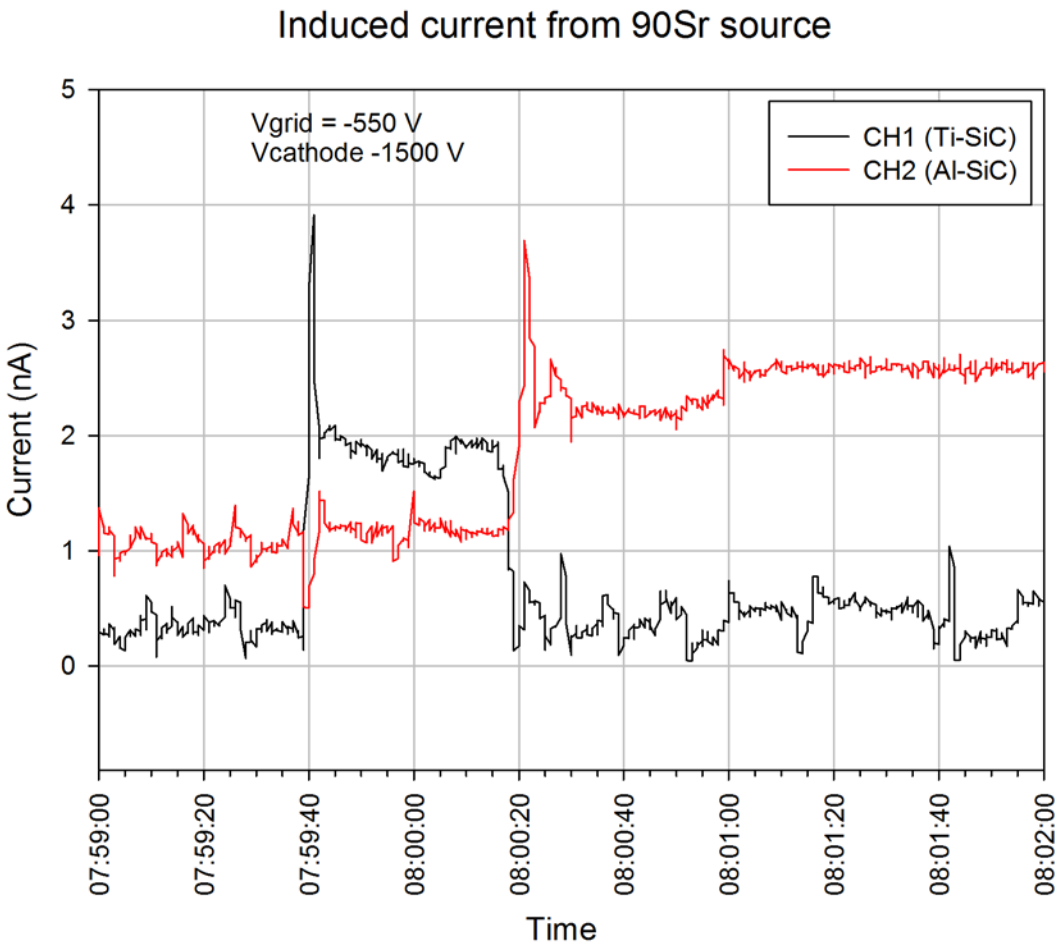
- Two test modules
  - => 8 chips may be tested in parallel
  - But we still need some 4 chips (electrically broken, but good grids)

- Planned Nov 2 – Nov 9 in T4 H8 (LHC-B), parasitic
  - Crew: Stergios, Kevin?, Fred, …..



Gas gain

- Gas: DME/CO2 50/50
  - O2 level 100 – 150 ppM
- Gas directed through two Thorium socks
  - => Alfa track every 4 s
  - Big pulses easily developing to spark discharge
- Using 55Fe source
  - Assuming 220 e-/conversion
- Low rate gain (approximate), needs verification
  - ~1500 at -550 V grid
  - ~6000 at -600 V grid
- Gain drops down by factor > 4 at high rate
  - Gain is restored in ~30 s after removal source
  - To be measured precisely => calculation of SiC resistivity



Spark test with Al-SiC substrate

- Several typical discharge points
- SiC layer has been burst
- Discharge also visible at the backside of the grid