Pulse shape analysis for KRATTA modules

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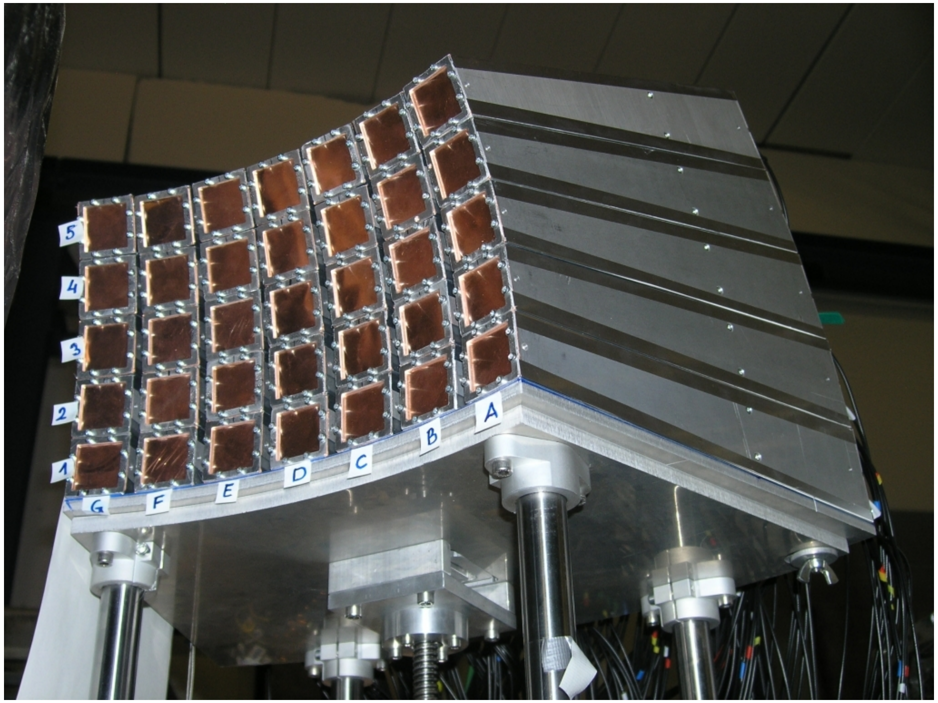


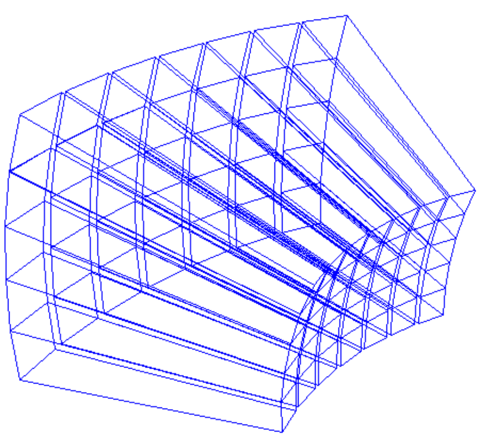
Siracusa, 4-7.09.2012

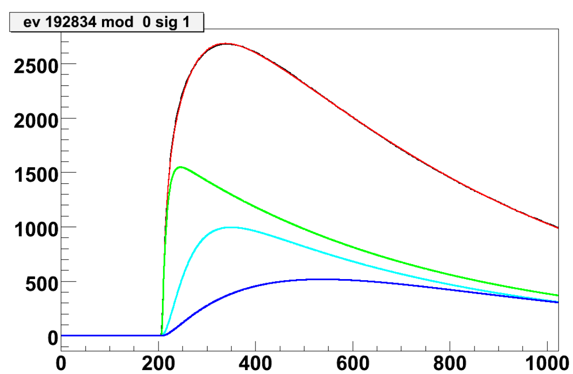
Ministry of Science and Higher Education

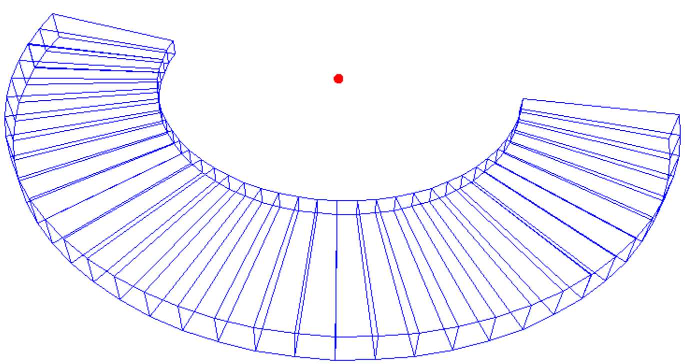
Republic of Poland

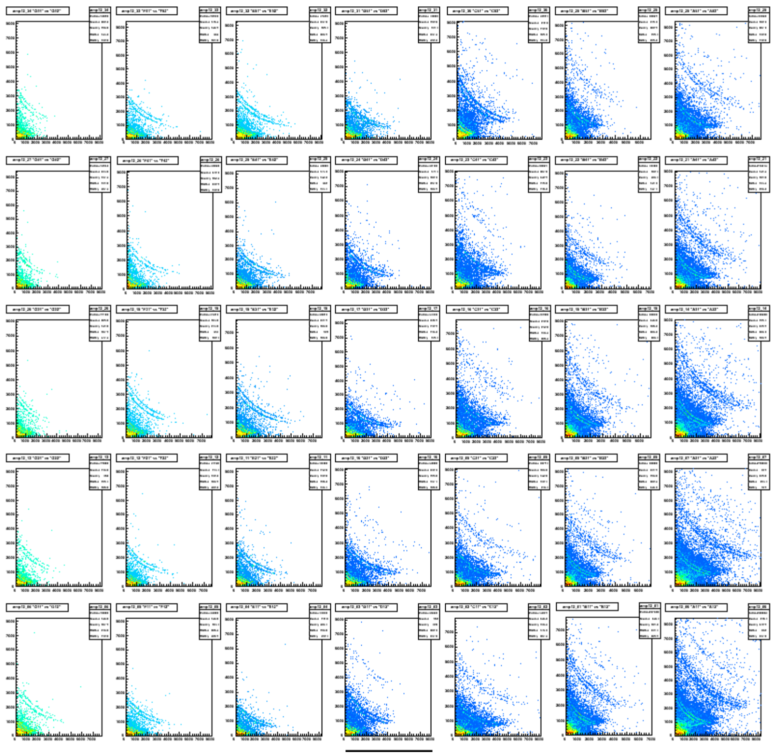
Main characteristics

- Broad energy range (from ~2.5 to ~260 MeV for protons)
- Mass resolution up to Z~4
- Modularity, versatility, portability (35 modules)
- Solid angle ~160 msr (~4.5 msr/module at 40 cm from the target)
- Low noise preamplifiers
- Digital pulse processing → 15 × V1724 CAEN digitizers (100 MHz, 14 bits)
- Off-line pulse shape analysis → reduced thresholds, improved resolution
- VME+RIO4+MBS data acquisition
- Budget friendly



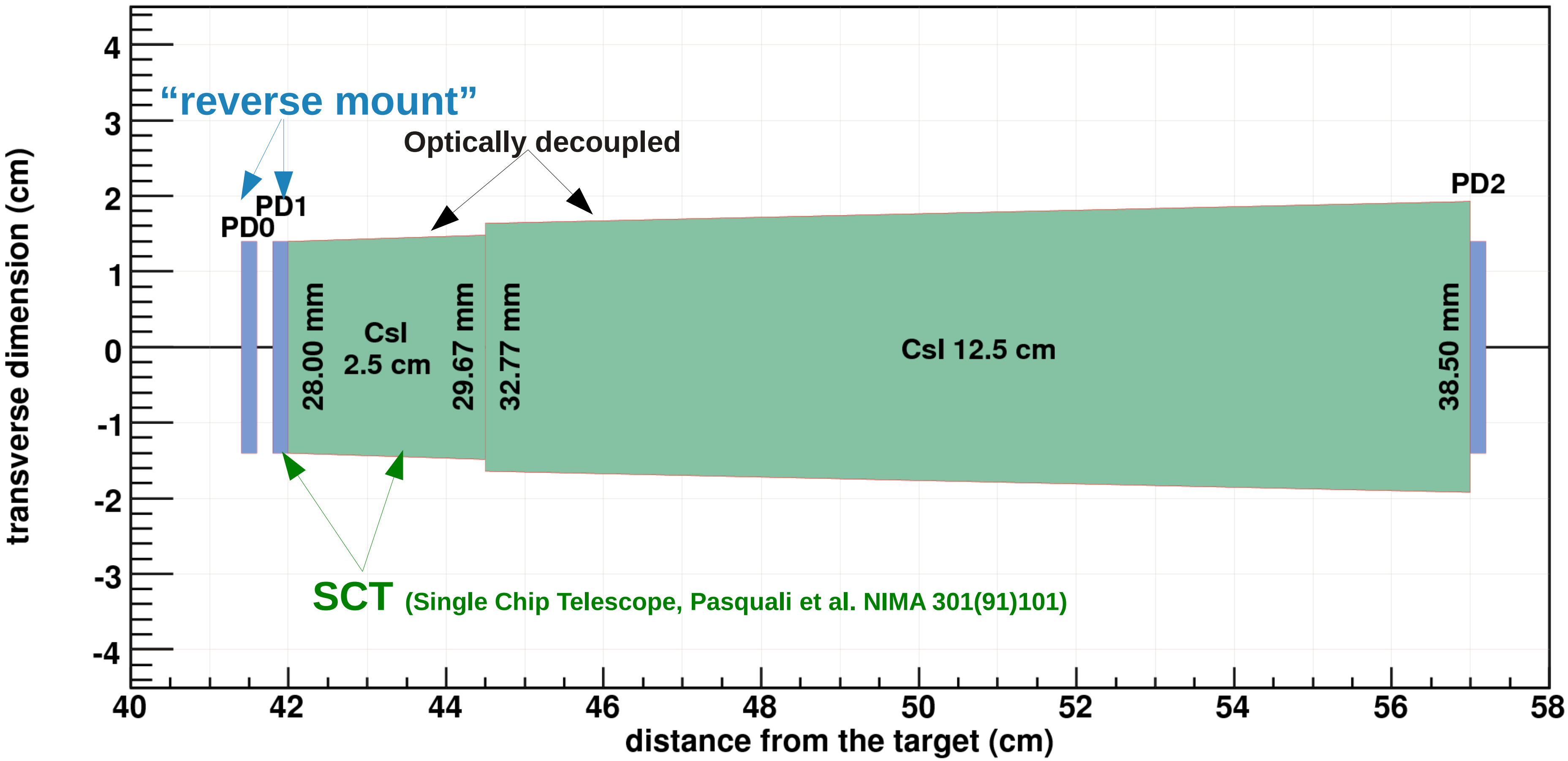






TRIPLE TELESCOPE

Active elements



Photodiodes: HAMAMATSU S5377-02

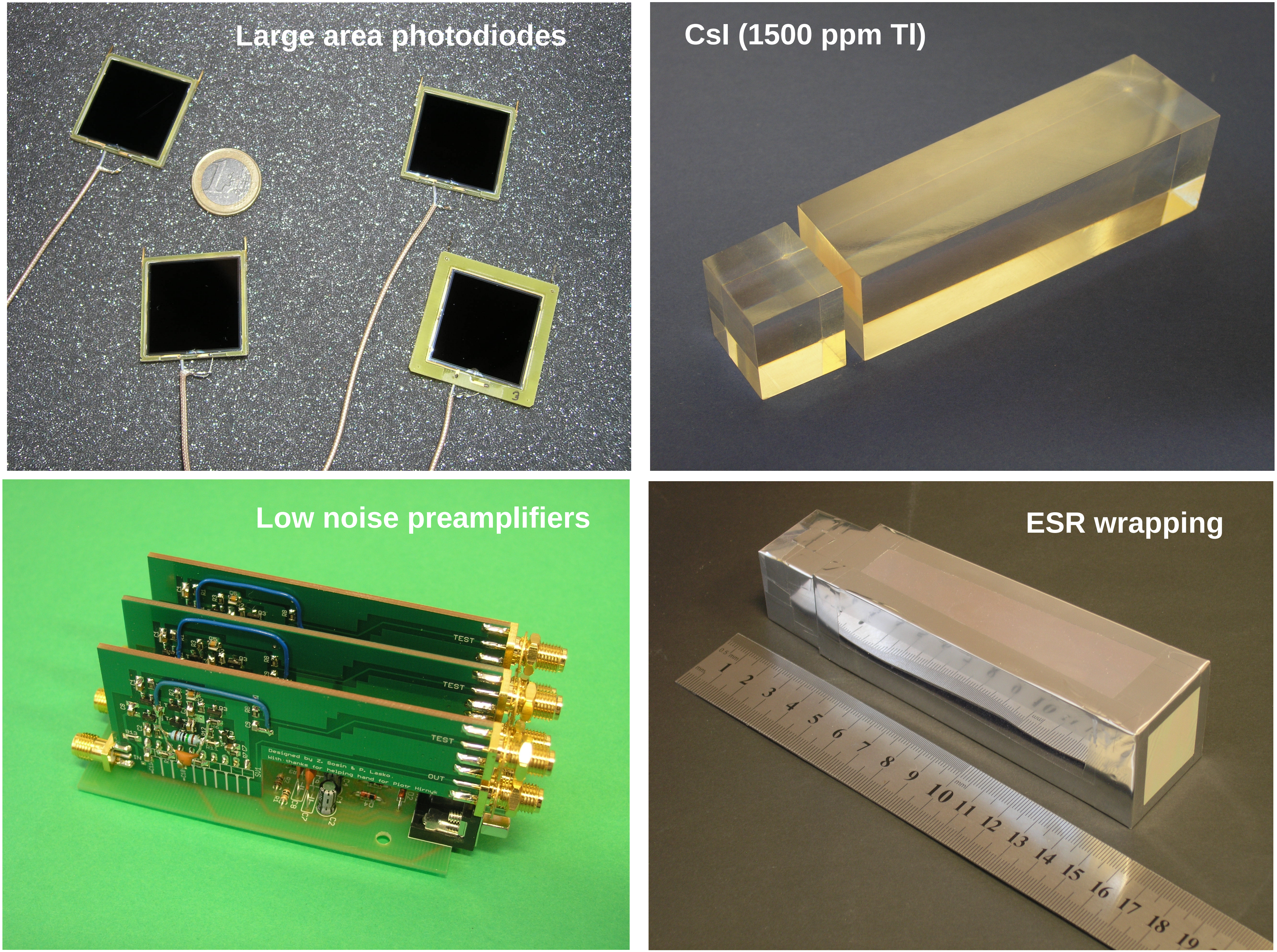
- Active Area: 28x28 mm^2
- Thickness: 500 ± 15 μm
- Orientation: (111)
- Dead Layers: 1.5 μm front, 20 μm rear
- Full Depletion: ~170 V
- Dark Current: 30 nA, (Max. 150 nA)
- Rise Time: 40 ns
- Capacitance: 200 pF

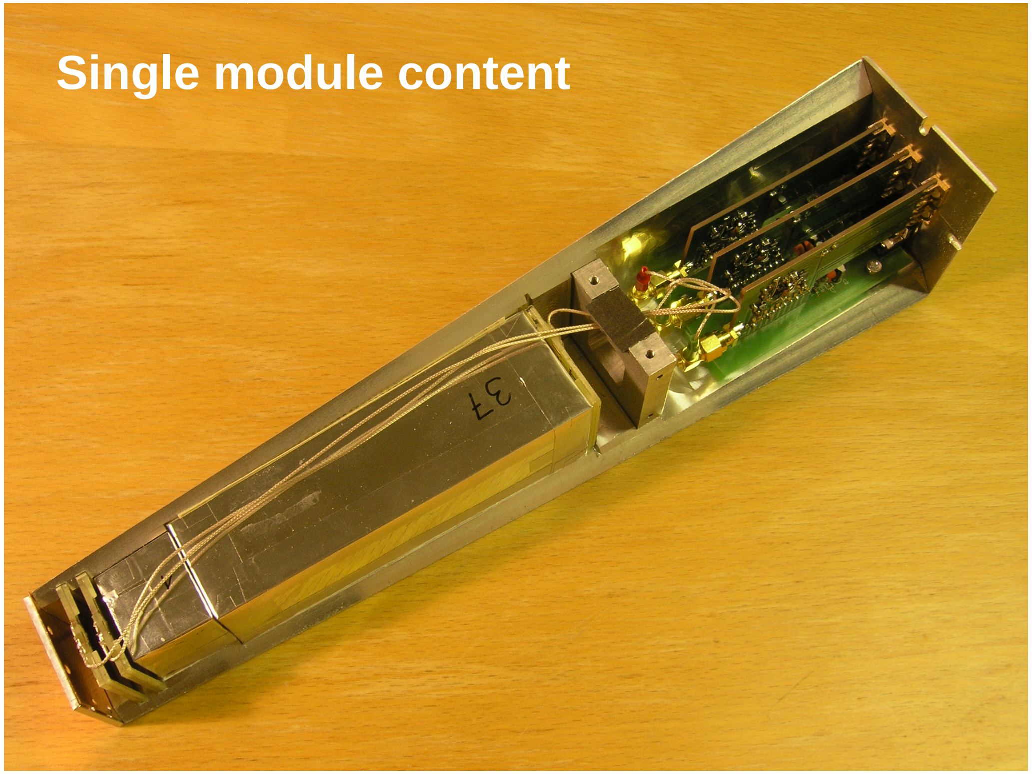
CsI(Tl): IMP-CAS, Lanzhou, China

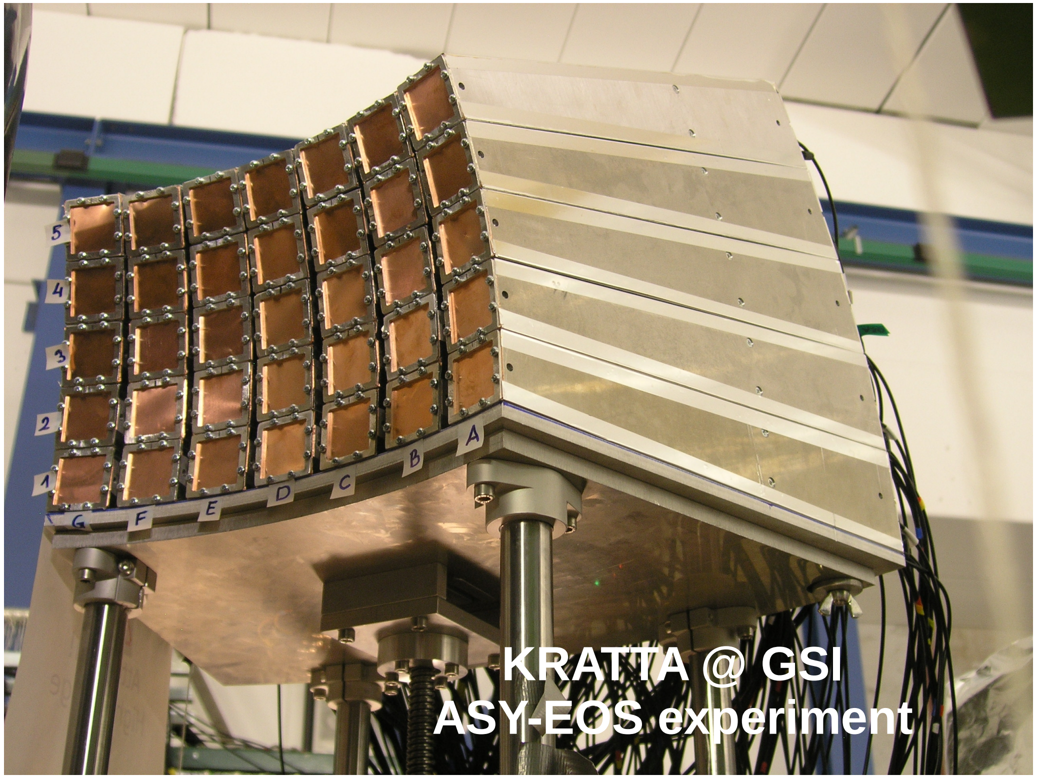
- Tl concentration: 1500 ppm
- LO non-uniformity: <7%
- Shape: Truncated pyramids
- Tolerance: ± 0.1 mm

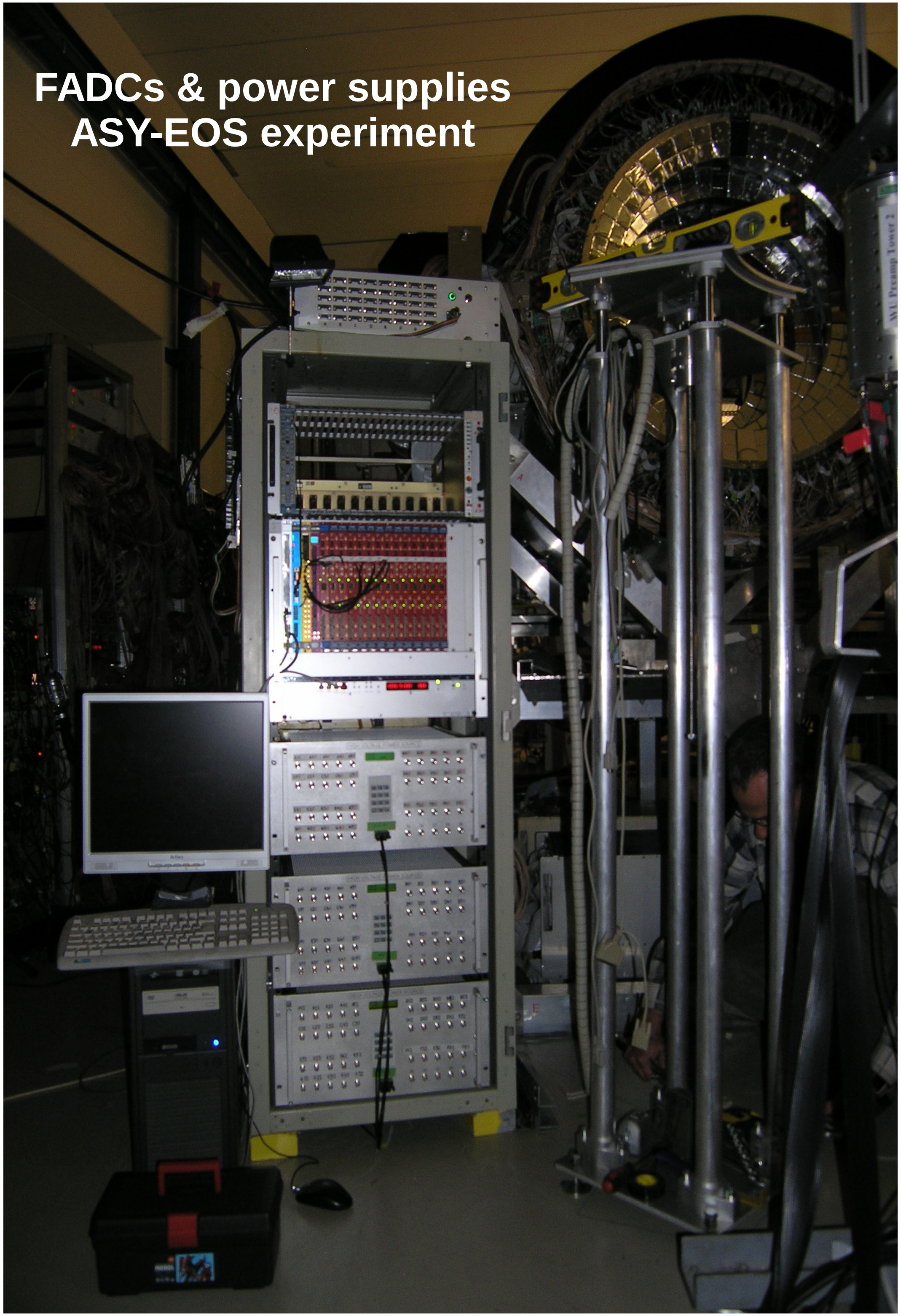
Wrapping: 3M Vikuiti™ ESR foil

- Reflectance: >98%
- Thickness: 65 μm


Large area photodiodes
CsI (1500 ppm Tl)
Low noise preamplifiers
ESR wrapping

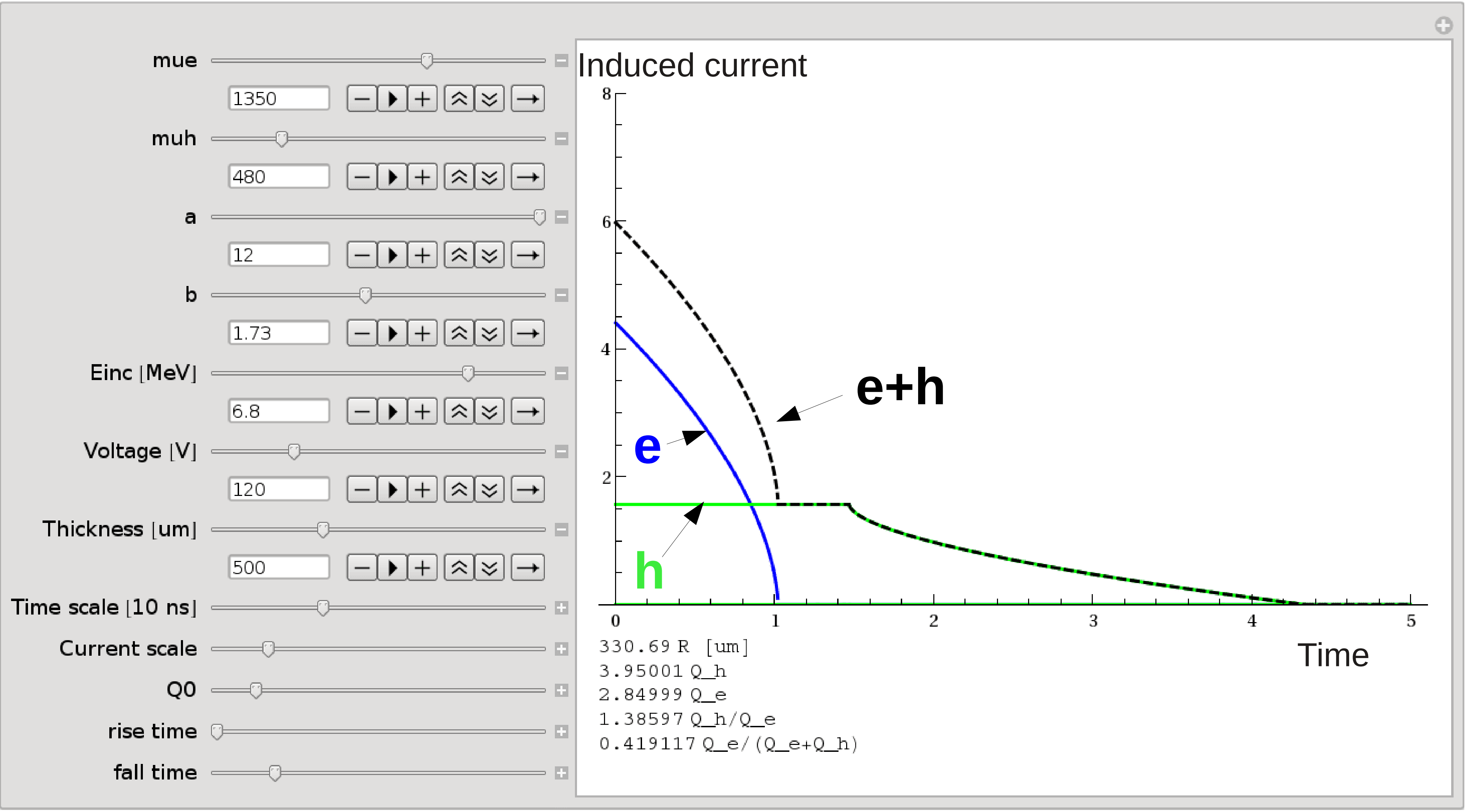

Single module content


KRATTA @ GSI
ASY-EOS experiment


FADCs & power supplies
ASY-EOS experiment

Pulse shape in Si PIN diode

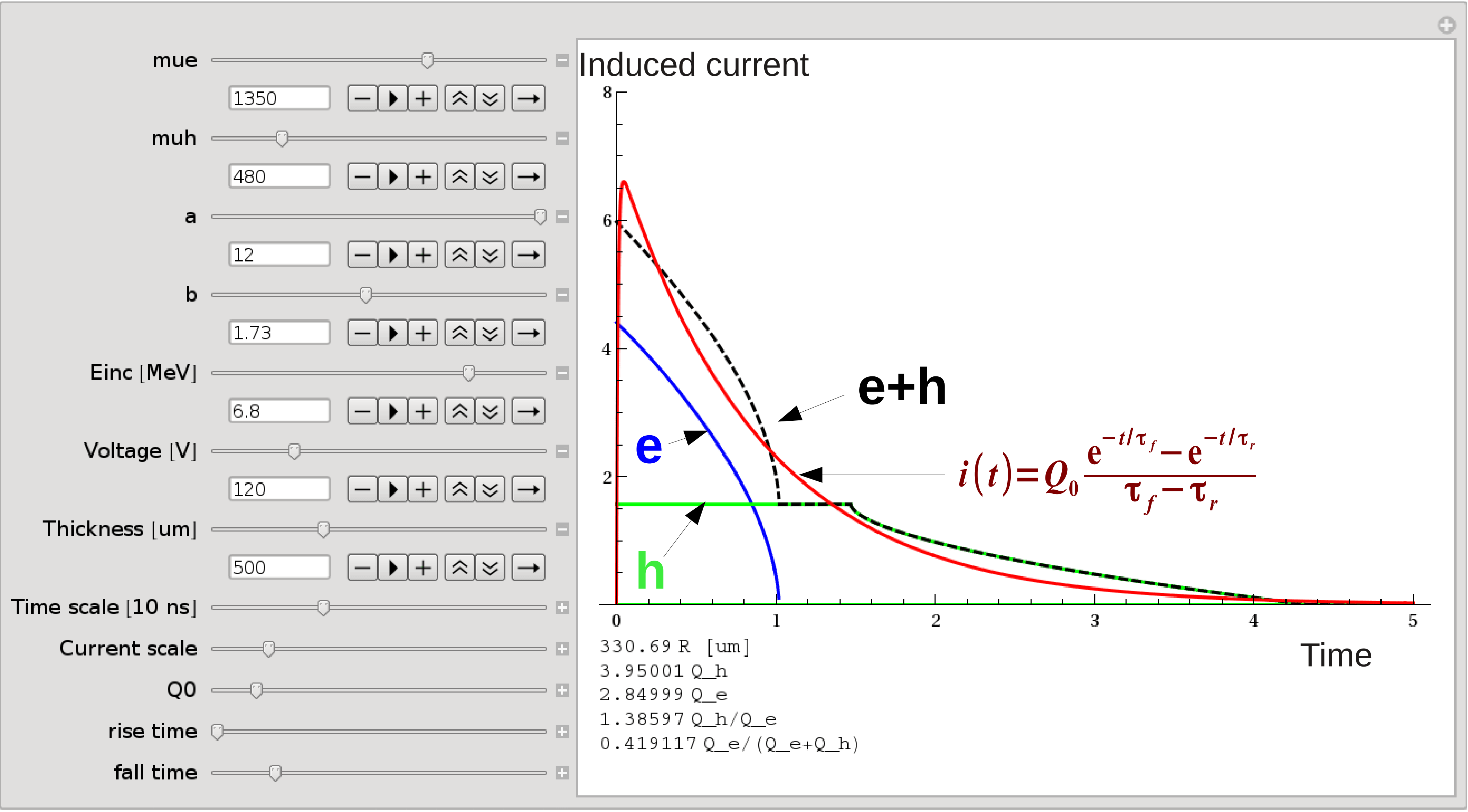
(simple model)



C.A.J. Ammerlaan et al. NIM 22 (1963) 189 ↔ Bragg curve + Ramo

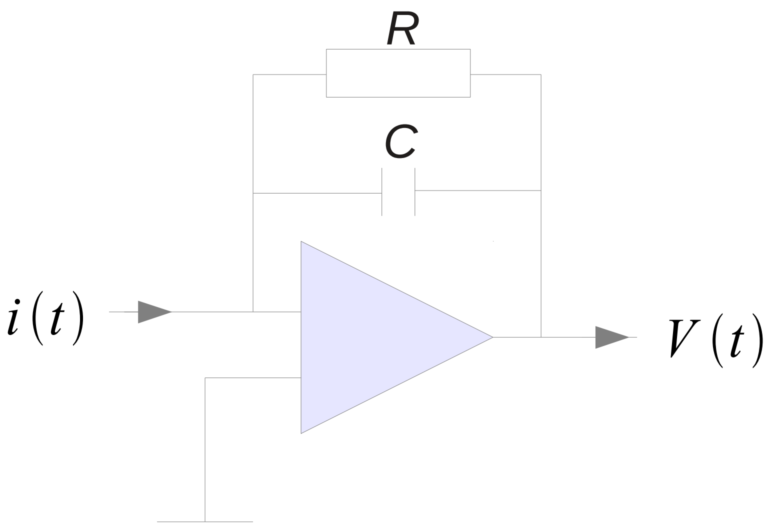
Pulse shape in Si PIN diode

(simple parametrization)



Pulse shape parametrization

- Zero rise time
- Infinite open loop gain

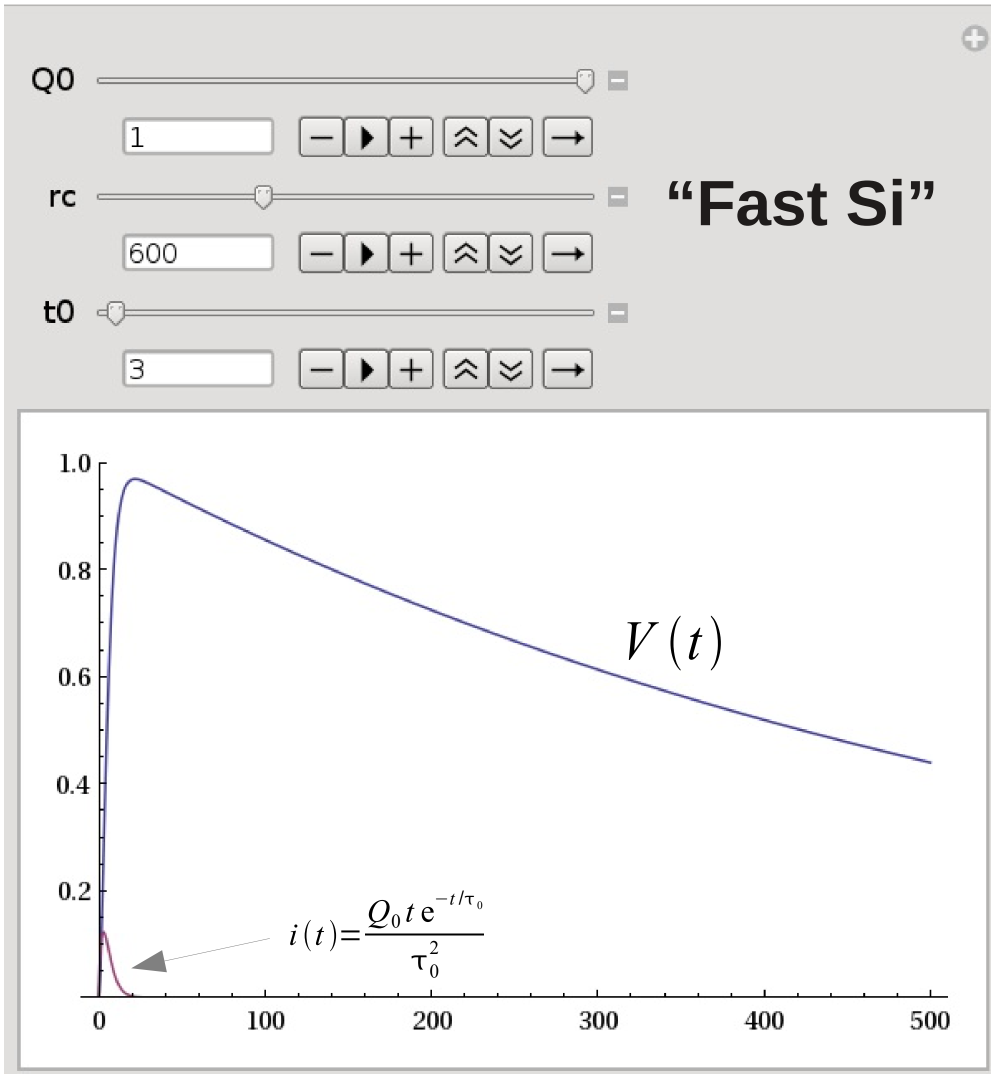


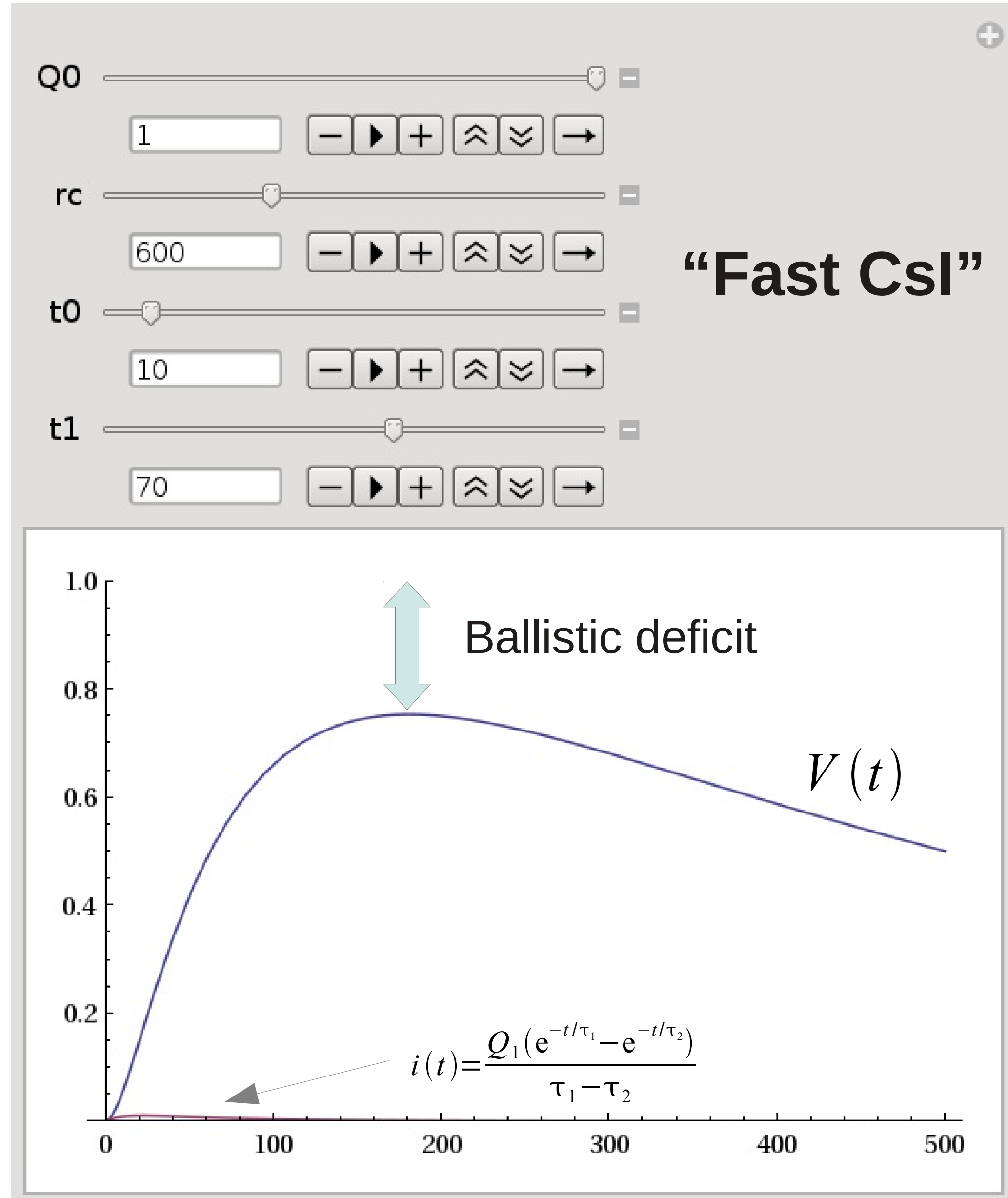
$$\Longleftrightarrow \quad \frac{dV(t)}{dt} + \frac{1}{RC} V(t) = \frac{i(t)}{C}$$

$$\frac{Q_1\left(e^{-t/\tau_1} - e^{-t/\tau_2}\right)}{\tau_1 - \tau_2} = i(t) \quad \Longrightarrow \quad V(t) = Q_1 RC \left(\frac{e^{-t/RC} RC}{(RC-\tau_1)(RC-\tau_2)} + \frac{e^{-t/\tau_1}\tau_1}{(\tau_1 - RC)(\tau_1 - \tau_2)} + \frac{e^{-t/\tau_2}\tau_2}{(\tau_2 - \tau_1)(\tau_2 - RC)} \right)$$

$$i(t) \quad \Longleftarrow \quad V(t)$$

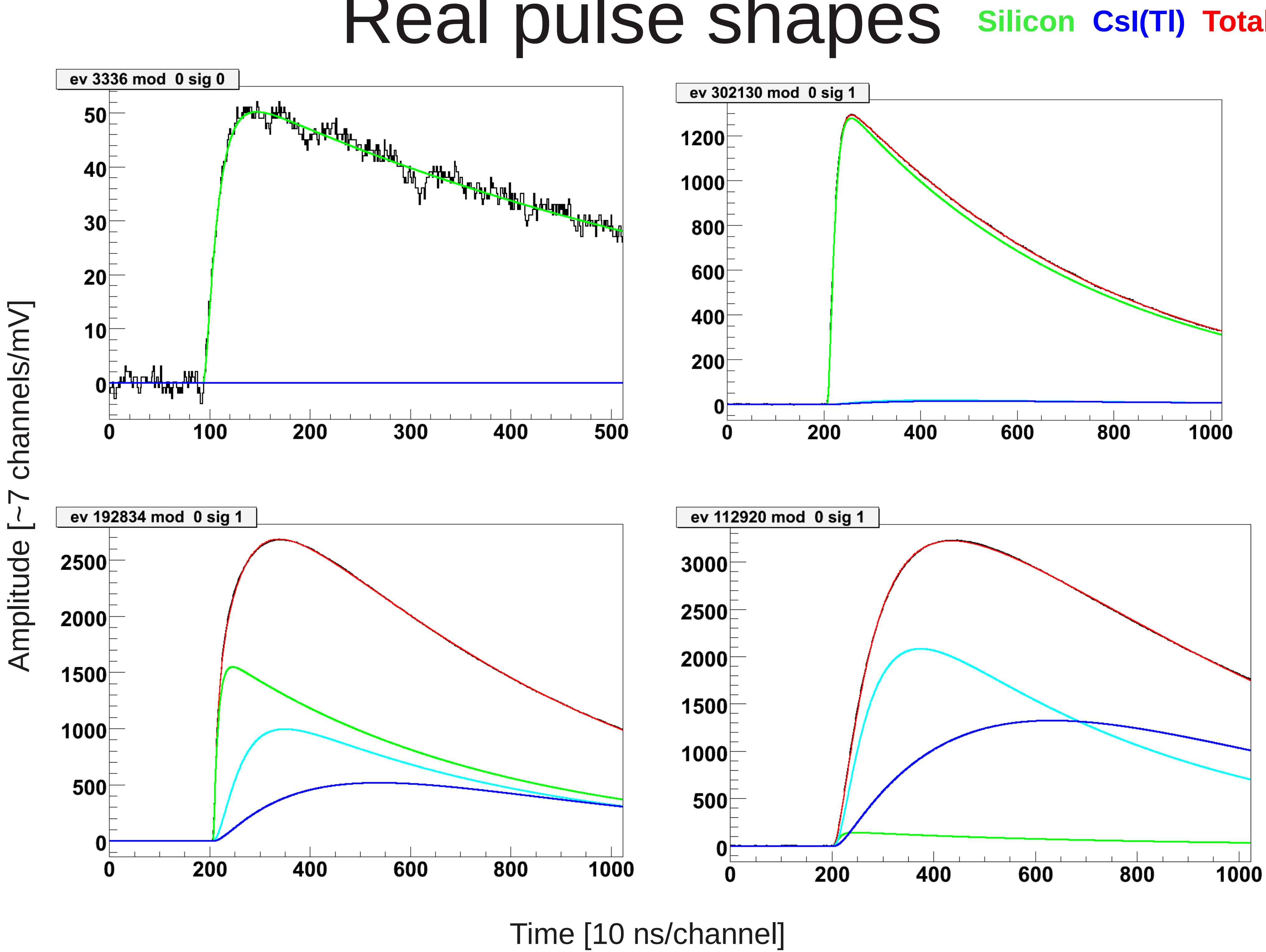
Model pulse shapes





Time [10 ns/channel]

Real pulse shapes



Decomposition of the pulse shape

1 Silicon component

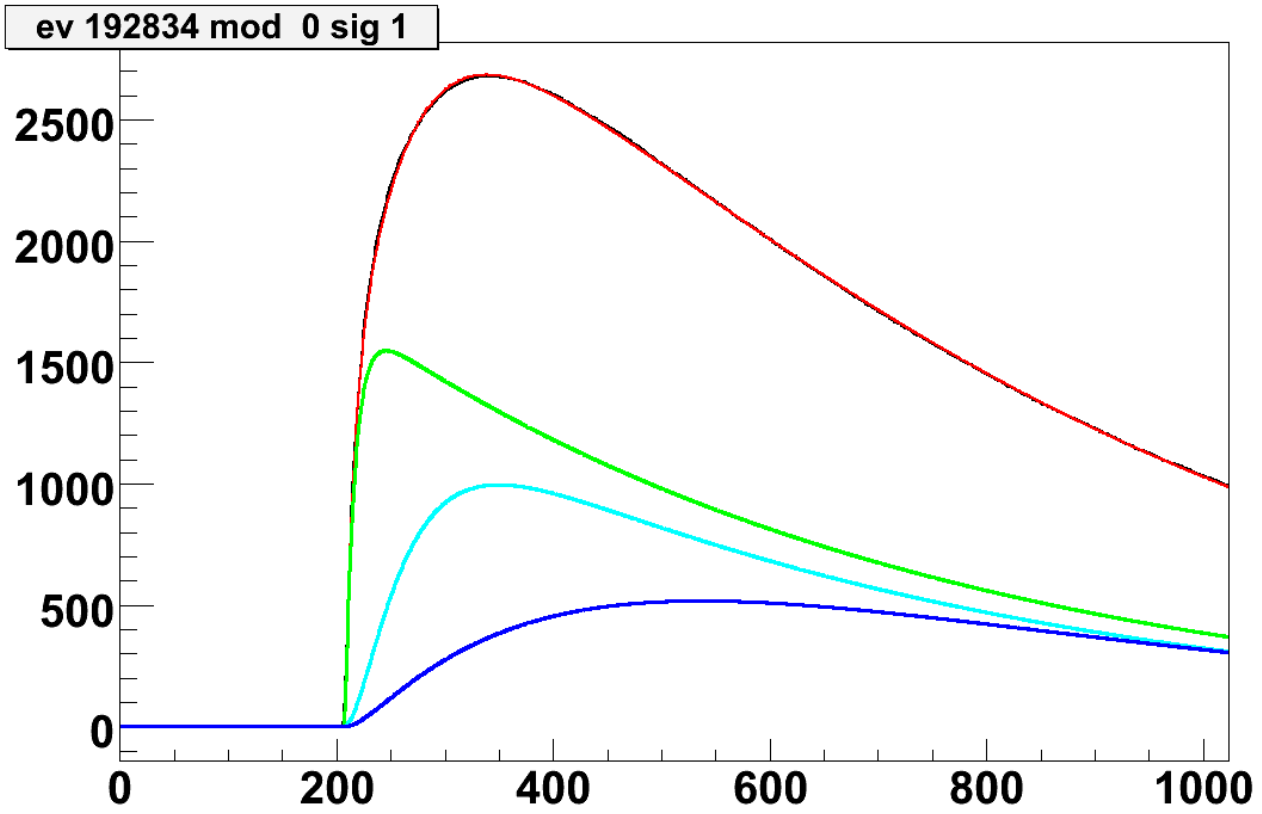
• Q_eh			fitted
• τ_1	≈	30-400 ns	fitted
• τ_2	≈	95 ns	fixed

2 CsI(Tl) components

• Q_R			fitted
• Q_L			fitted
• τ_R	≈	450-700 ns	fitted
• τ_L	≈	2-4 μs	fitted
• τ_rise	≈	160 ns	fixed

common

• RC	≈	6 μs	fixed
• T_0	≈	2 μs	fitted
• Baseline			calculated



11 parameters = 7(6) fitted + 4(5) fixed ⟵ **MOMENTS+FUMILI**

Use MOMENTS to calculate the time constants.

The simplest case (t1, rc = const):

$$Mn = \int_0^{TMAX} Q0\, rc \left(\frac{e^{-\frac{t}{rc}}\, rc}{(rc - t0)\,(rc - t1)} + \frac{e^{-\frac{t}{t0}}\, t0}{(t0 - rc)\,(t0 - t1)} + \frac{e^{-\frac{t}{t1}}\, t1}{(t1 - t0)\,(t1 - rc)} \right) t^n \, dt$$

$$M0 = Q0\, rc \left(\frac{\left(1 - e^{-\frac{TMAX}{rc}}\right) rc^2}{(rc - t0)\,(rc - t1)} + \frac{\left(1 - e^{-\frac{TMAX}{t0}}\right) t0^2}{(rc - t0)\,(t1 - t0)} + \frac{\left(1 - e^{-\frac{TMAX}{t1}}\right) t1^2}{(rc - t1)\,(t0 - t1)} \right)$$

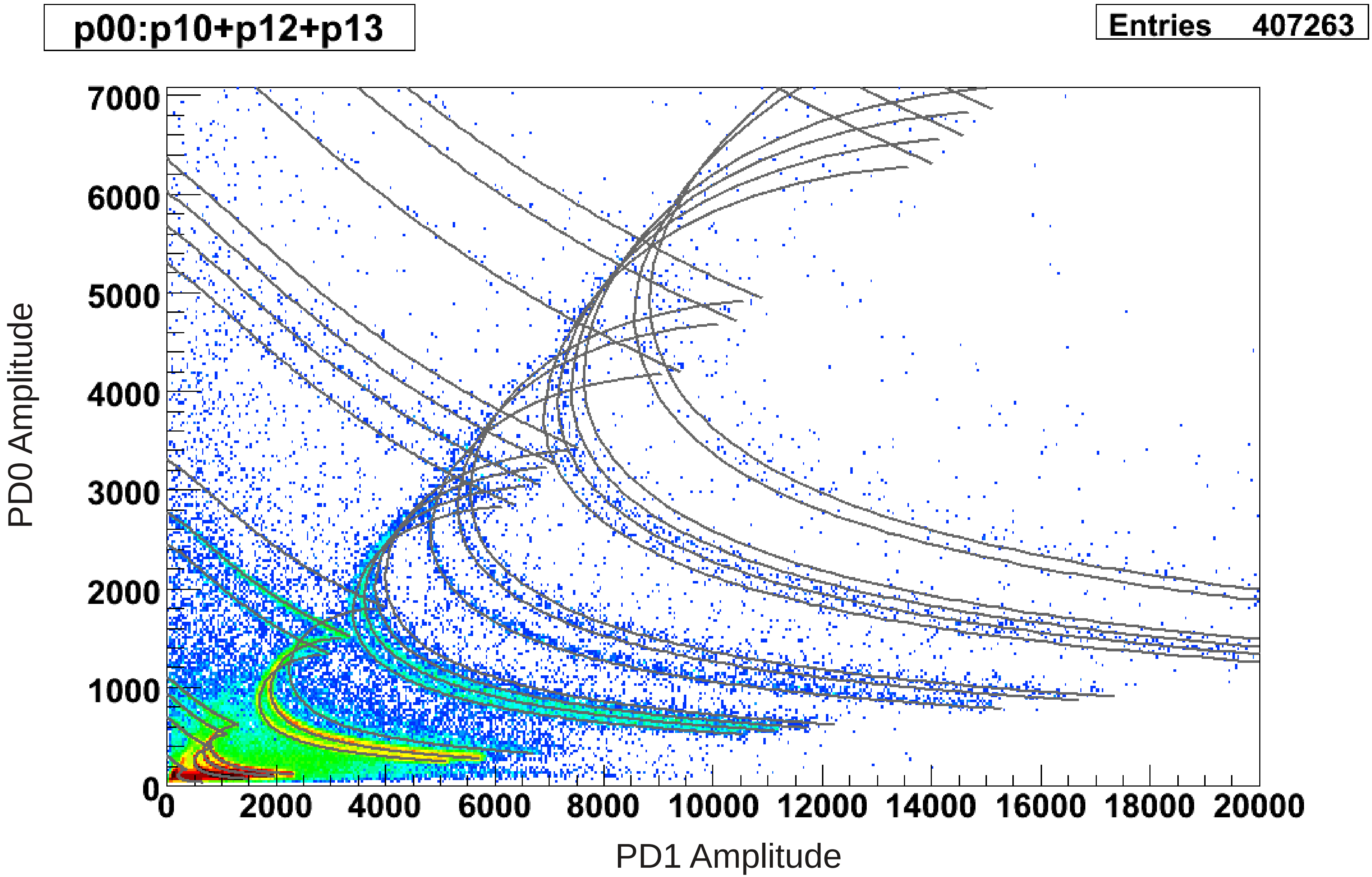
$$M1 = Q0\, rc \left(\frac{rc^2 \left(rc - e^{-\frac{TMAX}{rc}}\,(rc + TMAX)\right)}{(rc - t0)\,(rc - t1)} + \frac{t0^2 \left(t0 - e^{-\frac{TMAX}{t0}}\,(t0 + TMAX)\right)}{(-rc + t0)\,(t0 - t1)} + \frac{t1^2 \left(t1 - e^{-\frac{TMAX}{t1}}\,(t1 + TMAX)\right)}{(-rc + t1)\,(-t0 + t1)} \right)$$

etc ...

eliminate $e^{-\frac{TMAX}{t0}}$ using M0

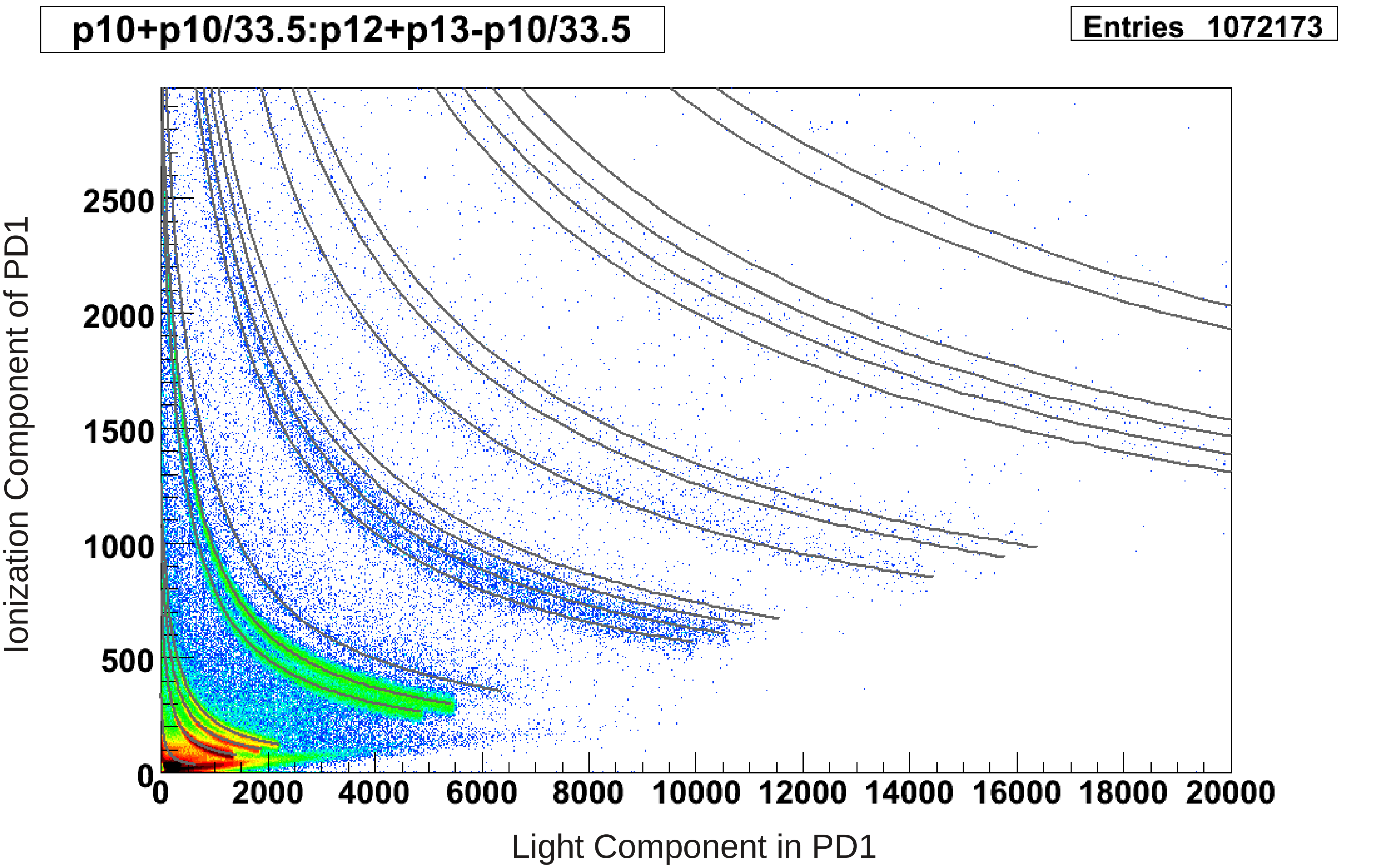
use M1, M2 to calculate Q0 and t0 (can be reduced to quadratic equation)

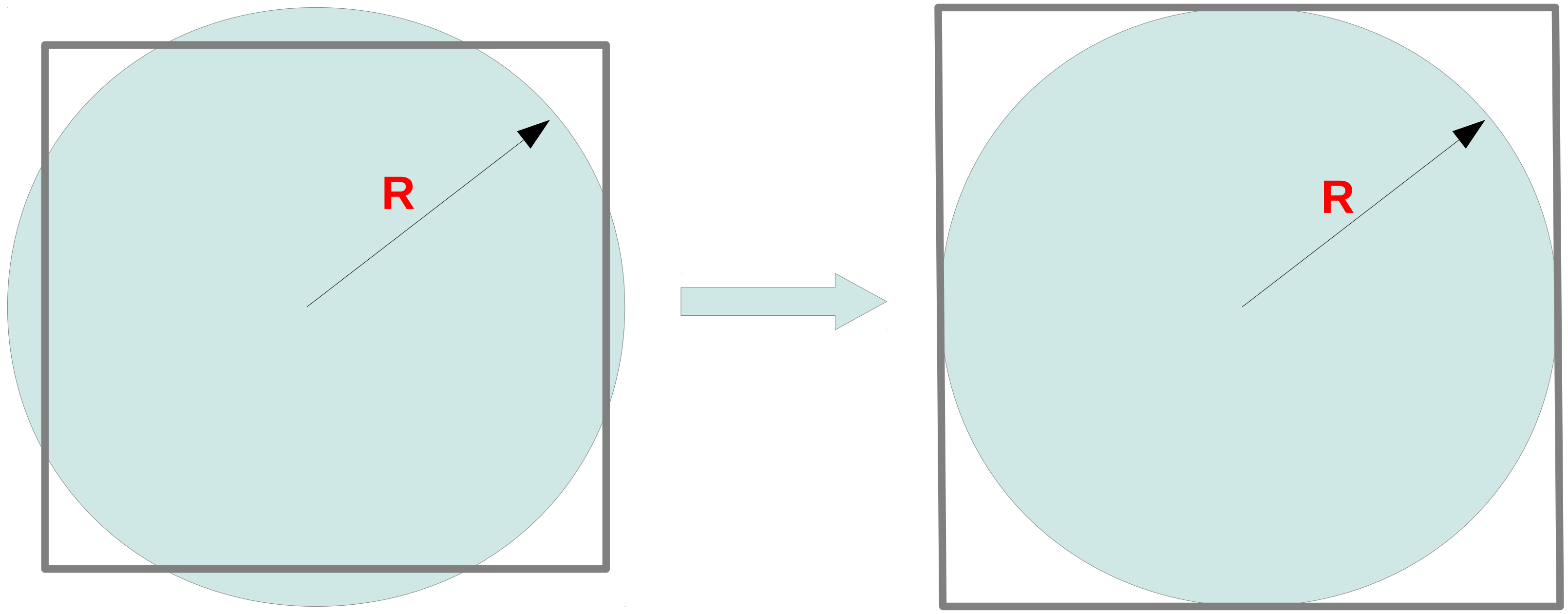
Perform energy calibration of first 2 photodiodes (using ATIMA)



SCT ID map after decomposition

This is quite non-trivial...

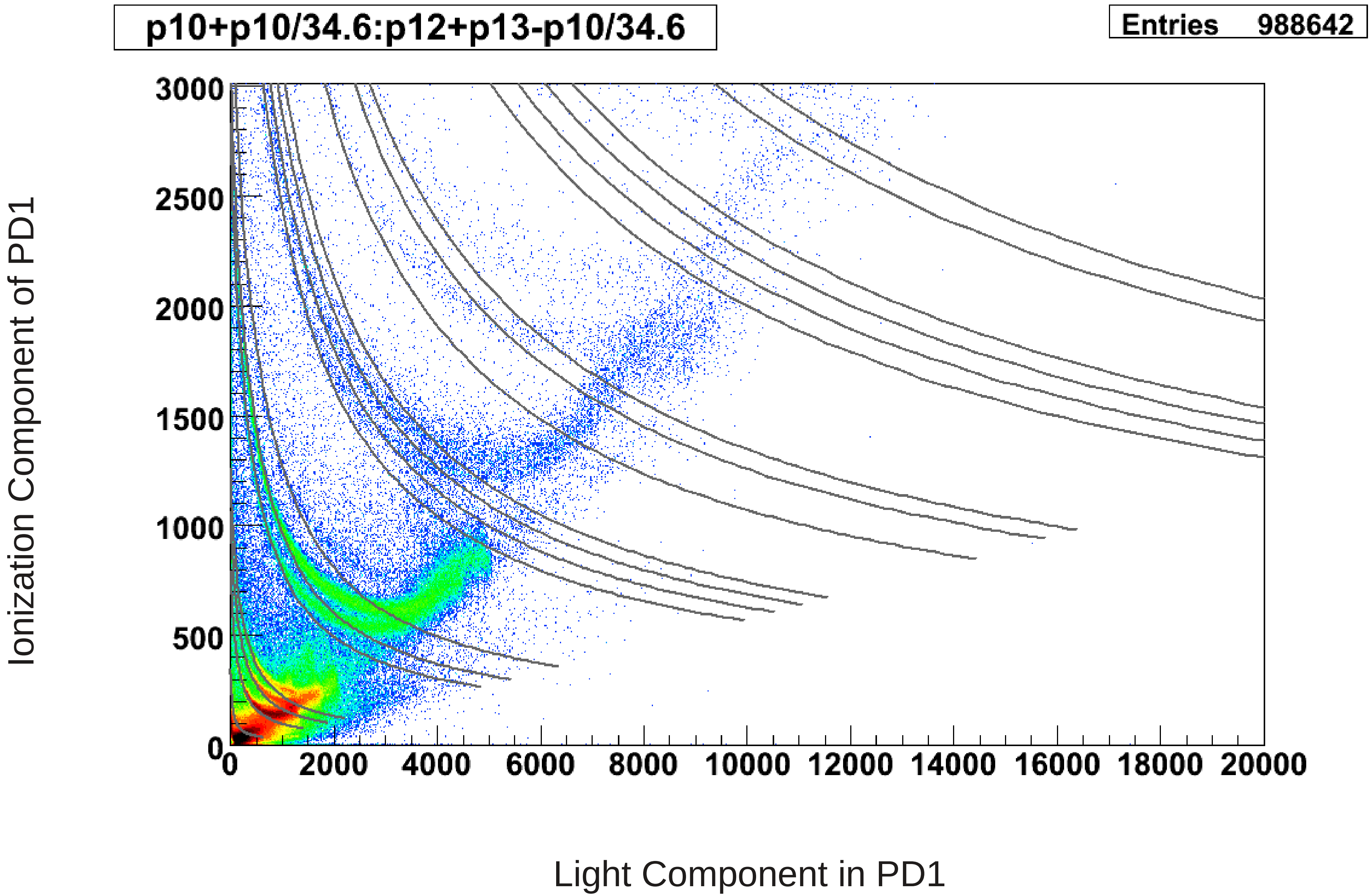



R
R

Good χ^2 is not enough...

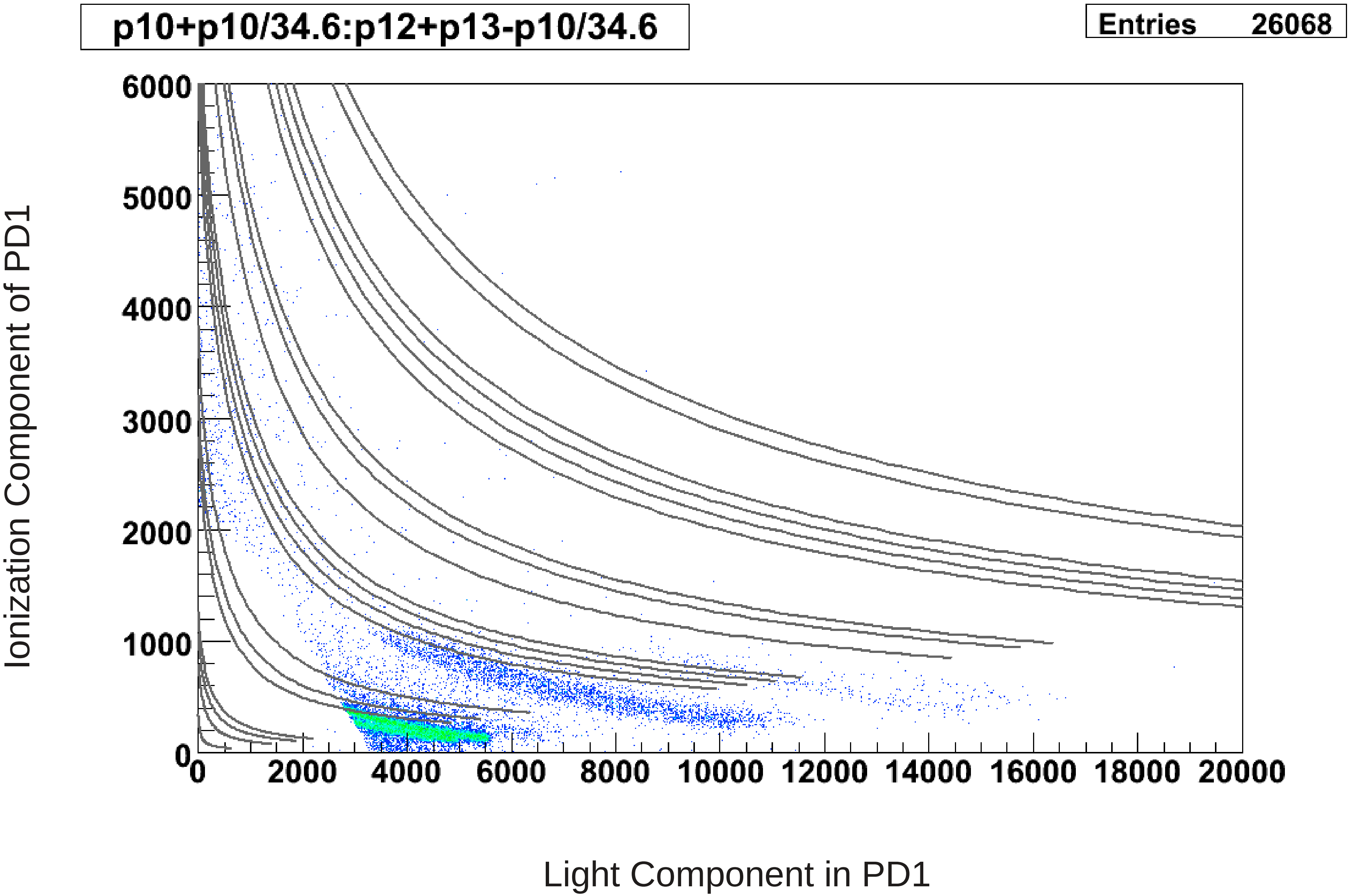
Force the model to be more physical

Use constraints → Restrict available parameter space → Fix fixable parameters



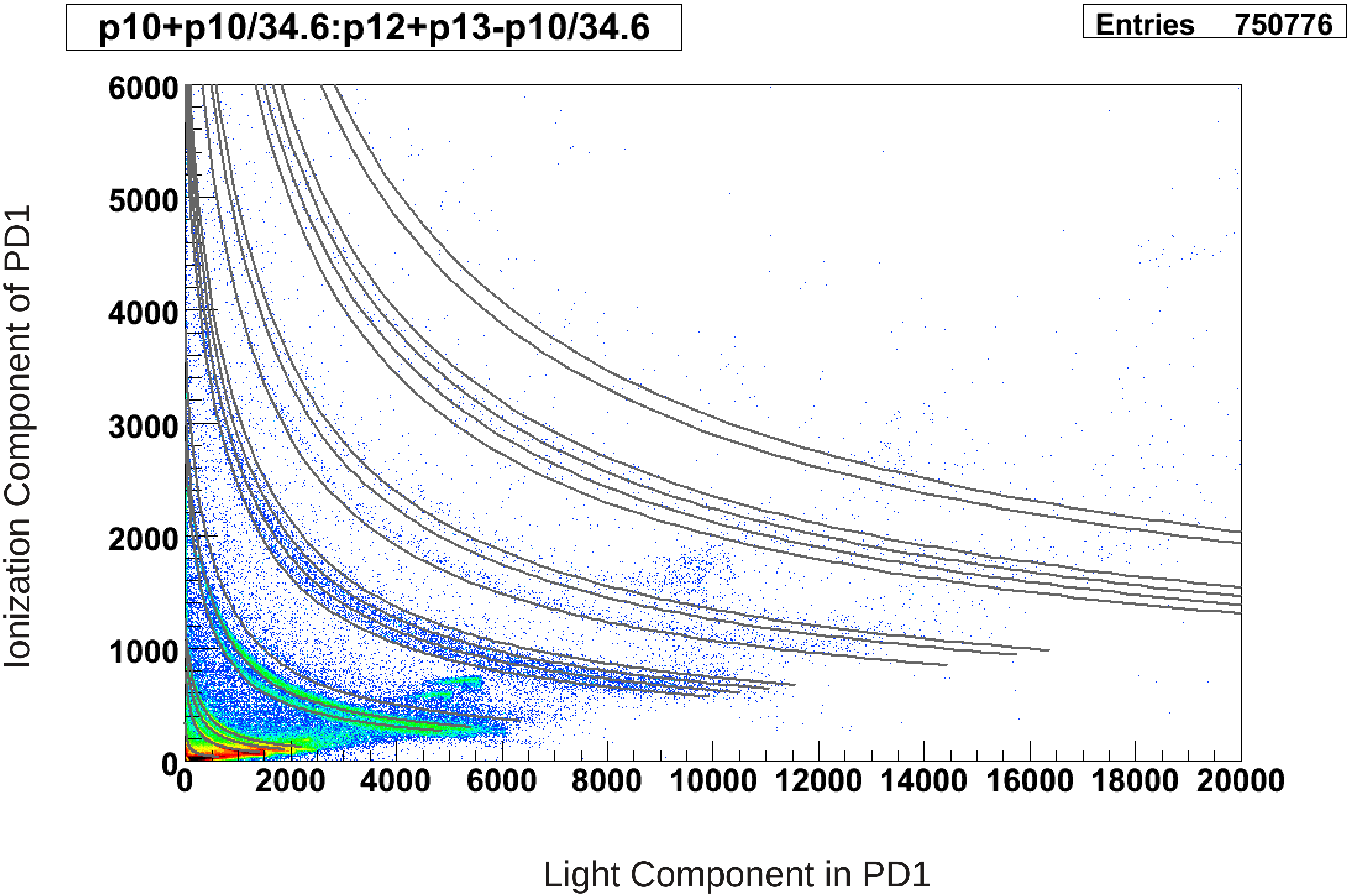
Can easily be overdone...

use proper weights as well

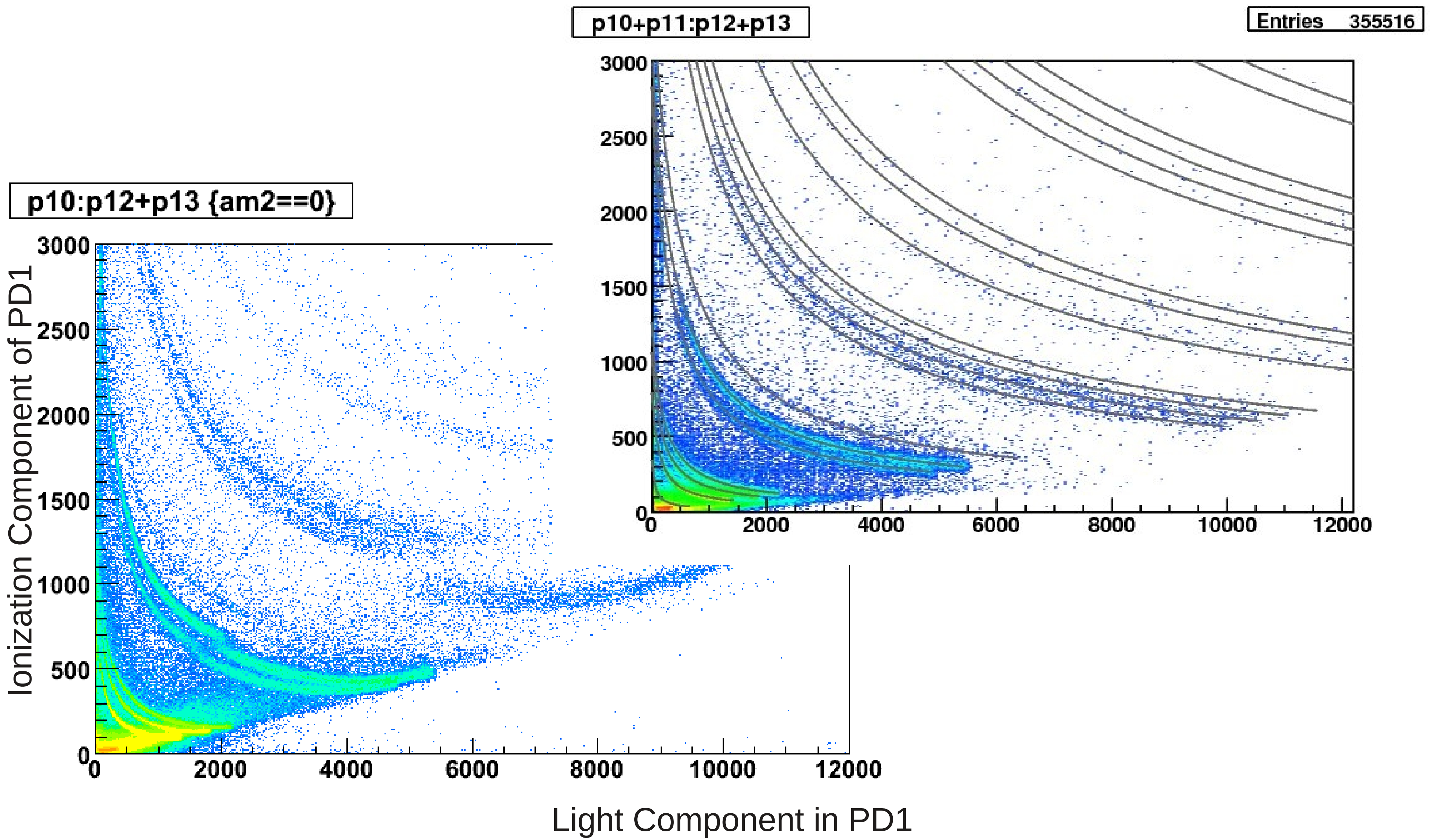


Be aware of local minima...

take care of initial values

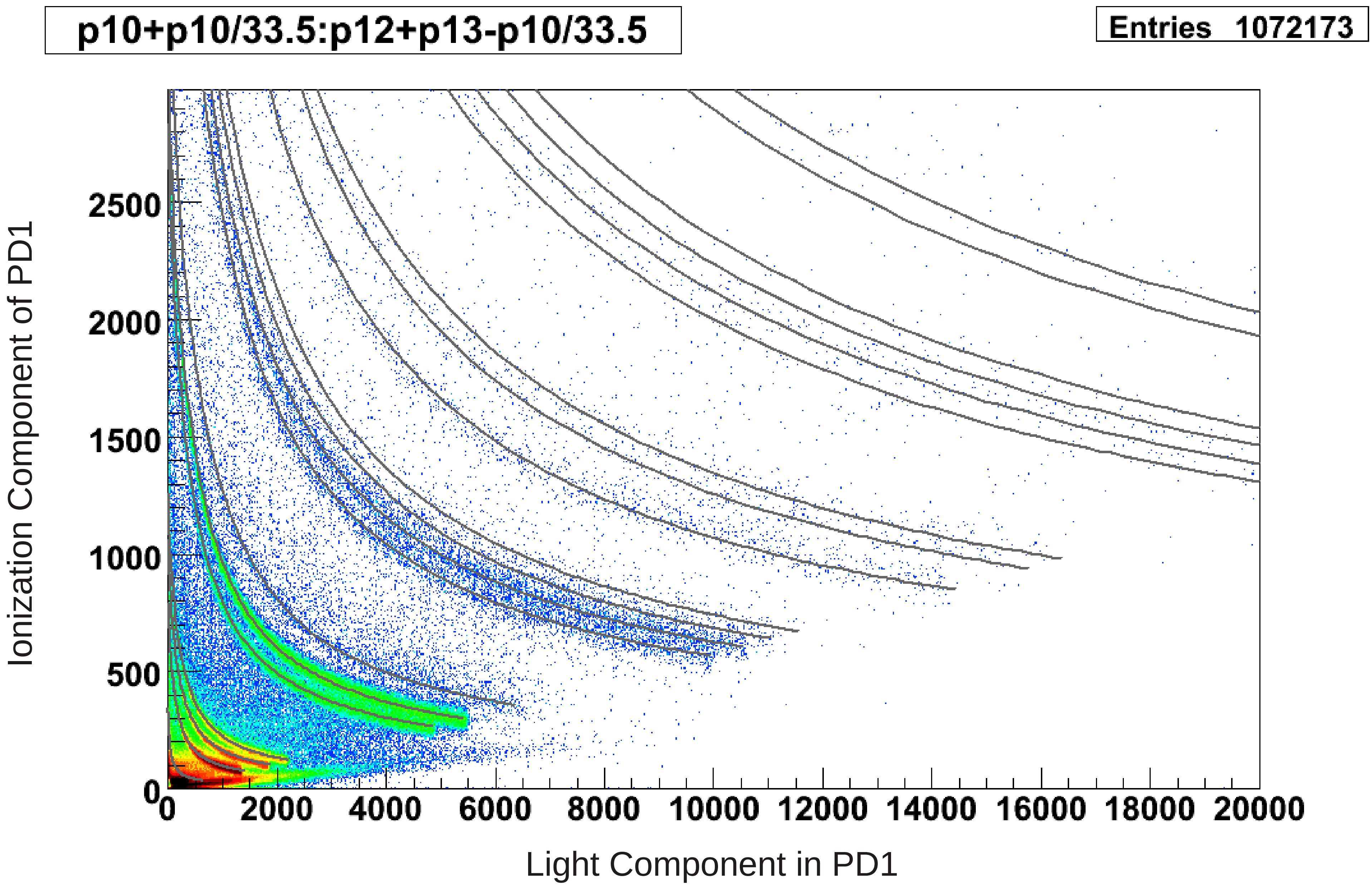


Avoid conditions...



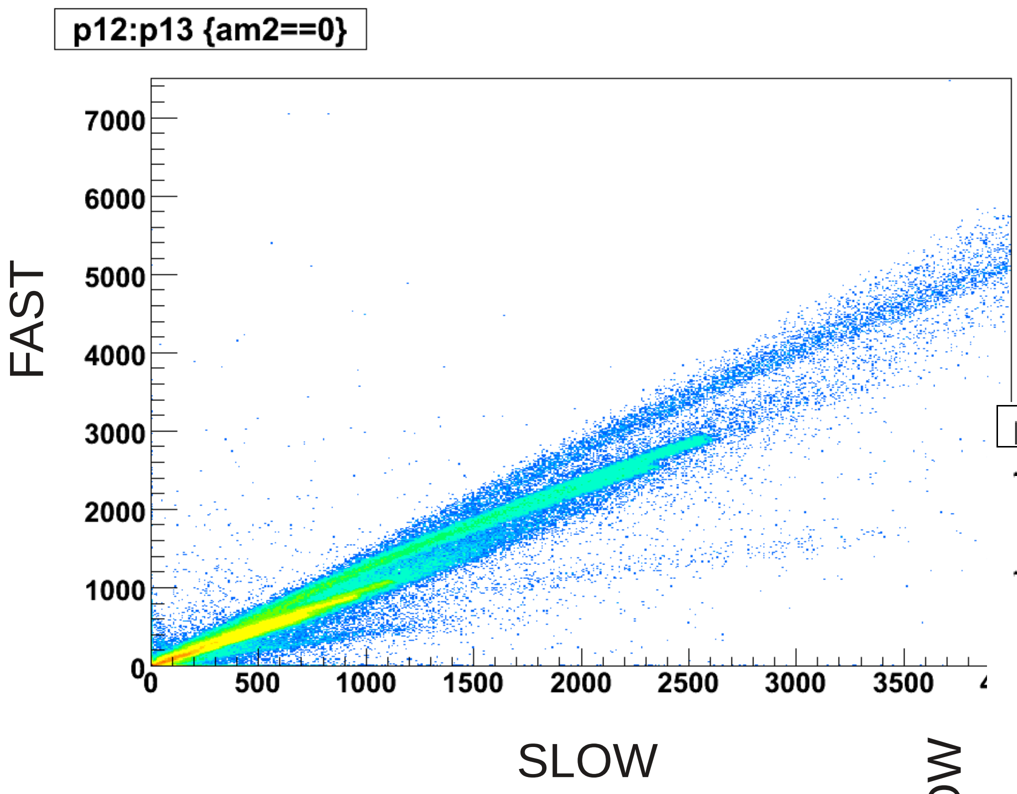
Fit with a variable CsI(Tl) τ_{slow}

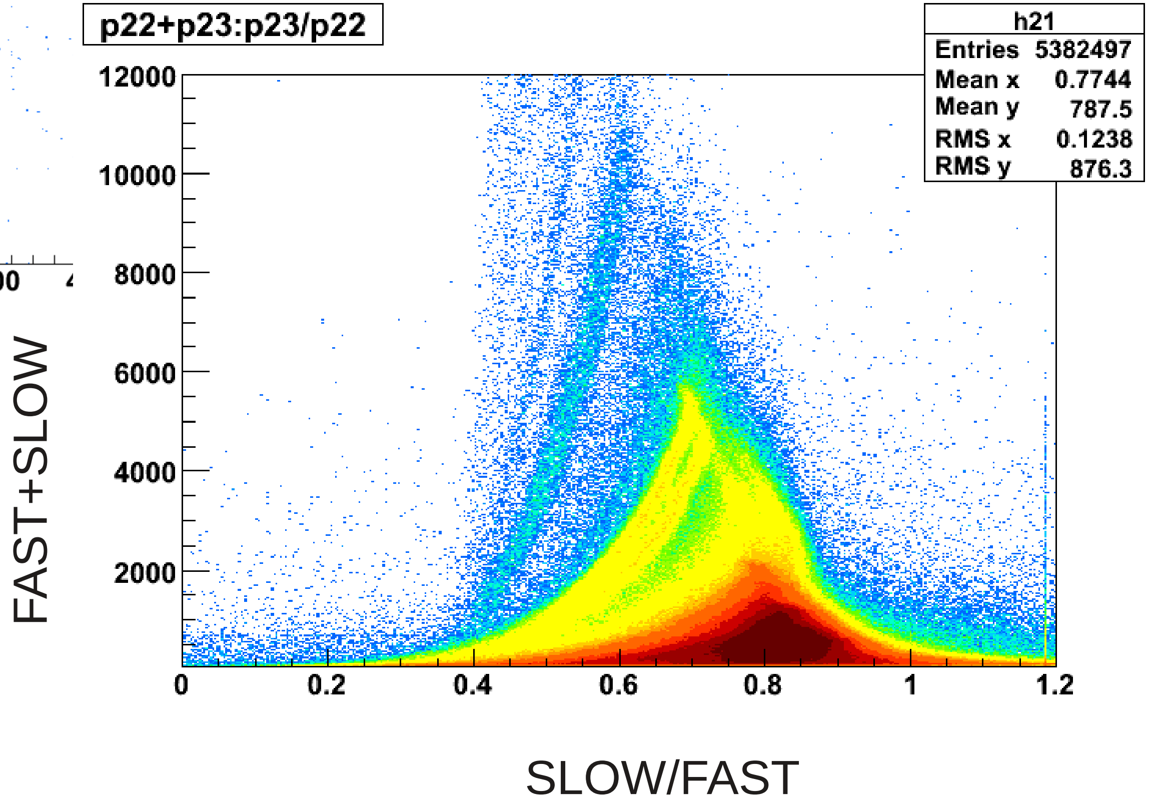
Find a compromise...



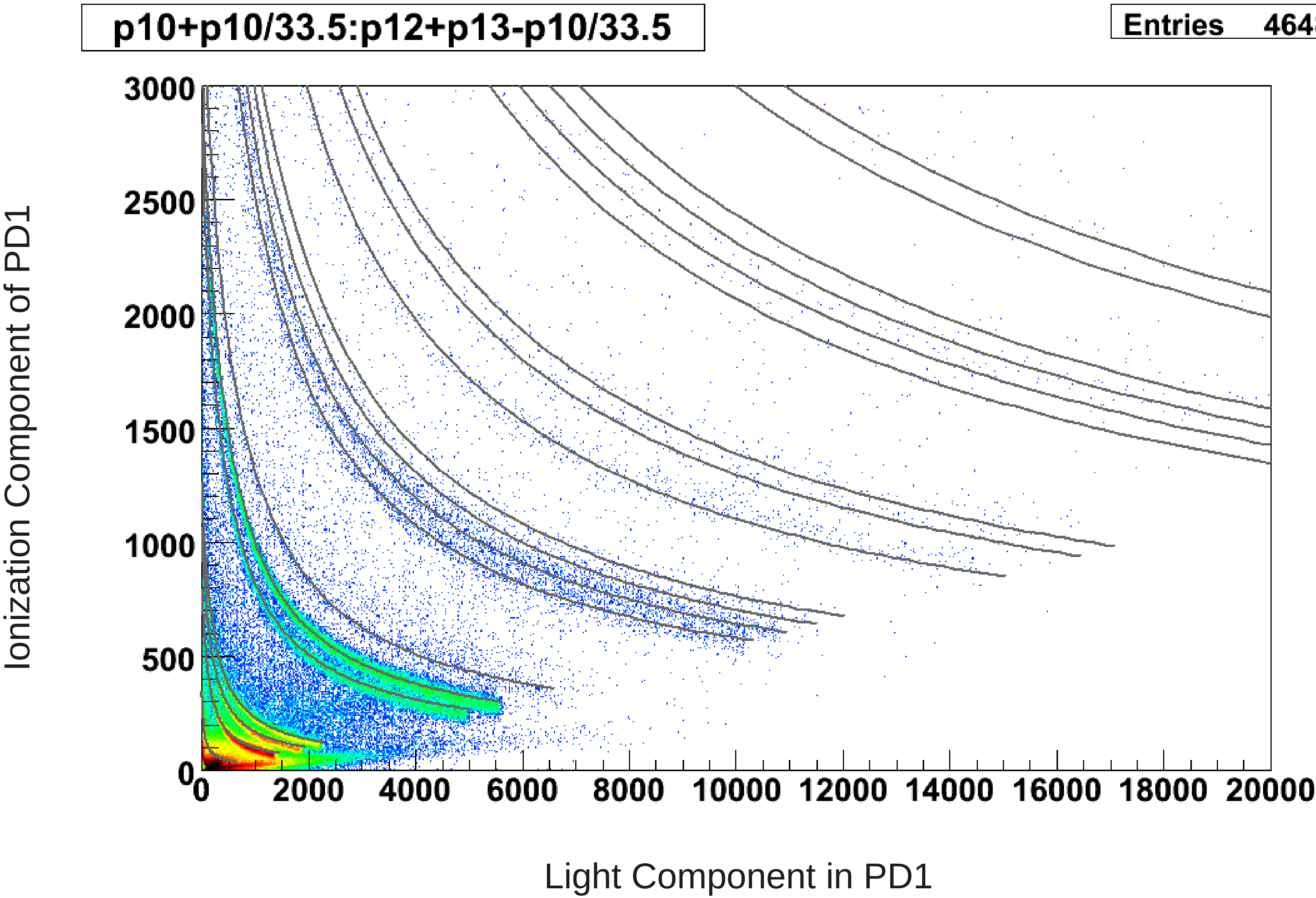
Fit with a variable CsI(Tl) τ_{slow}

but...



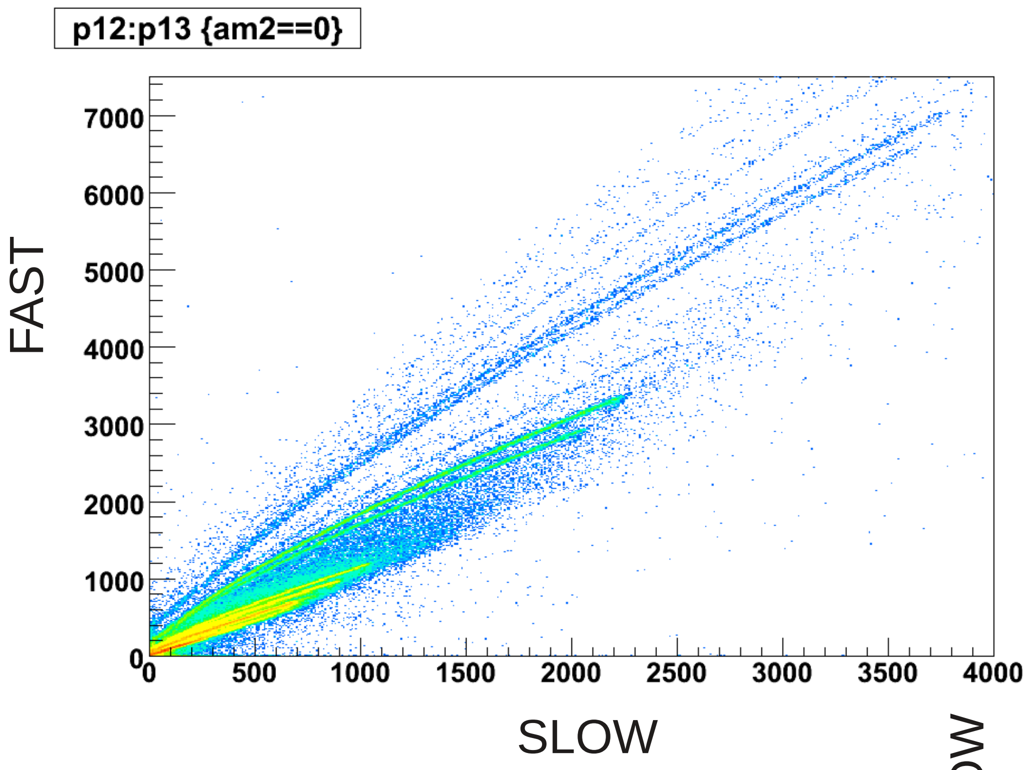


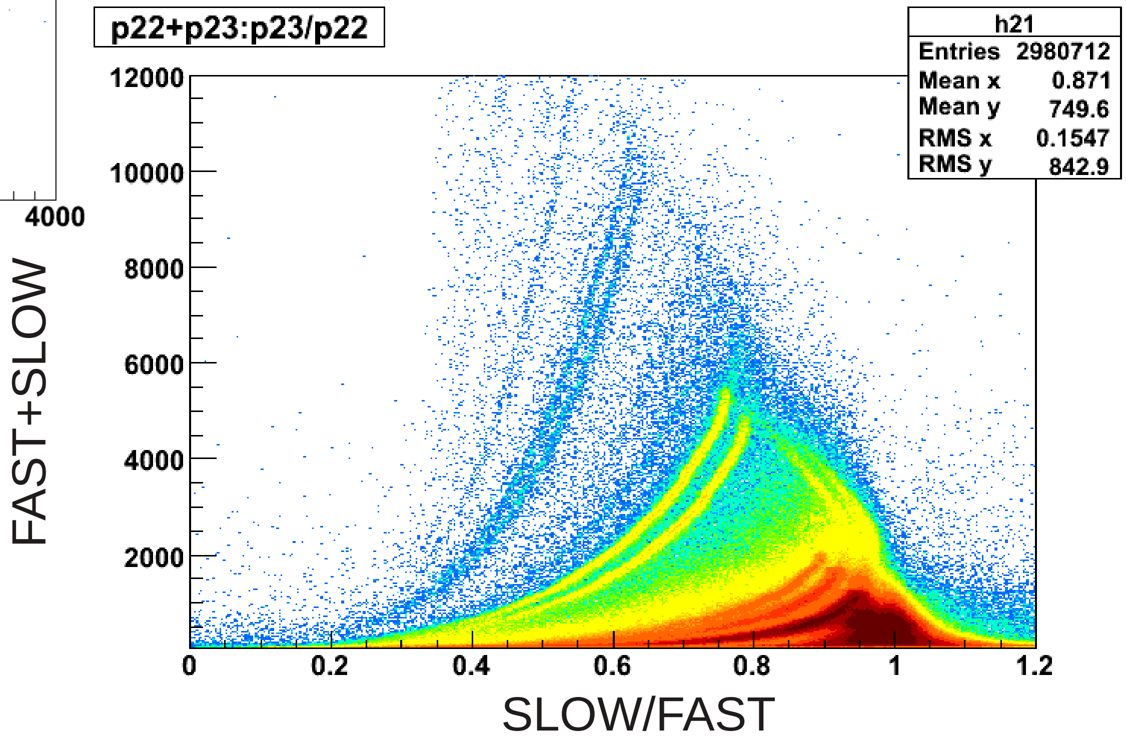
Fit with a <u>fixed</u> slow CsI(Tl)



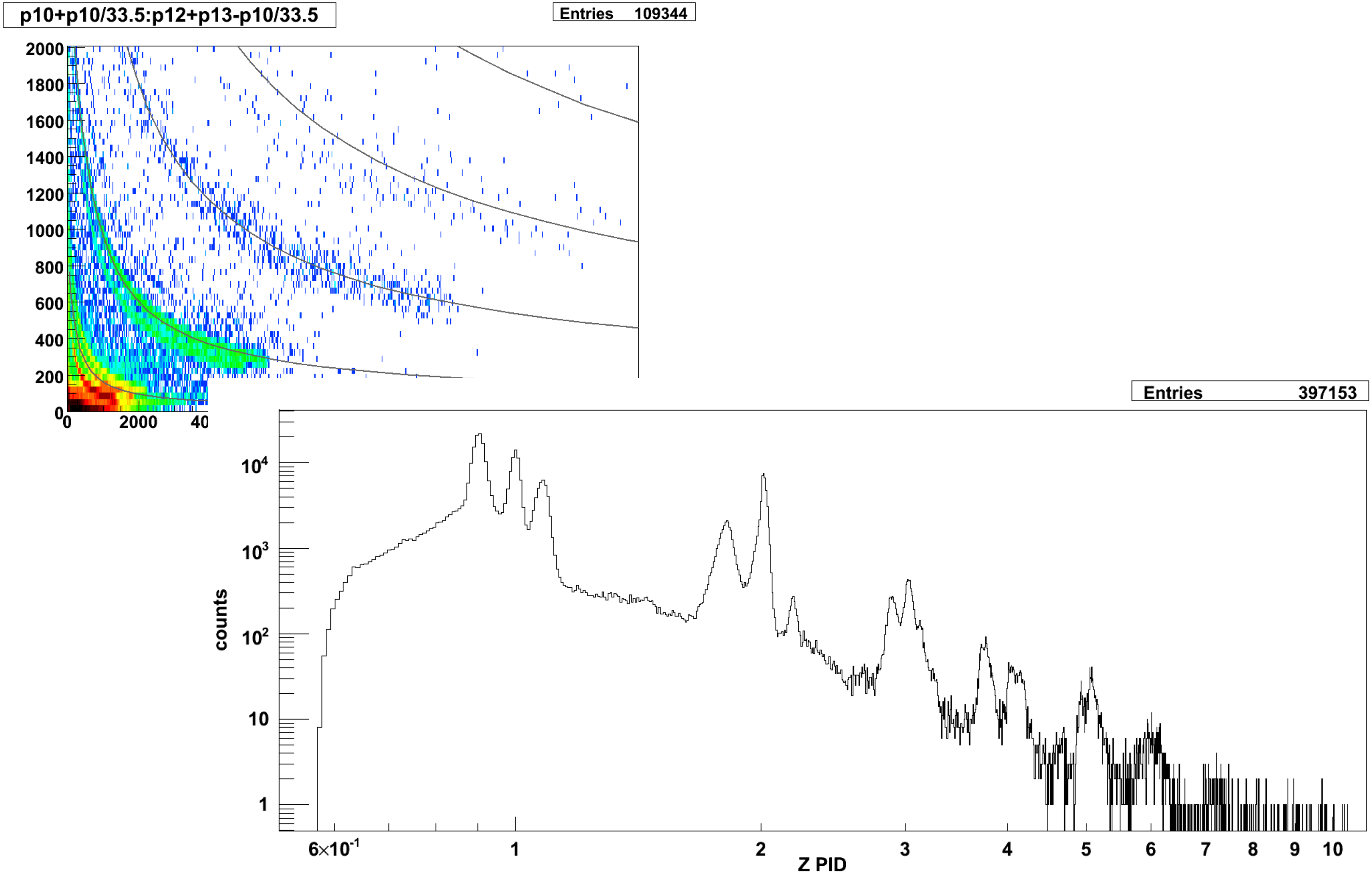
Fit with a fixed slow CsI(Tl)

but...!





Z-distribution (SCT)



Particles stopped in PD0
(Si alone)

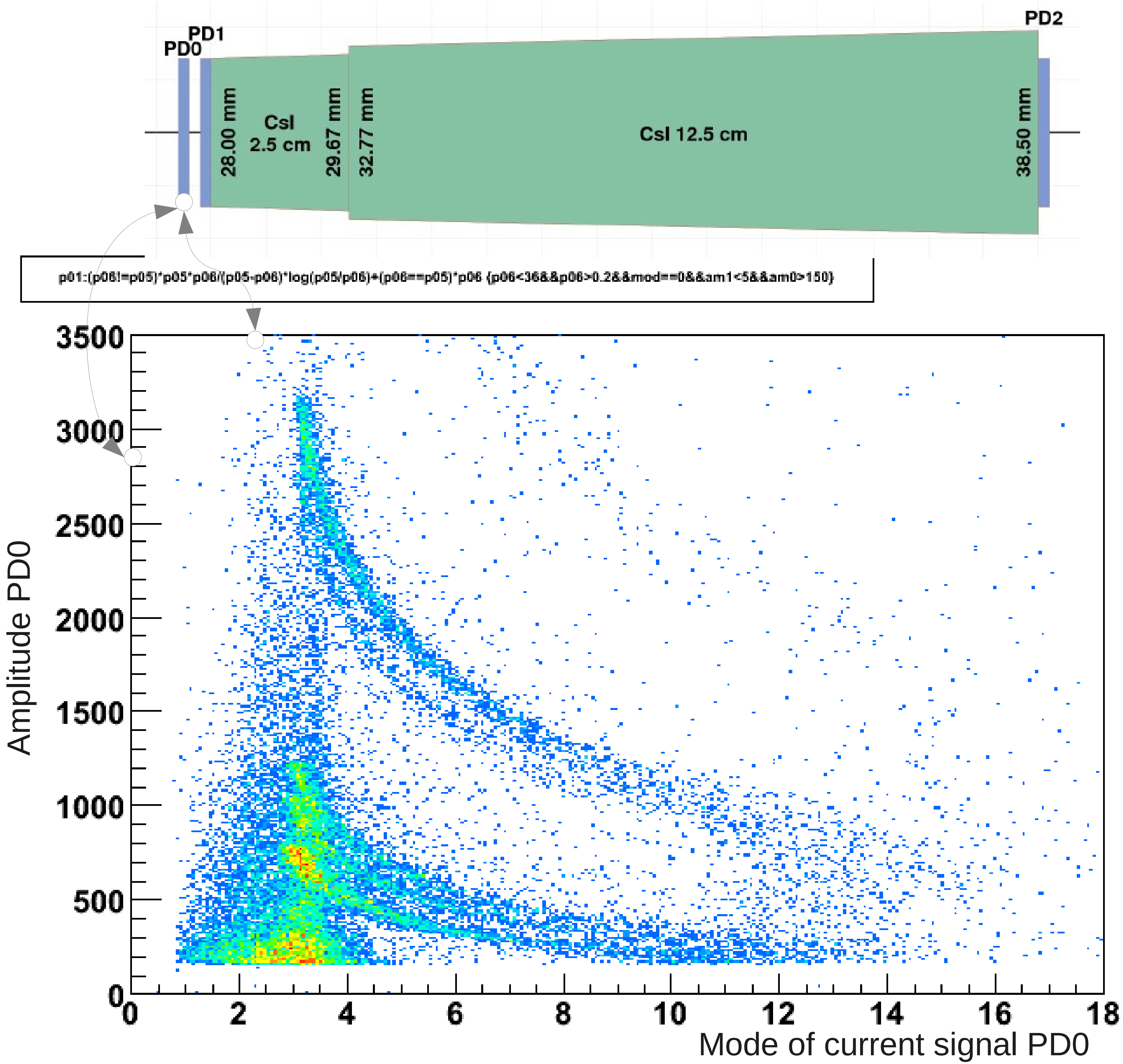
- Fit using single model pulse shape
- Both time constants fitted (τ_1 and τ_2)

$$V(t)=Q_1 RC\left(\frac{e^{-t/RC}RC}{(RC-\tau_1)(RC-\tau_2)}+\frac{e^{-t/\tau_1}\tau_1}{(\tau_1-RC)(\tau_1-\tau_2)}+\frac{e^{-t/\tau_2}\tau_2}{(\tau_2-\tau_1)(\tau_2-RC)}\right)$$

$$i(t)=Q_1\frac{e^{-t/\tau_1}-e^{-t/\tau_2}}{\tau_1-\tau_2}$$

$$Mode=\frac{\tau_1\tau_2\ln\tau_2/\tau_1}{\tau_2-\tau_1}$$

(position of maximum)


PD0
PD1
PD2
28.00 mm
CsI
2.5 cm
29.67 mm
32.77 mm
CsI 12.5 cm
38.50 mm
p01:(p06!=p05)*p05*p06/(p05-p06)*log(p05/p06)+(p06==p05)*p06 {p06<36&&p06>0.2&&mod==0&&am1<5&&am0>150}
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
Amplitude PD0
Mode of current signal PD0

KRATTA

- Broad energy range (2.5-260 MeV for protons)
- Lower threshold reduced to ~65 µm of Si equivalent thank to the pulse shape analysis
- SCT decomposed thank to the pulse shape analysis
- Mass resolution up to Z~4
- Digital pulse processing of all 105 channels
- Low noise, own-design preamps
- Modularity, flexibility, versatility, portability
- Budget friendly
- Ready for data taking...