



UNIVERSITÉ
DE GENÈVE

FACULTÉ DES SCIENCES



New idea for the target detector: SuperFGD

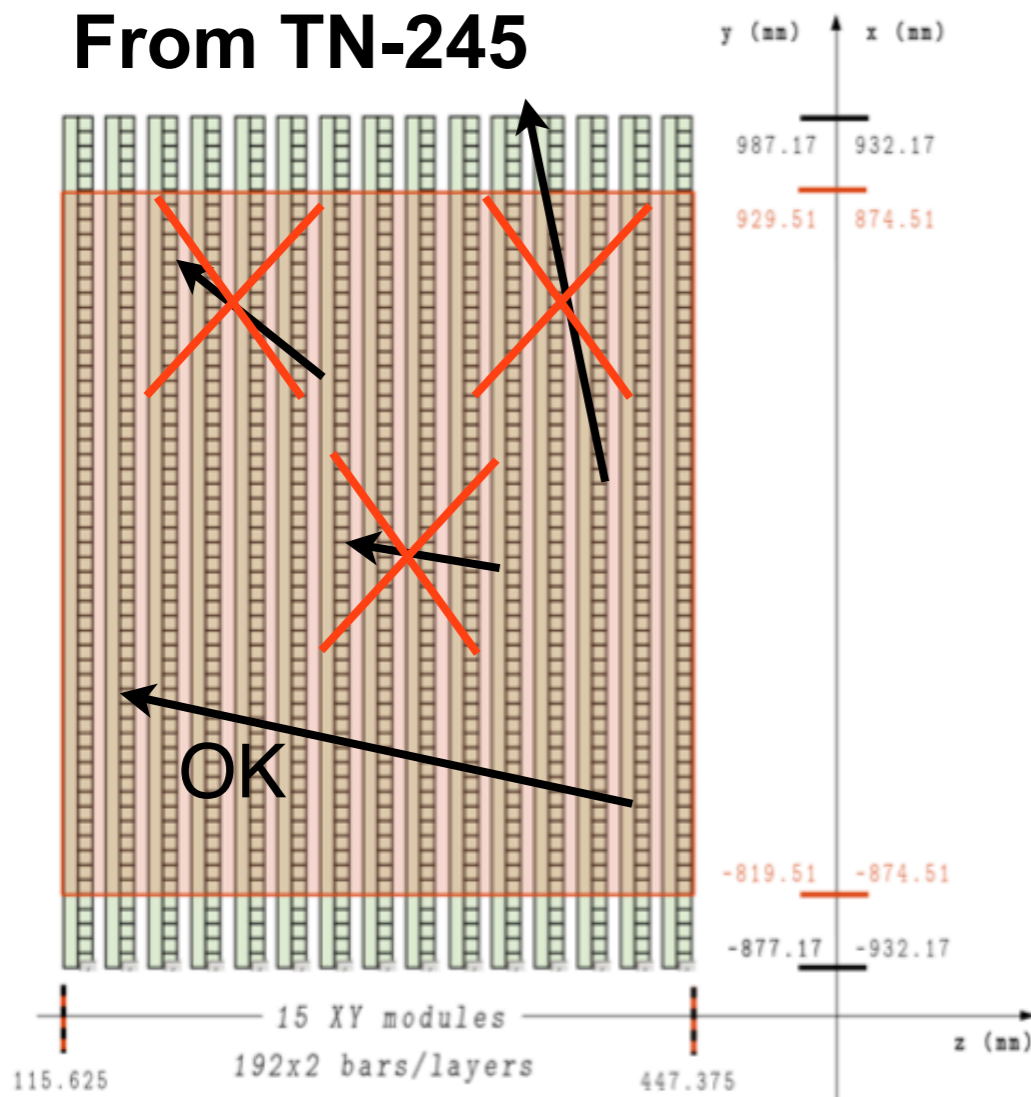
Davide Sgalaberna

“Neutrino Near Detector” Workshop, Tokai 20/5/17

FGD-like detector

- X-Y plastic scintillator bars (1cm² cross section)
- Need tracks crossing at least 4 transversal layers
- Need at least 6 hits: >5cm track length (not ideal for protons)
- Reconstruction not reliable at $|\cos\Theta| < 0.3$
- Ambiguity in 3D track reconstruction
- Not optimized for a accurate measurement of e^+e^- conversion in FV
- No low energy protons

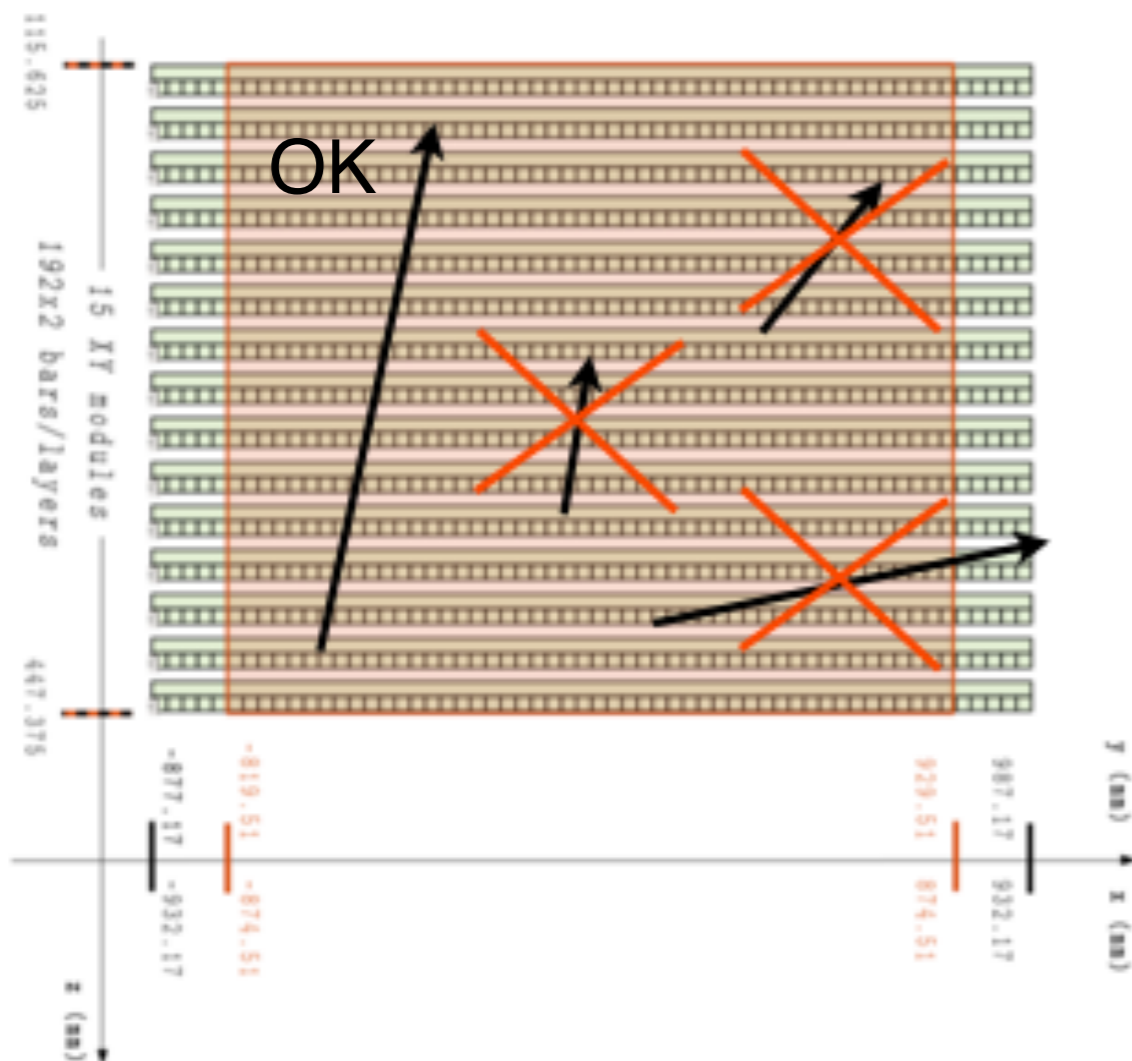
From TN-245



- Need a full 3D detector (no XY bars) to obtain a precise 4π acceptance
- Also need a very good PID --> proton/pion separation is very important (WAGASCI not optimal for PID)
- A water target is useful only if we can do still a very good job

FGD-like detector

- X-Y plastic scintillator bars (1cm² cross section)
- Need tracks crossing at least 4 transversal layers
- Need at least 6 hits: >5cm track length (not ideal for protons)
- Reconstruction not reliable at $|\cos\Theta| < 0.3$
- Ambiguity in 3D track reconstruction
- Not optimized for a accurate measurement of e^+e^- conversion in FV
- No low energy protons

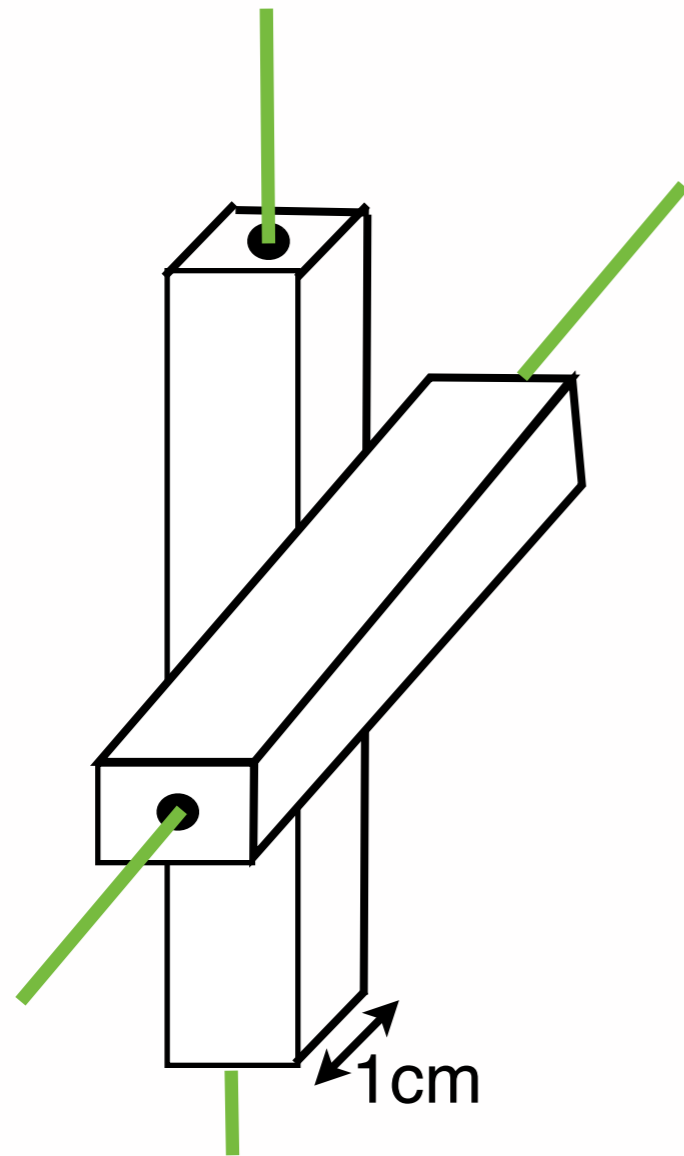


- Need a full 3D detector (no XY bars) to obtain a precise 4π acceptance
- Also need a very good PID --> proton/pion separation is very important (WAGASCI not optimal for PID)
- A water target is useful only if we can do still a very good job

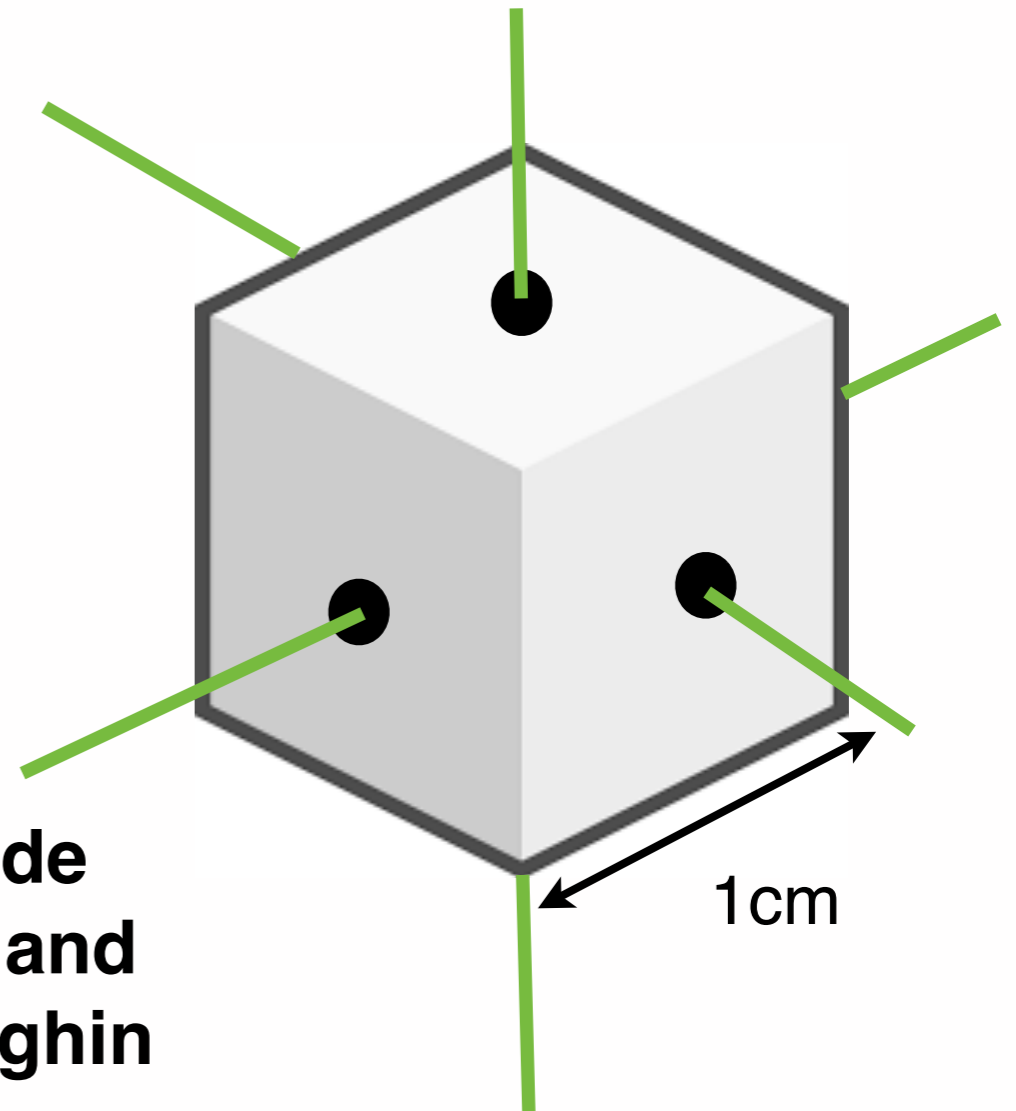
Goals

- Fully active plastic scintillator detector
- 4pi acceptance track reconstruction
- Provide 3D reconstruction, i.e. 3 projections-2D (FGD has 2 projections): ability to solve the track hits ambiguity
- Fine granularity --> track reconstruction down to 300 MeV/c or below for protons
- Very good PID --> high light yield

SuperFGD

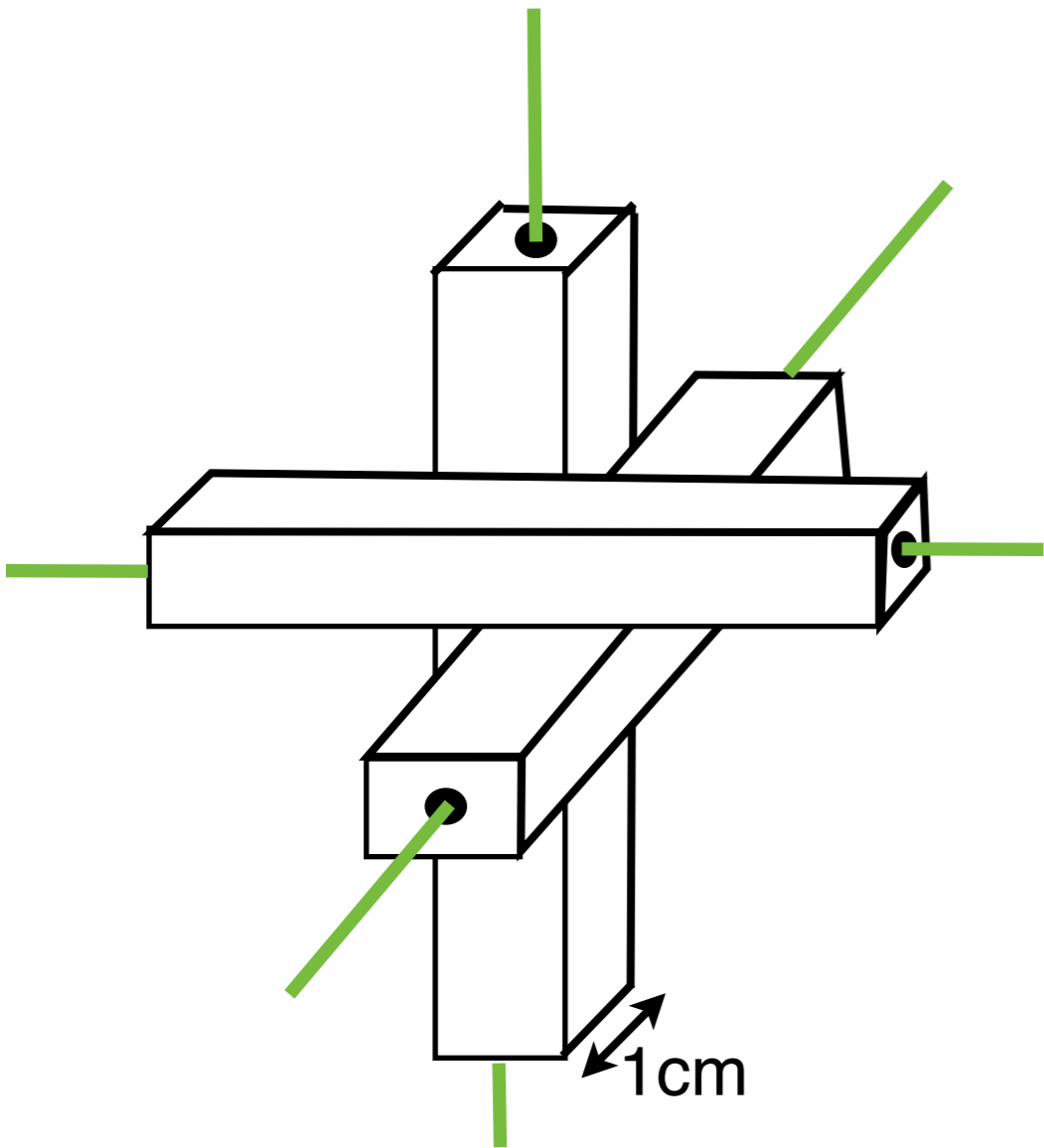


**Idea of Davide
Sgalaberna and
Andrea Longhin**

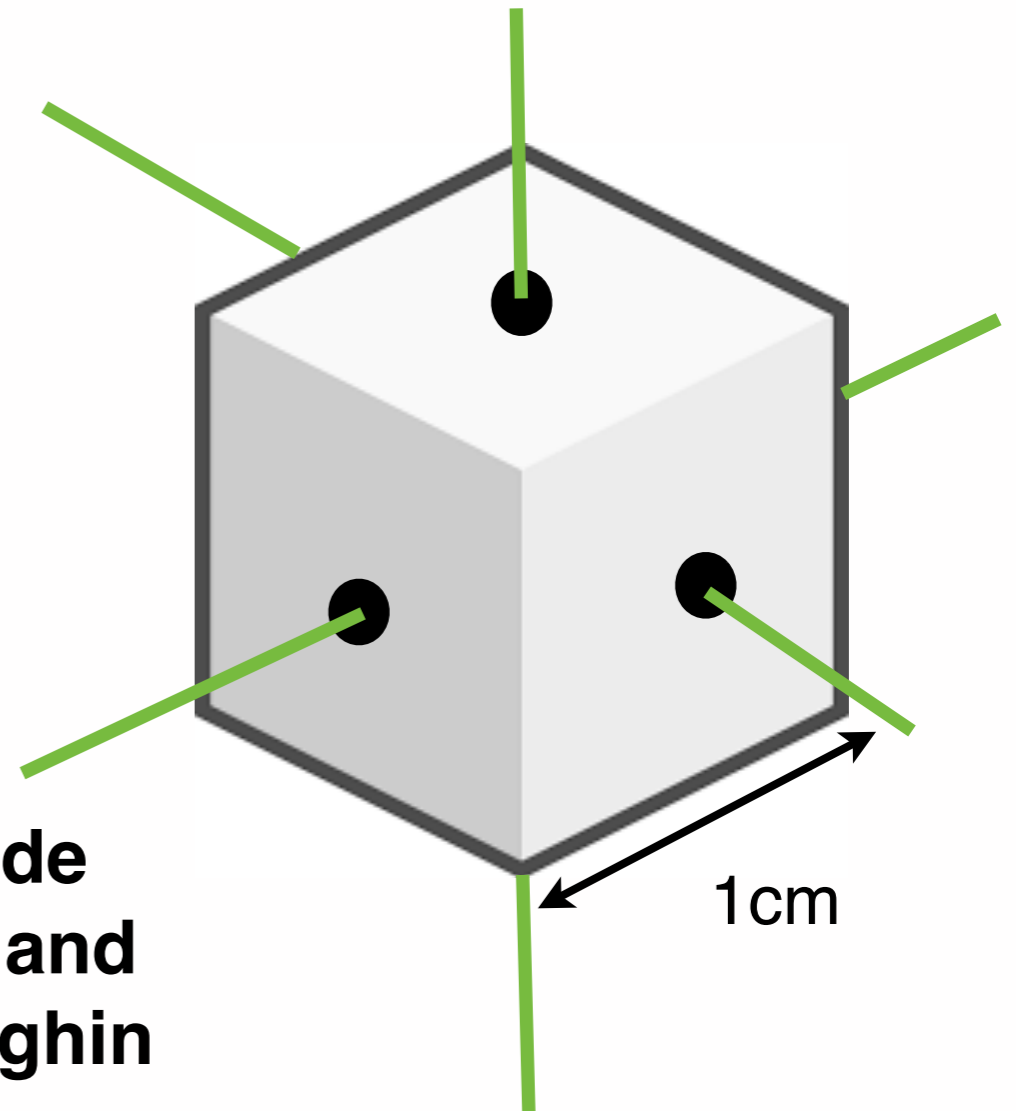


- Standard plastic scintillator
- Light collected by 3 fibers --> Tot # of p.e. $\sim \times 3$ than (needs teste)
- Each cube coated with TiO_2 to keep light entrapped inside the cube --> may expect better light yield than long plastic bar (needs test)
- 1 particle interaction (energy released) would produce light collected in the 3 fibers at the same time --> 1 track interaction = 1 hit!!!

SuperFGD

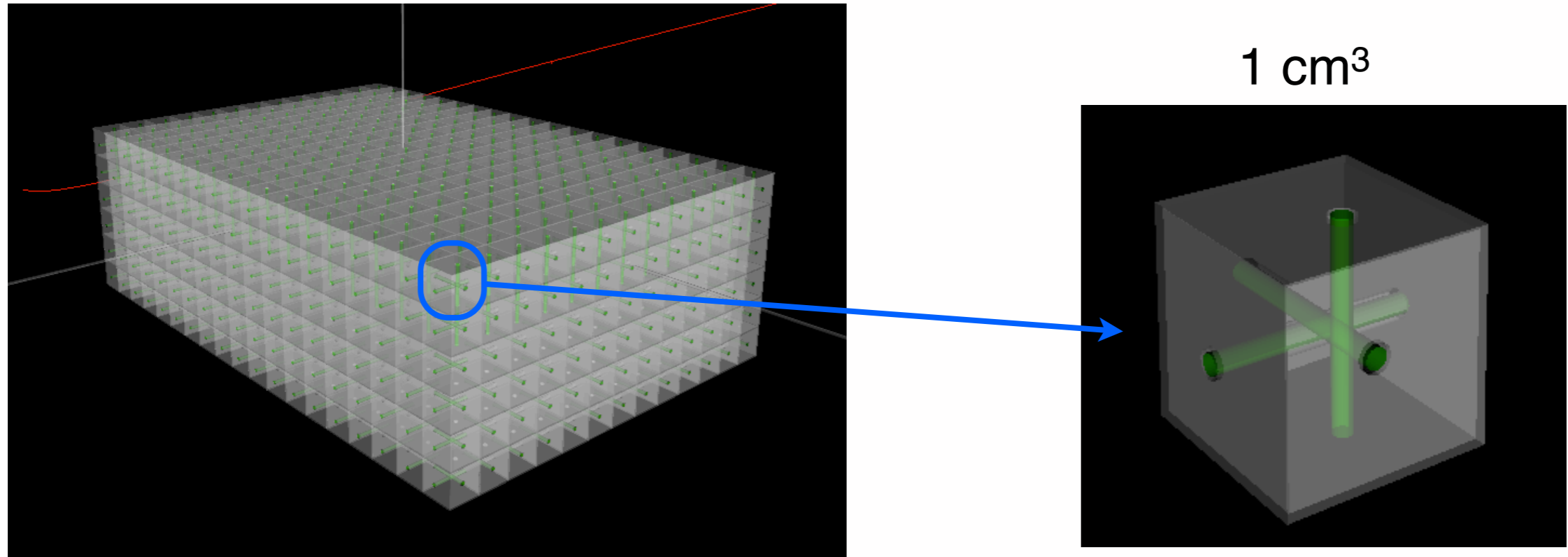


**Idea of Davide
Sgalaberna and
Andrea Longhin**



- Standard plastic scintillator
- Light collected by 3 fibers --> Tot # of p.e. $\sim \times 3$ than (needs teste)
- Each cube coated with TiO_2 to keep light entrapped inside the cube --> may expect better light yield than long plastic bar (needs test)
- 1 particle interaction (energy released) would produce light collected in the 3 fibers at the same time --> 1 track interaction = 1 hit!!!

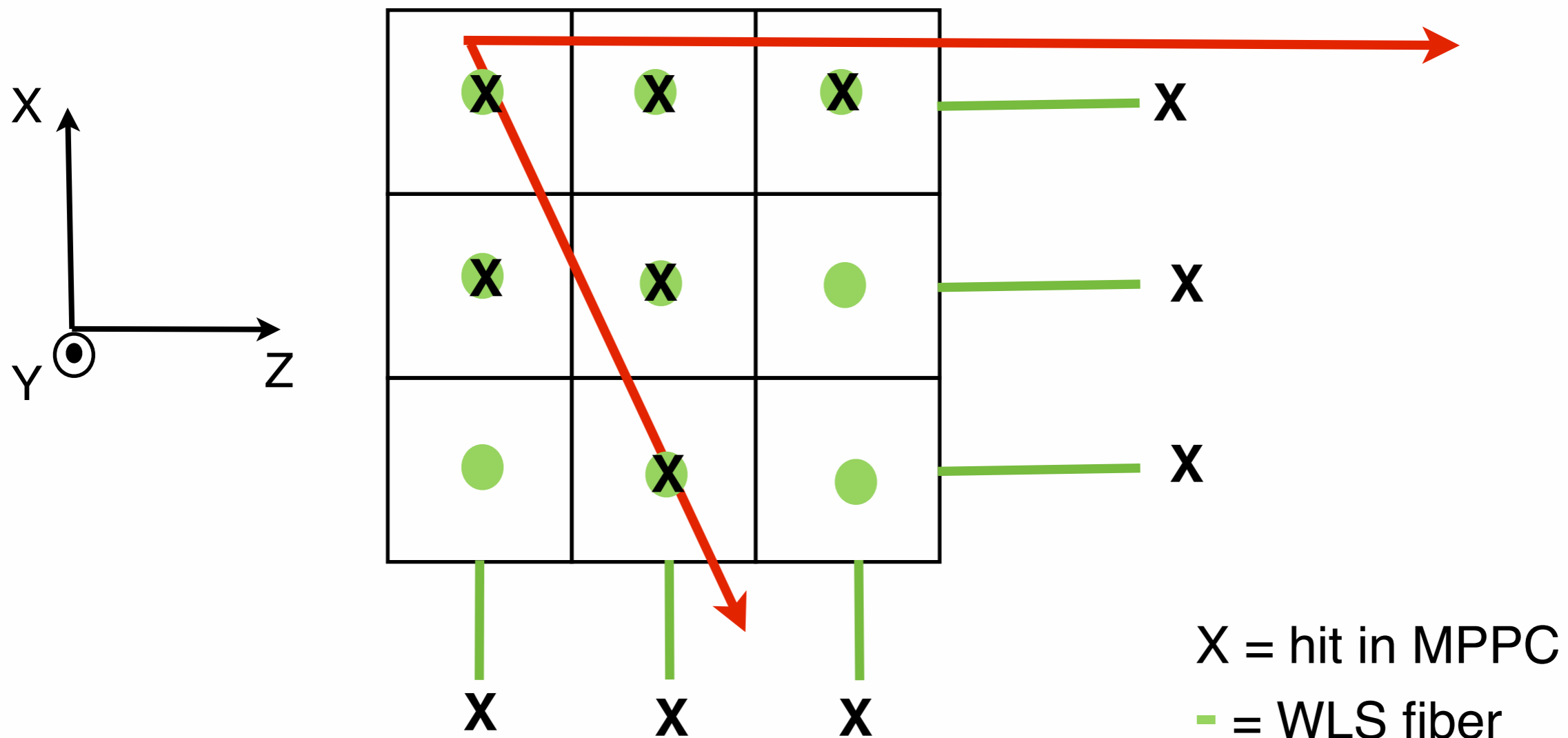
SuperFGD



- Possible cross talks:
 - between cubes through the coating: should be same as standard plastic scintillator bars
- Cross talk along the fiber holes is not a problem:
 - light has same direction as the one collected by the fiber transported toward the fiber-end
 - should be limited given the small hole size
- Tests needed to confirm the expectation

Tracking

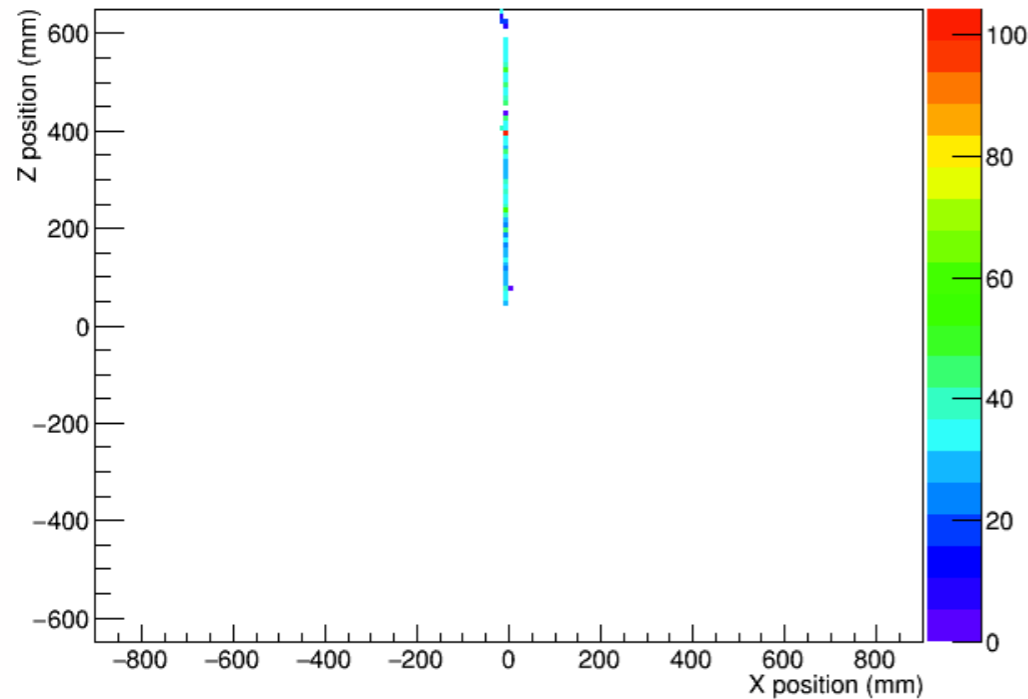
- How easy is separating tracks? Not a real 3D detector but we have 3 projections (XY, XZ, YZ)
- It should be enough to solve the ambiguity of several tracks in the same XZ layer



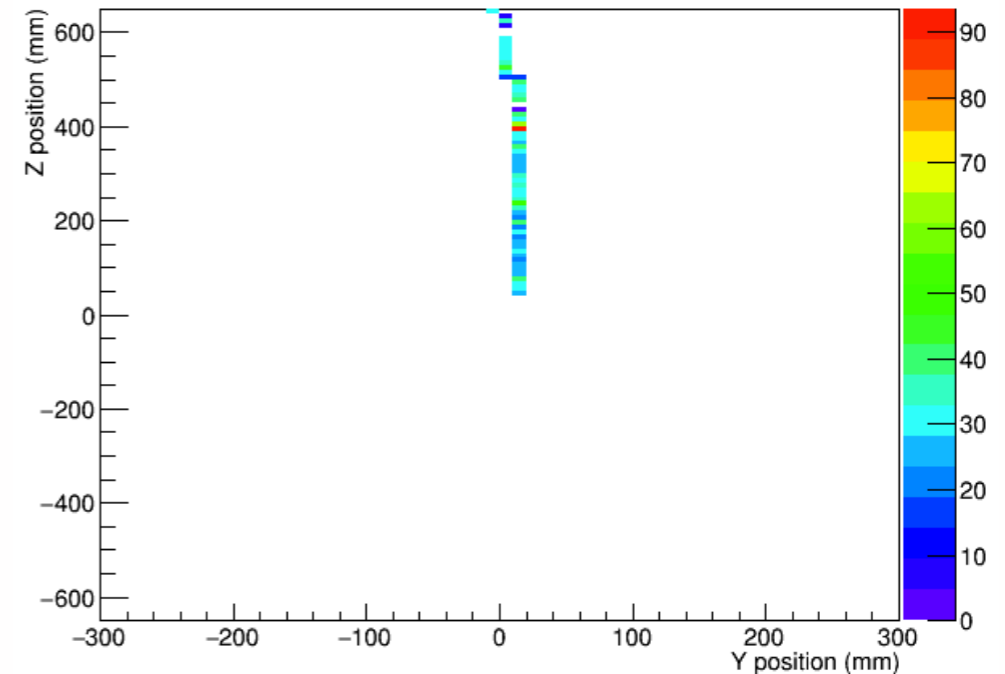
Simulation of SuperFGD

Muon particle gun: $E_{\text{kin}}=400$ MeV, Along Z axis

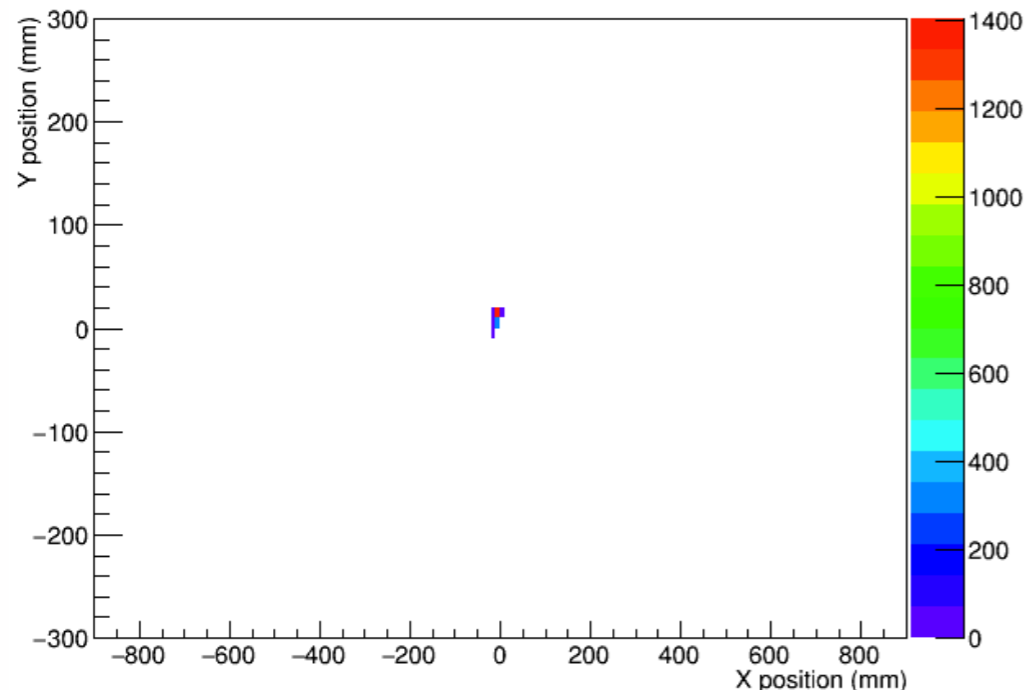
Projection on the XZ readout plane



Projection on the YZ readout plane



Projection on the XY readout plane

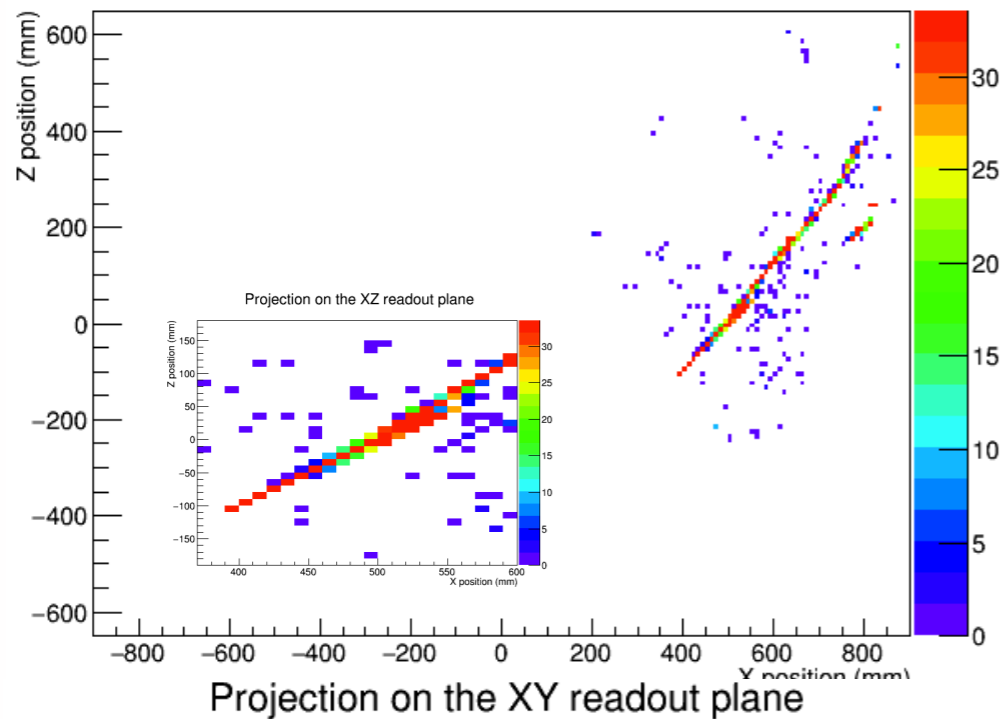


- # of p.e. / cm (MIP) $\sim 30\text{-}40$ p.e. / fiber
- $\sim x2$ than FGD because of new MPPC
- But we have 3 fibers / $\text{cm}^3 \rightarrow \sim 100$ p.e./cm
- Expect very good PID ($>\sim 100$ p.e. / cm for MIP) and tracking (1cm on the single hit, better than FGD, FGD3D or water-WAGASCI)

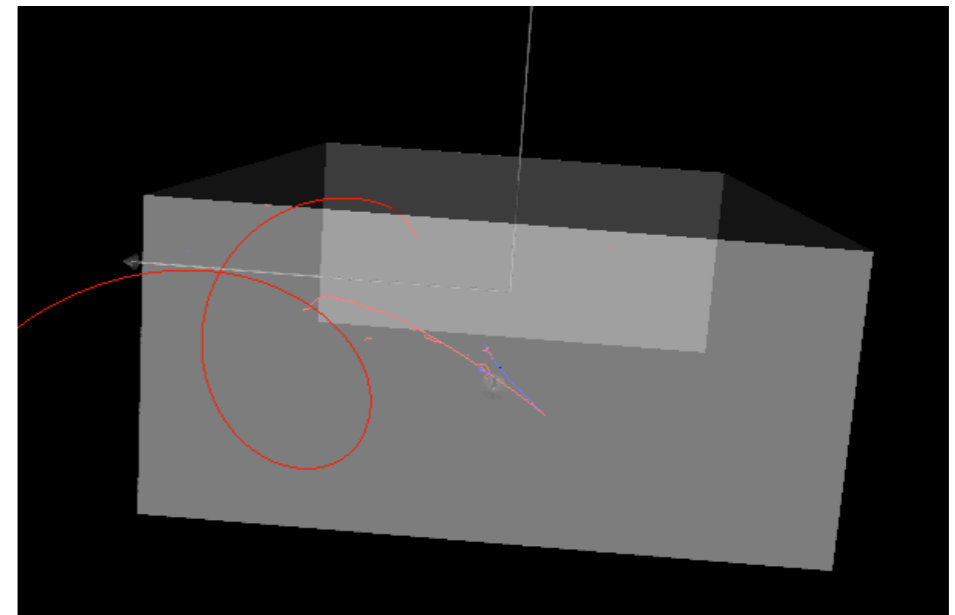
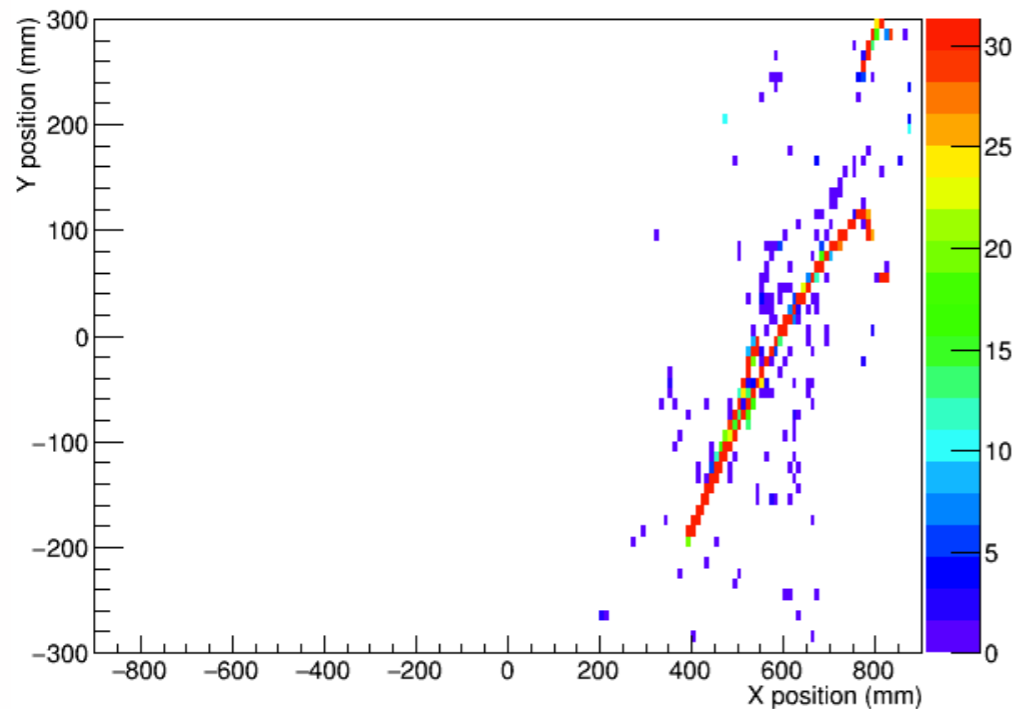
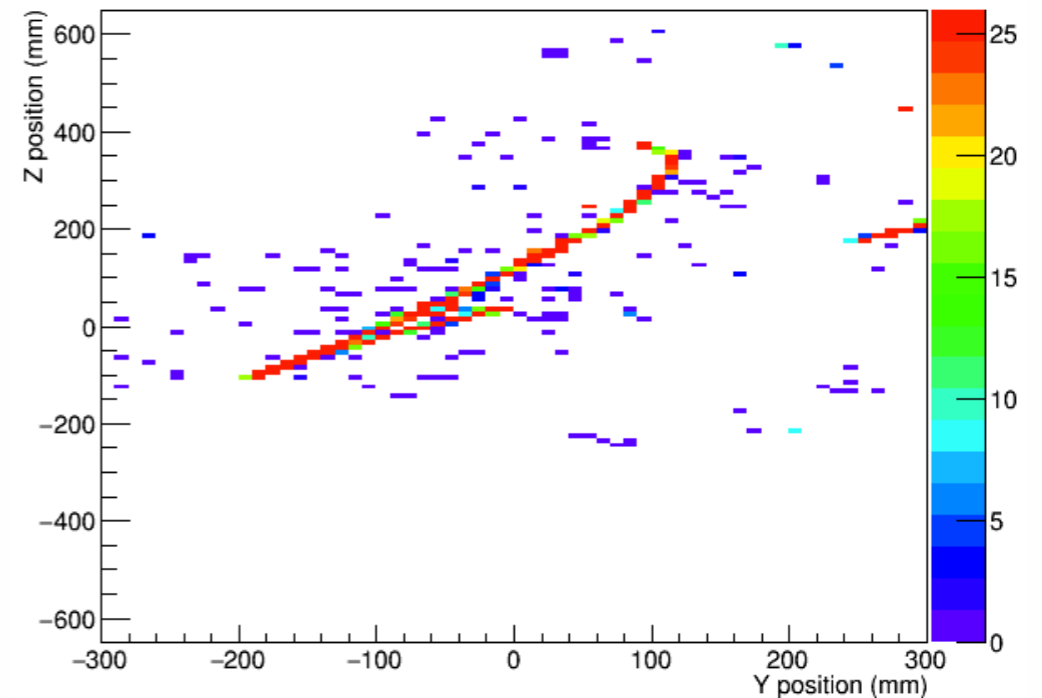
Simulation of SuperFGD

Gamma particle gun: $E_{\text{kin}}=400$ MeV

Projection on the XZ readout plane



Projection on the YZ readout plane



- Gamma is well detected inside the target and visible in all the projections

Mechanical constraints

- For $1.8 \times 0.6 \times 1.3 \text{ m}^3$, ~ 1.5 tons:

Size cube	1 cm ³	1.5 cm ³	2 cm ³
# of channels	$\sim 42\text{k}$	$\sim 18.7\text{k}$	$\sim 10.5\text{k}$
# of cubes	180x60x130 $\sim 1.4\text{M}$	120x40x87 $\sim 420\text{k}$	90x65x30 $\sim 175\text{k}$
fiber length	$\sim 42\text{km}$	$\sim 18.7\text{km}$	$\sim 10\text{km}$

- Discussed with Franck Cadoux (mechanical engineer at UniGe):
 - 1) cut standard plastic scintillator bars in many cubes
 - 2) coating on each cube, put in a bath of TiO_2
 - 3) make holes by drilling on XYZ
 - 4) gluing cubes is not needed: cubes inside a box closed by screw
 - 5) when assembling pull the fibers inside all the holes with standard techniques used by electricians: take a rigid row with the fiber glued on one end and pull through all the holes.
- Steps 1), 2) and 3) should be done in serie by a company. More expensive costs probably still dominated by the electronics
- Approximative cost is $\sim 2\text{-}3\text{M}\$$ (dominated by electronics)

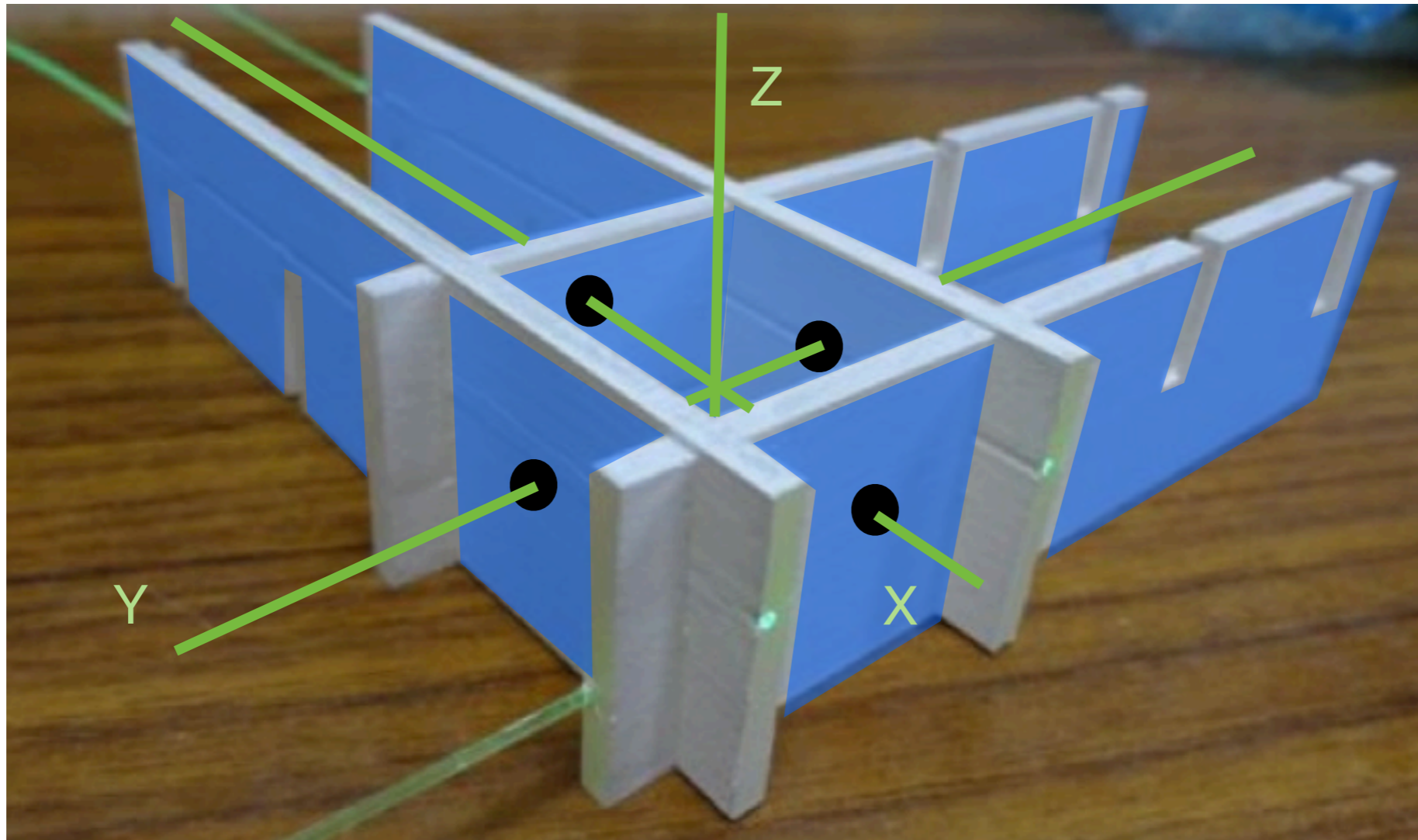
Conclusions

- SuperFGD seems a good idea for:
 - fully active detector
 - 4π acceptance
 - good tracking
 - good PID
- Production not as simple as FGD-like detector, but possible
- Many things should be tested to check its real behavior
- Best would be a small prototype (e.g. $5 \times 5 \times 5 \text{ cm}^3$) for test beam
 - 125 cubes
 - 75 readout channels
- Low costs. Pieces (e.g. plastic, fibers, MPPC) could be recycled
- Joint efforts of different institutes may reduce costs even more

BACKUP

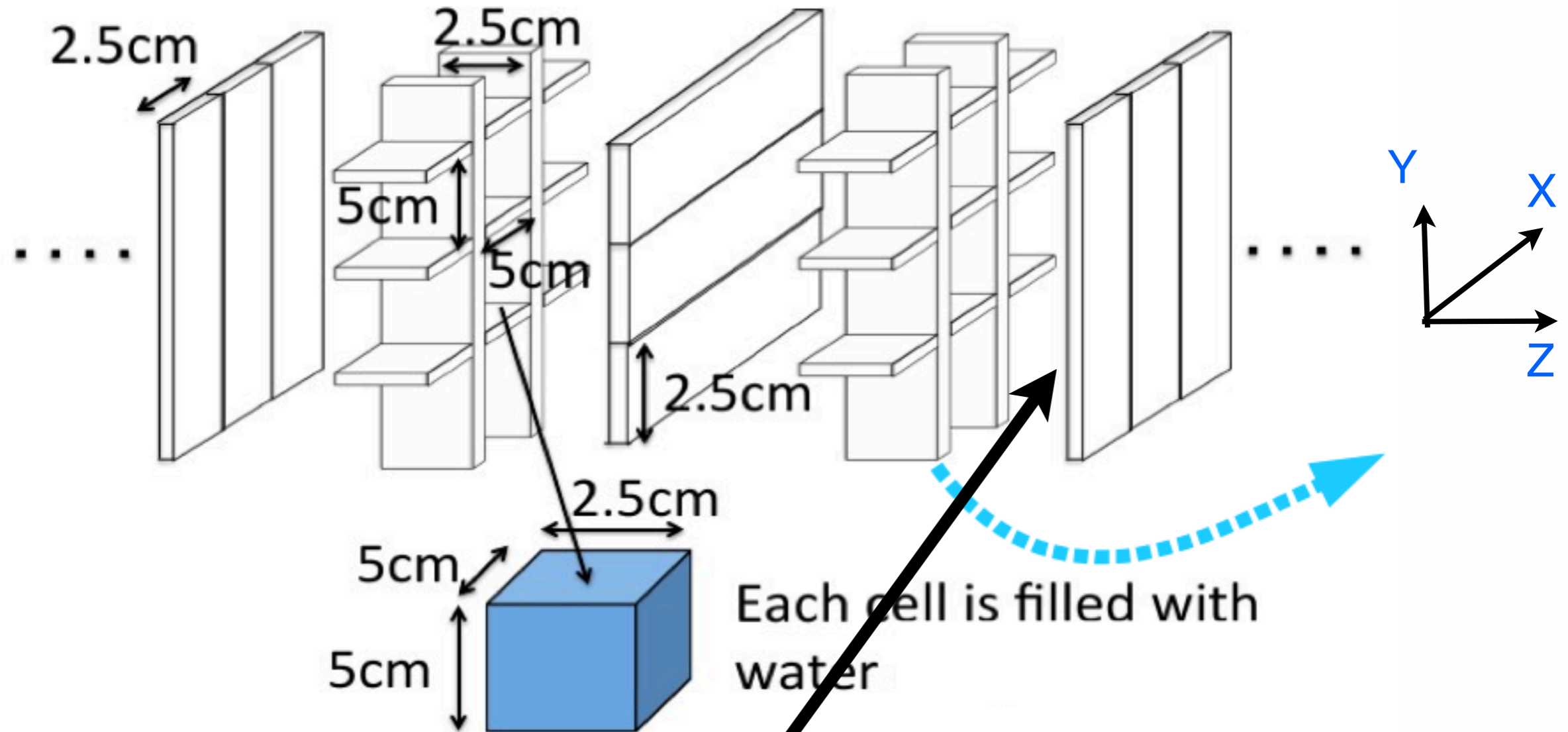
Option 1: Fully active WAGASCI

- WAGASCI structure + LS (also Water-based LS)
 - Need WLS fiber immersed in LS
- REFLECTIVE COATING
WLS FIBERS



- 3 WLS fibers for each scintillator bar
- In order to let the fibers going for ~2m 3D --> small holes (1-2mm) in crossing bars

Option 1: Fully active WAGASCI



- Since in Z we don't have a
- This bars need (Z) needs a WLS on both sides --> interaction in LS gives automatically 2 hits along Z --> this coordinate is defined
- Same as WAGASCI reconstruction but only for Z coordinate

Costs

	Basic costs	Total costs
Scintillators	750 JPY/m	5e6 JPY
Make slits in Grid scintillators	500 JPY/m	2e6 JPY
Array MPPC	2000 JPY/ch $\sim 17\text{E}/\text{ch}$	6e6 JPY
WLS fiber	400 JPY/m	3e6 JPY
Mechanical structure	15e6 JPY	15e6 JPY
Readout electronics	4,000 JPY/ch $\sim 33\text{E}/\text{ch}$	12e6 JPY
Assembly & testing	4e6 JPY	4e6 JPY
UA1 integration	4e6 JPY	4e6 JPY
Total		51e6 JPY

1JPY ~ 121E ~ 112\$

	<u>5x5x2.5 cm³</u>	<u>2.5³ cm³</u>	<u>1.0³ cm³</u>
<u>H₂O:CH</u>	8:2	7:3	4:6 ~ FGD2
<u>Proton threshold</u>	500 MeV	400 MeV	300 MeV
<u>Costs (2 tanks)</u>	1,400,000 US\$	1,800,000 US\$	7,400,000 US\$

Cost of Fully active WAGASCI ~ WAGASCI x 2

1target (2x2x0.6 m³ - 1cm³ cube) --> ~64k channels --> \$ ~3-4M

Prices are getting lower --> estimation is conservative and may be lower by 2