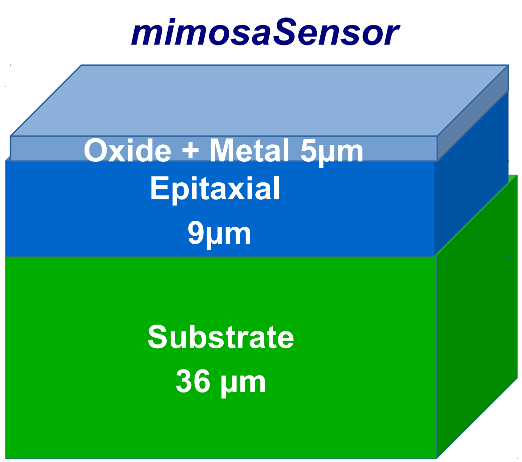
Alignement d'échelles double face avec mini-vecteurs et détecteur de vertex



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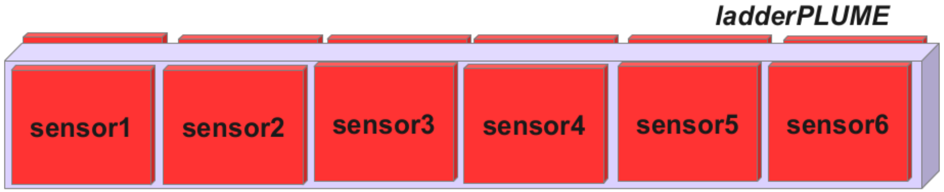
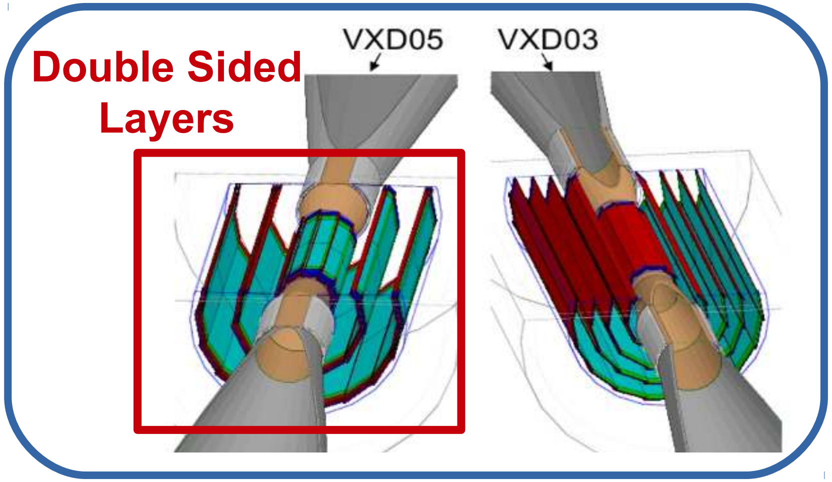
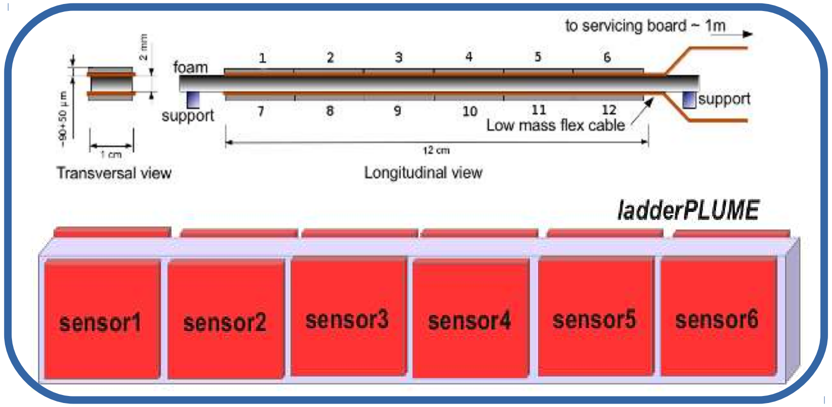


Outline

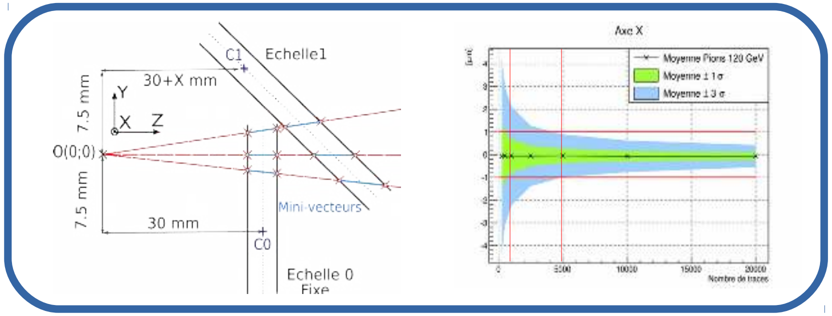
- **Motivations for double sided setup**
  - *ILC*
  - *Double sided layers*
  - *Mini-vectors*



- **Simulations of double sided ladders**
  - *Tools :*
    - *GEANT4*
    - *Charge carriage*
    - *Digitizer*

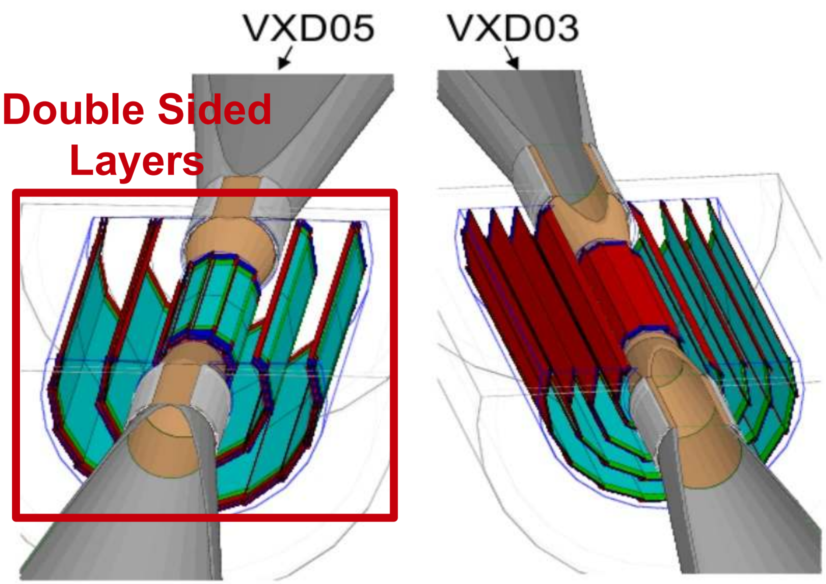


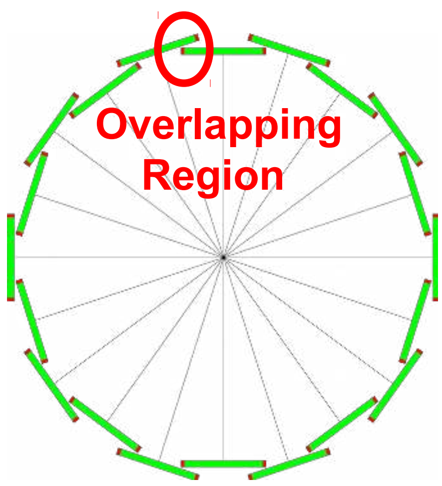
- **Alignment**
  - *Local alignment on the* ***overlapping region*** *of* ***double sided layer***



Motivations for double sided setup

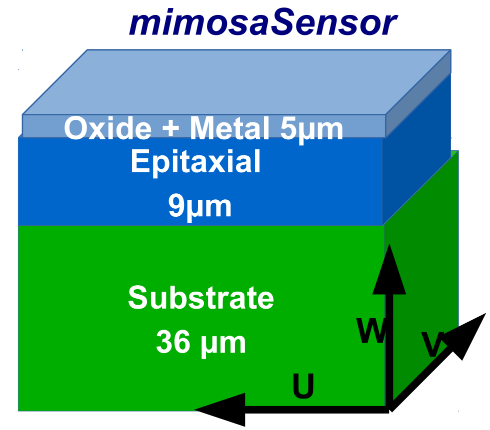
- Context : ILC Vertex detector
- Geometry of the vertex detector :
  - 5 single layers OR 3 double sided layers.
- Focus on 3 ***double sided layers***
  - ***Material budget reduction*.**
    - 1 support for 2 layers.
  - 1 track → 2 hits → 1 mini-vector
  - ***Mini-vectors***
    - ***Potential improvment on tracking and alignment.***
- Goal : Studies of **alignment** with ***double sided ladders*** and ***mini-vectors***
- Alignment on the overlapping region of two consecutive ladders in the same doubel layer.
- **Tool : Geant4 simulation**
  - sensor simulation
  - Double sided ladder simulation





Simulation : GEANT4

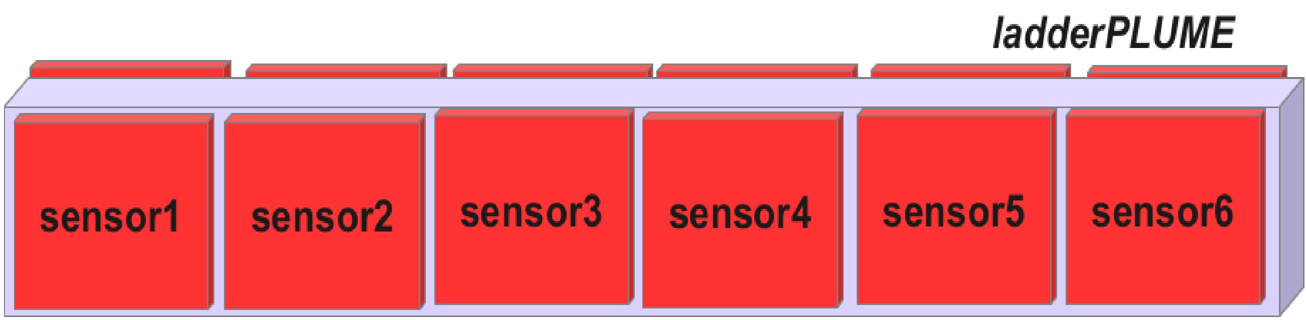
- ***CMOS sensors with GEANT4 :***
  - MIMOSA sensors : 3 layers design
    - **Substrate layer** (silicon) + **Epitaxial layer** (silicon) + **Oxide+Metal layer**
    - **Total thickness = 50 µm**
  - ***Energy deposition { Landau (MPV =80e⁻/µm) }***
  - Geometry modules :
    - ***Single sensor*** (MIMOSA-28 like)
    - ***Single and double sided ladders* (PLUME)**
    - ***Modular tool : New modules for a new geometries.***
  - ***Charge carriage & digitizer for MIMOSA sensors.***

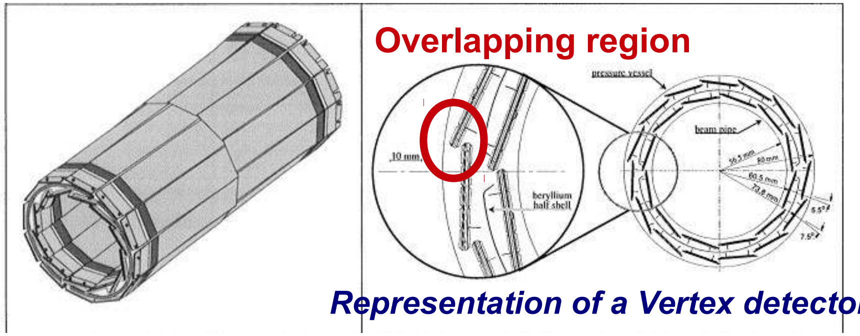


CMOS sensor simulated geometry

- Double sided ladder simulation : PLUME ladder (Pixel Ladders with Ultra-low Material Embedding)

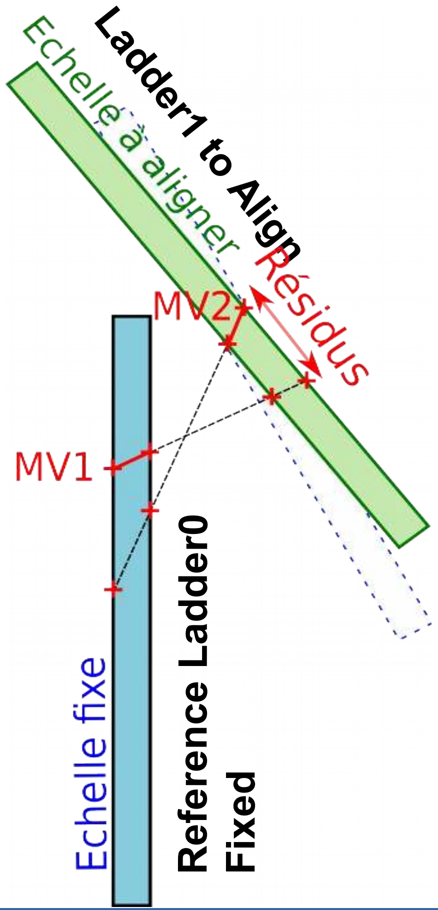
- Built with **12 sensors** MIMOSA-28 like, 6 per side
- Gap between two sensors = 420 µm
- *Support = **2 mm** SiC (Density 8 %)*
- ***Spatial resolution = 3.5 µm*** *(normale incidence)*





Representation of a Vertex detector.

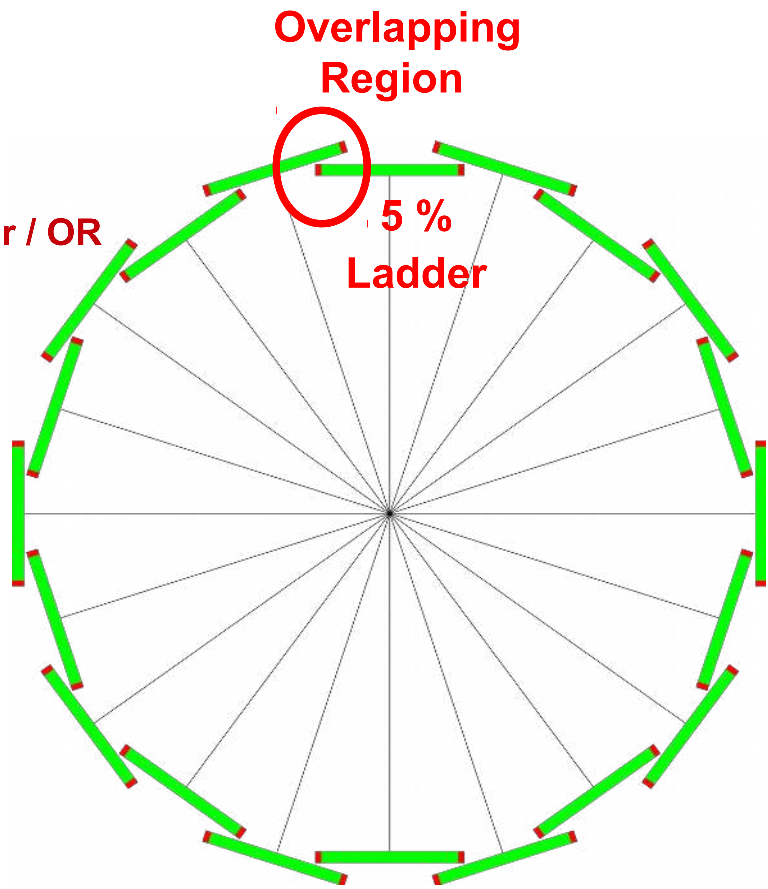
- **Alignment with mini-vectors**
  - On the ***overlap region*** of two consecutive ladders
  - First studies of tracking with mini-vectors → efficacity improvement at low momentum.
  - ***Potential improvment on pattern recognition at low momentum***
  - ***Idea : Standalone alignement with mini-vectors***
- **Reconstruction of mini-vectors**
  - **A *hit at the first side* with the *closest hit of the other side*.**
- **Method of alignment with mini-vectors**
  - On the **overlapping region (OR).**
  - Fixed reference (ladder0) + Misaligned ladder (ladder1)
  - Spatial residuals = Projection of the mini-vectors of the fixed ladder on the other ladder
  - Residuals = spatial residuals + mini-vectors tilt residuals.
  - Alignment = Chi2 Minimisation.



- **Let's see the statistic …**

Statistic (Order of magnitude only)

- ***Order of magnitude for Statistic for 1 Overlapping Region***
- ***We want a minimum increase of material budget***
  - ***1 OR = 5 % Ladder Surface***
- ***Hard processes***
  - $L=1.8 \times 10^{34}\ cm^{-2}\ s^{-1}$
  - **e+ e- → μ+ μ- (500 GeV)** : **1400/2800 μ per Year / OR**
  - **e+ e- → qq (500 GeV)** : **8000/16000 particles per Year / OR**
- ***GigaZ option***
  - $L=10^{33}\ cm^{-2}\ s^{-1} \rightarrow 10^9$/Year
  - Example : Z → μμ (3.5%) + Z → ee (3.5%)
  - **14000/26000 particles per Month / OR**
- ***Photon collider option***
  - $L=10^{34}\ cm^{-2}\ s^{-1}$ / 500 GeV
  - Ex : σ(γ γ-> μ+μ-μ+μ-) ≈ 150 pb (TDR Tesla)
  - **40000...80000 μ per Month / OR**
- Optimistic : ***Beamstrahlung*** (see after)
  - **7500/20000 e-/+ per Hour /OR**
  - But **Low Momentum particles**
- **Sum** of tracks from different processes

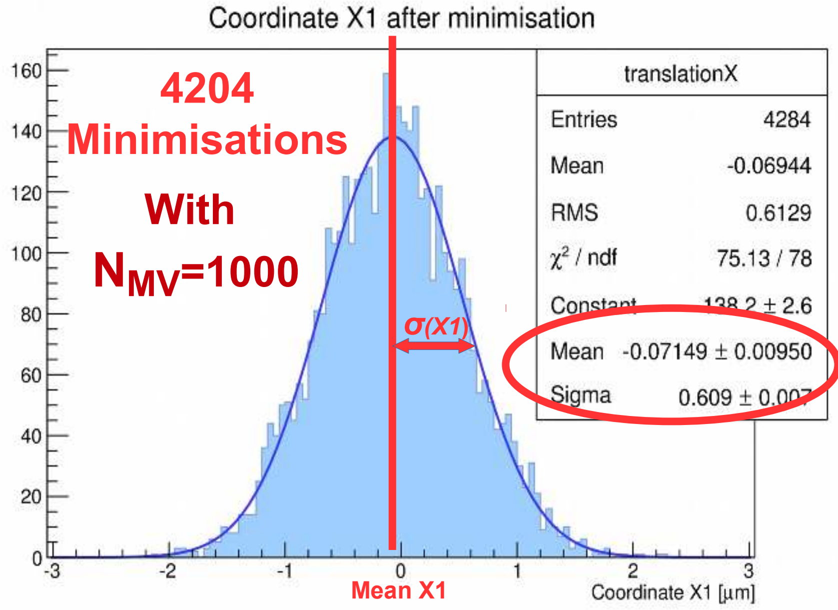


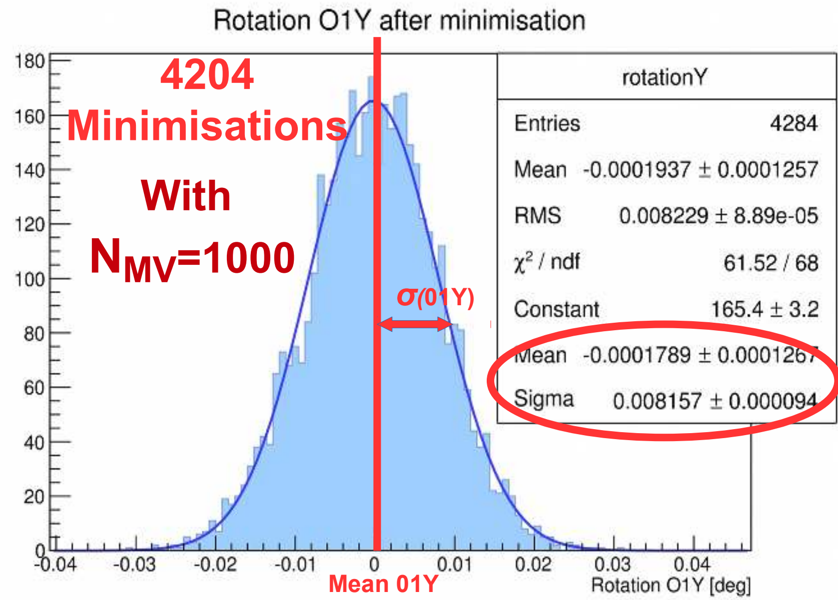
Configuration : Pions High Momentum (120 GeV/c)

- **Alignment Step 1 : Proof of principle with high momentum particles.**
- Relative tilt between ladders = **30 deg** (Rotation X)
- Beam
  - Negative pions 120 GeV/c
  - Distributed in a cone
    - Vertex position O(X,0,0) : random position in X axis
    - Opening angle = Random[0,15] deg
- Mini-vectors association
  - 2 mini-vectors in the overlapping region.
  - Association by pairs before minimisation
  - In the next : **perfect associations** of mini-vectors
- Center position of ladder 1 (ladder to align) :
  - O1(X1,Y1,Z1) = (0,7500,35000) µm
- Rotation ladder 1
  - Rot X = 30 deg, Rot Y = 0 deg, RotZ = 0 deg

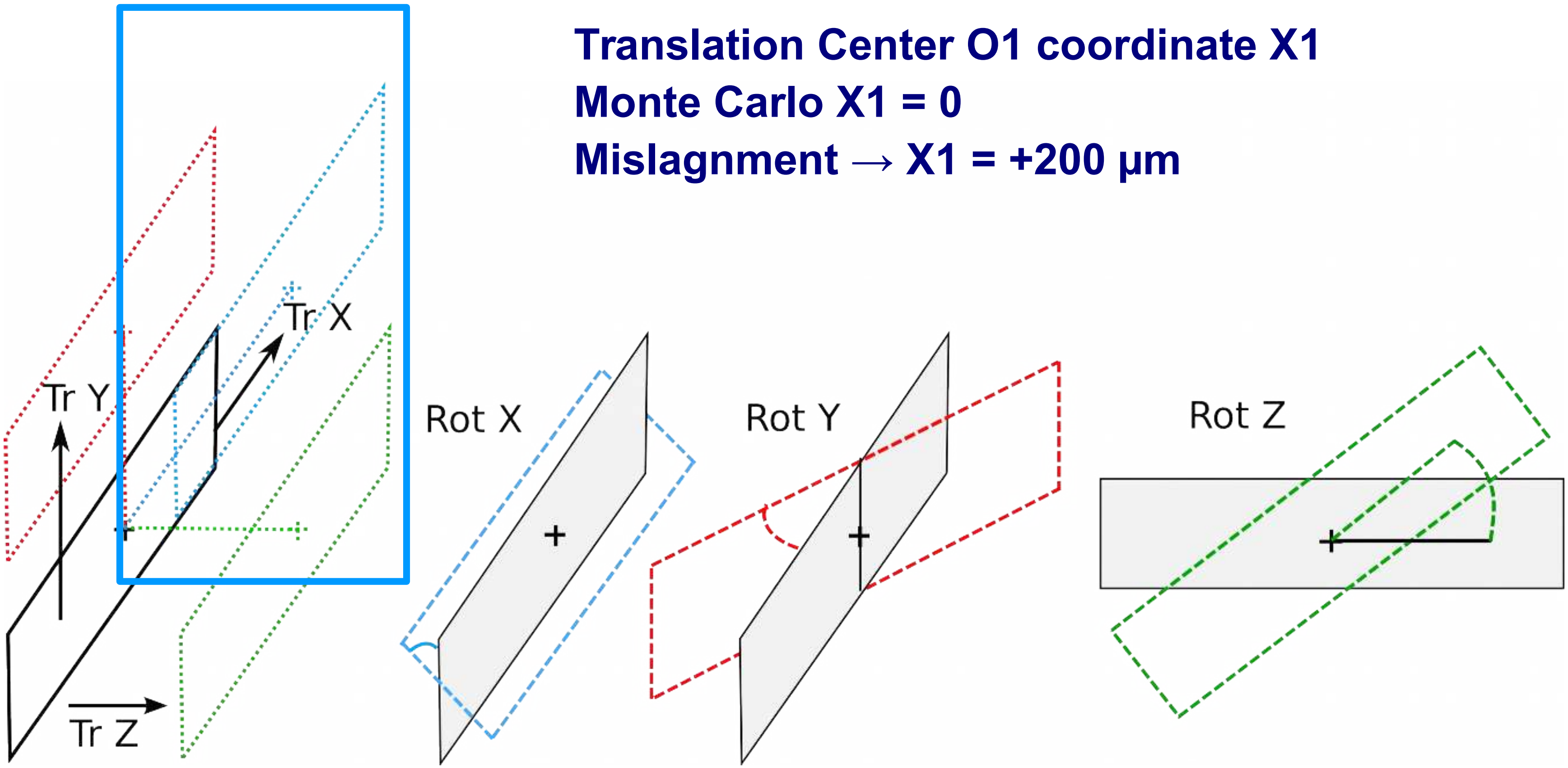
Alignment with mini-vectors : method precision

- Alignment with 6 degrees of freedom
  - 3 Translations : X, Y, Z,
  - 3 Rotations : Rot X, Rot Y, Rot Z
- Misalignment :
  - Translations of the center O1 (Ladder 1)
    ΔX = +200 µm, ΔY = -200 µm, ΔZ = +200 µm
  - Rotations about the center O1 :
    ΔRotX = +0.5 deg, ΔRotY = -0.5 deg, ΔRotZ = +0.5 deg
- Estimation of the alignment precision :
  - ***N minimisations*** with ***N different samples***
  - ***N_{MV} mini-vector pairs*** per sample.
- For each variable after 1 minimisation → 1 entry in each histogram (6 DoF = 6 Histos).
- **Bias =** Histogram ***Mean*** - **Monte Carlo Values**
- **Method Precision** = Histogram ***Width (1 σ)***





Parameter X1

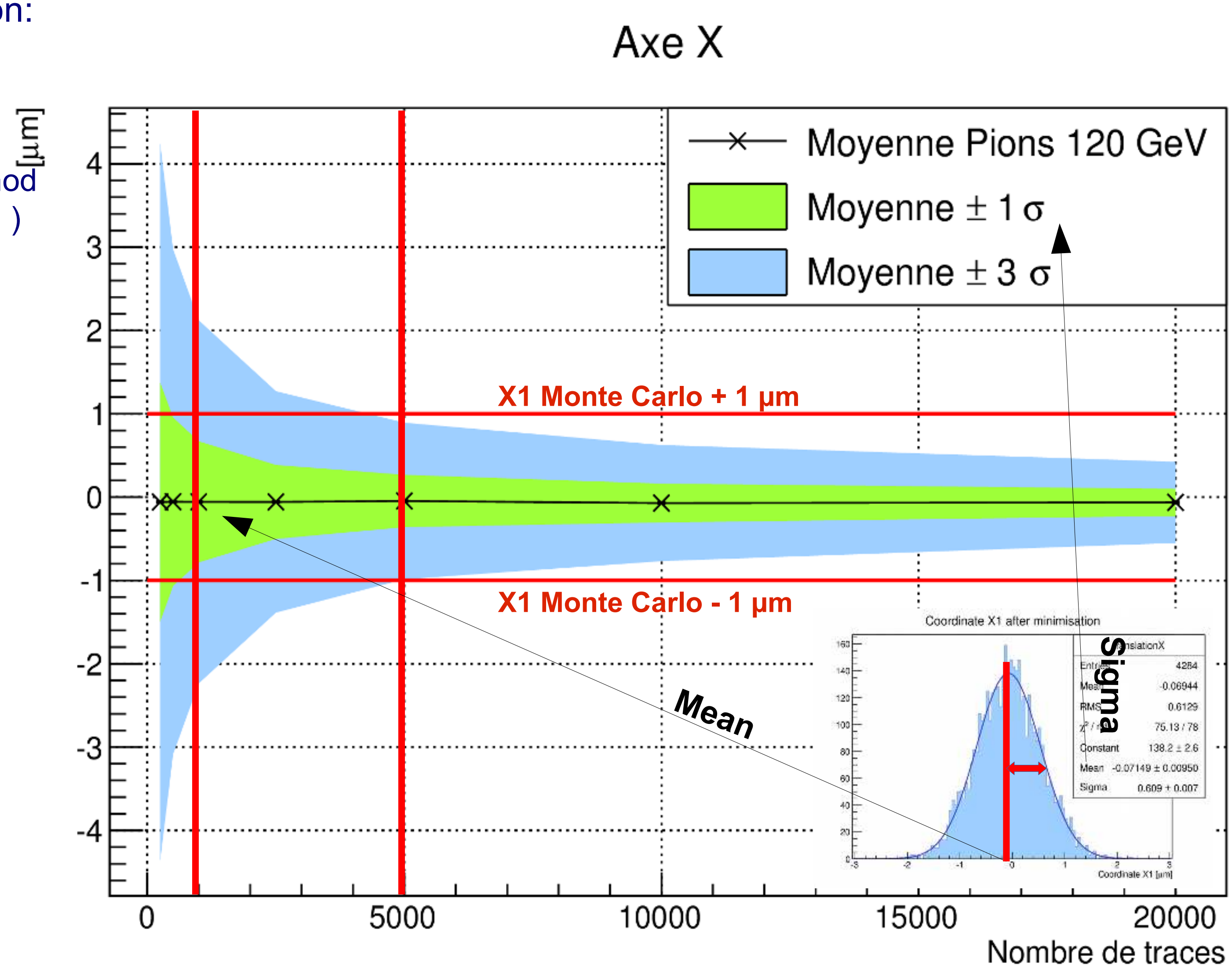


Translation Center O1 coordinate X1
Monte Carlo X1 = 0
Mislagnment → X1 = +200 µm

Alignment with mini-vectors : Results

- Ladder Center X1 position:
  - Mean vs statistic (deviation from MC values)
  - Width vs statistic (method precision : *± 1 σ*, *± 3 σ* .)
- Starting from **1000** good pairs of mini-vectors
  - ***precision (1 σ) better than 1 µm***
- **≤ 5000 good pairs of mini-vectors**
  - ***Precision (3 σ) better than 1 µm***
- **Y1 Position :**
  - **Similar results**
- **Z1 Position**
  - **Bias = -10 µm**
  - **Bias suppresion by increase tilt Y of Mvs.**
  - New Precision ***(1 σ)*** **< 2µm** with **1000 pairs**

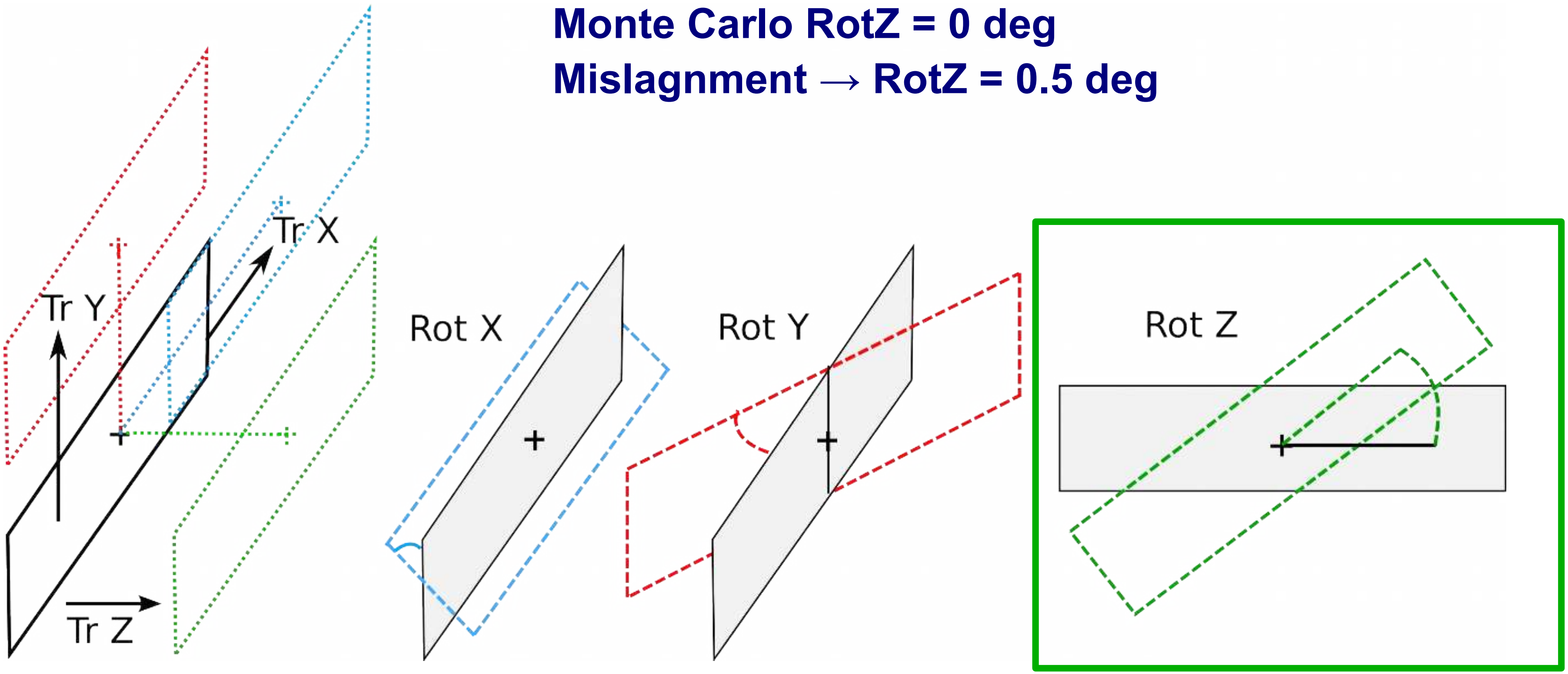
Position after minimisation in function of statistics



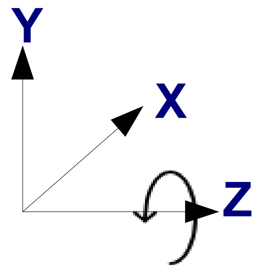
Good tracks = Good pairs of mini-vectors

Parameter RotZ

Rotation Center O1 : Rotation O1Z
Monte Carlo RotZ = 0 deg
Mislagnment → RotZ = 0.5 deg

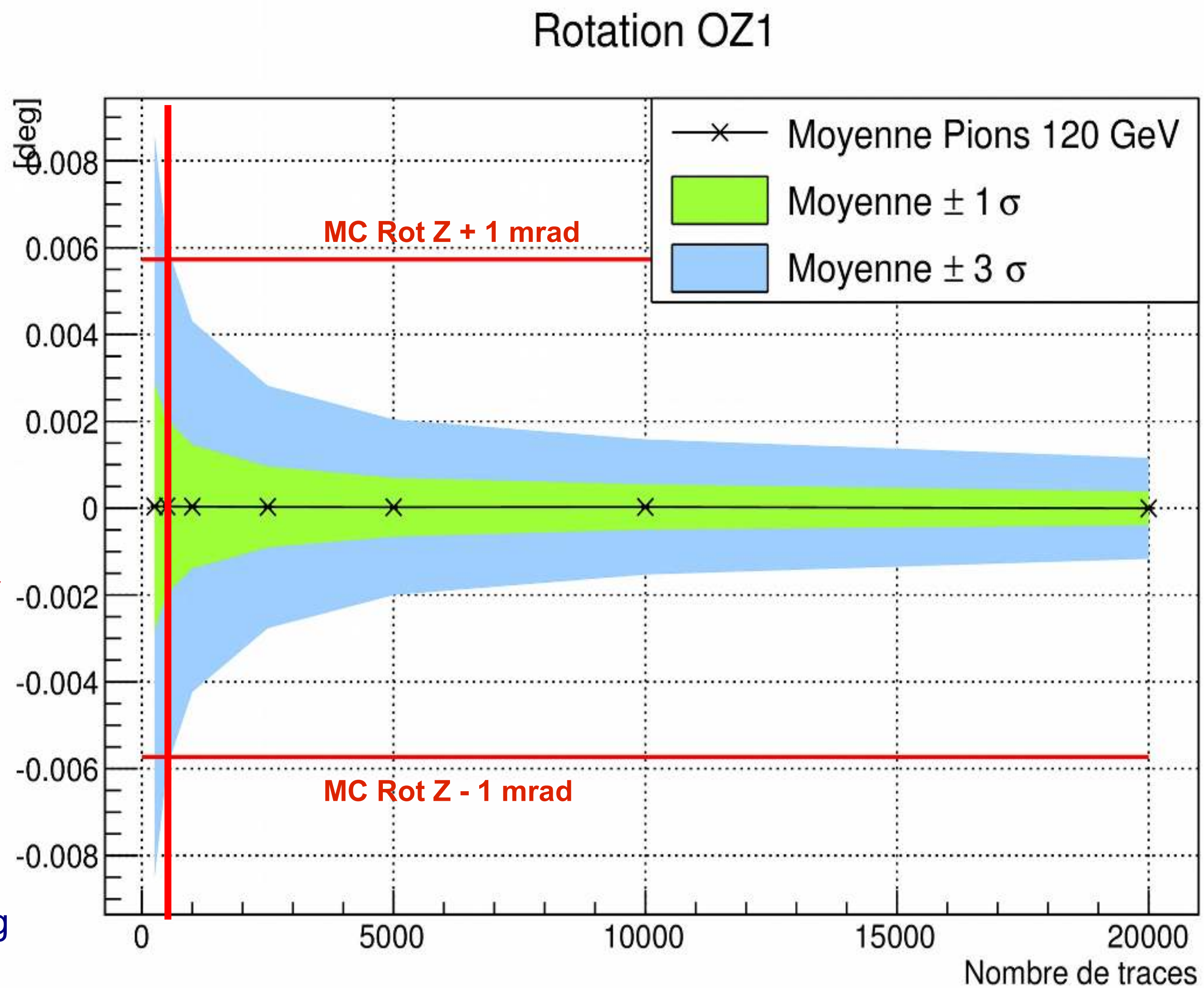


Alignment with mini-vectors : Results



- **Rotation Axe Z :**
  - Mean vs statistic
  - Width vs statistic
- Red lines : Monte Carlo Value ± *1 mrad*
- **≥ 500 good pairs** of mini-vectors and more
  - No bias
  - ***precision (3σ) better than 1 mrad (!)***
- **Rotation Axe Y :**
  - No bias + precision (3σ) < 1 mrad with ≥ 20000 MV pairs
- **Rotation Axe X :**
  - Small bias = -0.01 deg
  - **Width < 1mrad** (1σ) with ≥ **2500 Mvs pairs**

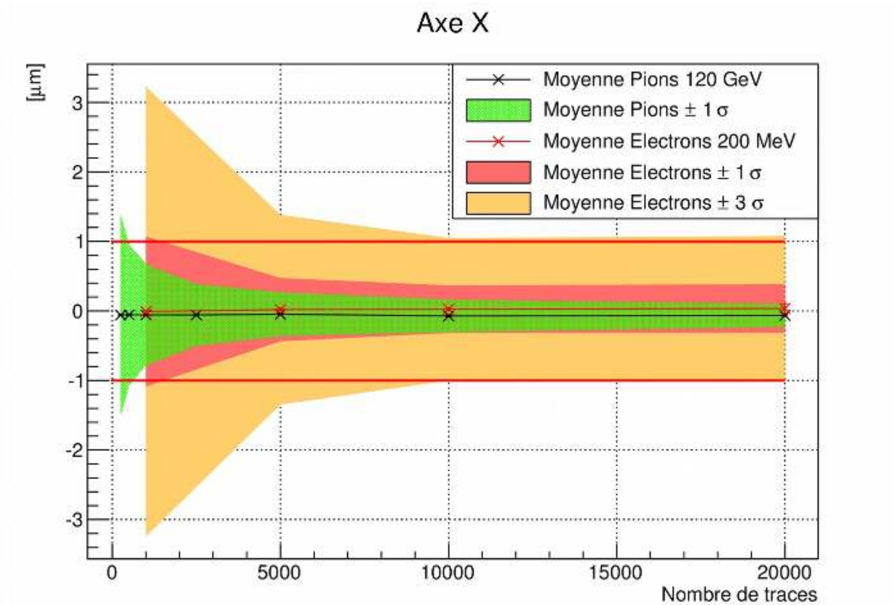
Position after minimisation in function of statistics

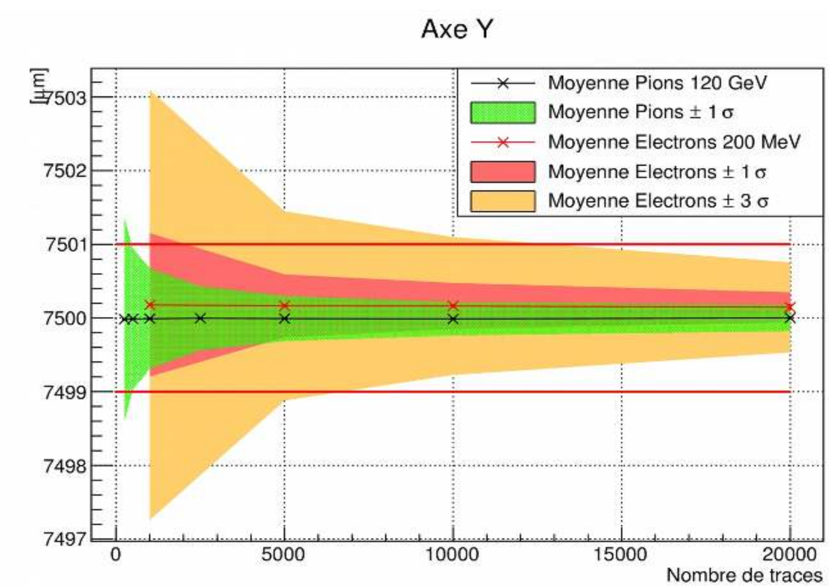


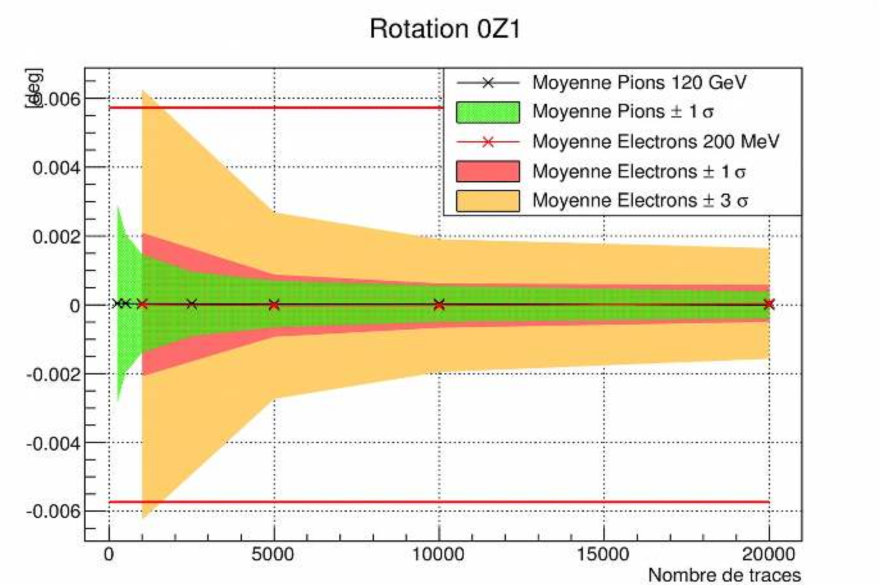
Good tracks = Good pairs of mini-vectors

Low Momentum Electrons (200 MeV/c)

- Same configuration as before
- **No magnetic Fiels B=0**
- **Electrons** : P = **200 MeV/c**
- **Green : 120 GeV/c pions (± *1 σ*)**
- ***Red : 200 MeV/c electrons (± 1 σ), Orange (± 3 σ)***
- **Multiple scattering** effect
  - **No bias** or **very small bias**.
  - Small loss in precision

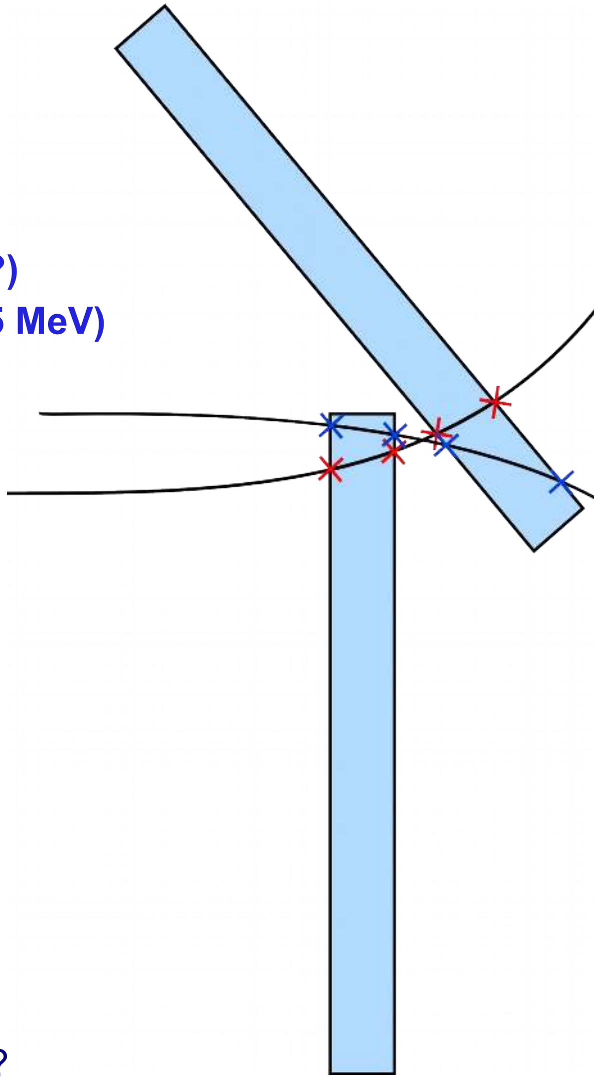






Alignment with Beamstrahlung ?

- **Step 2 : Standalone alignment with beamstrahlung and mini-vectors**
- **Beamstrahlung**
  - **High statistic in small amount of time**
  - **But Low momentum**
    - Multiple Scattering
    - In Magnetic Field : Helices
    - Very Low Momentum : Particles loopers (<30 MeV)
  - **Use high transverse momentum beamstrahlung (>100, 200 MeV ?)**
  - **SIT projections (Layer 1 : Pt min=80.5 MeV Layer 2 : Pt min=157.5 MeV)**
- **Statistic** :
  - **P_T>100 MeV** : Around **20000 MVs pairs in 1 hour** !
  - **P_T>200 MeV** : Around **20000 MVs pairs in 3 hours !**
- Can we **select these high momentum tracks** with **mini-vectors** ?
  - **Ambitious**
- **Mini-vectors**
  - 2 points of measure
  - New information = **Direction of the track**
  - Other information : **2 cluster shapes**
  - Association by couple of mini-vectors = **4 points**
  - Search region : Cylinder of radius 15 mm from IP.
- **Opened questions :**
  - Can we reconstruct these helices/momentum with mini-vectors ?
  - If we can, what is the resolution of the alignment with beamstrahlung ?



Summary and outlook

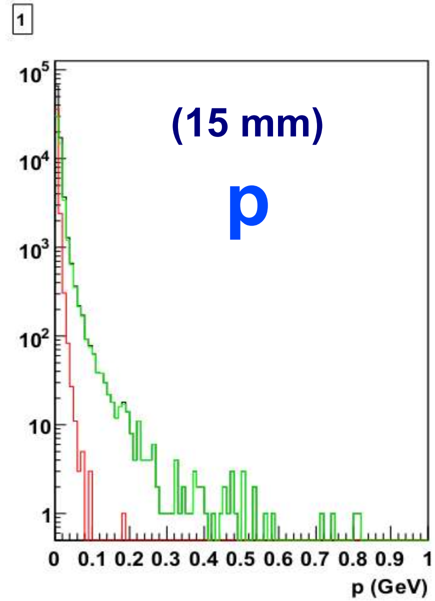
- Full simulation chain for :
  - Single sensors
  - Double sided ladders (PLUME)
  - Others …
- Detector response based on the beam test data
  - Data and simulation agreement better than 10 %
- Alignment with mini-vectors
  - Precision on the center (X1, Y1) < 1 µm.
  - Precision on Z1 < 2 µm.
  - Precision on tilts < 1 mrad.
- Principle proof with high momentum particles

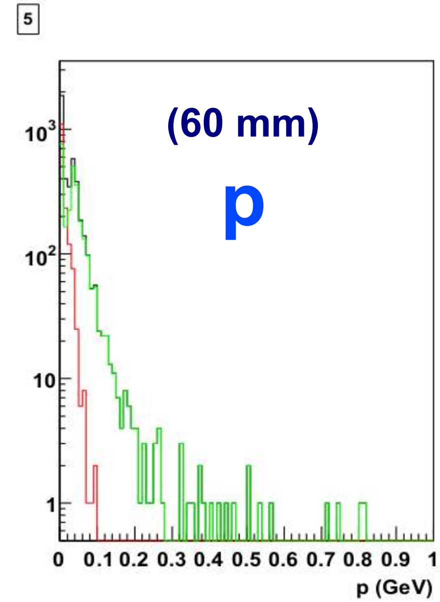
- Outlook : Studies on this alignment method with low momentum particle and magnetic field : Work In Progress.

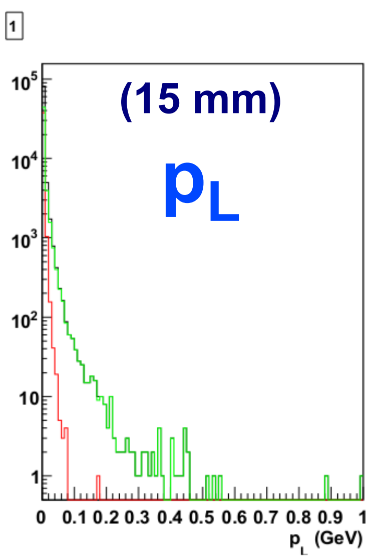
Thank you for your attention !

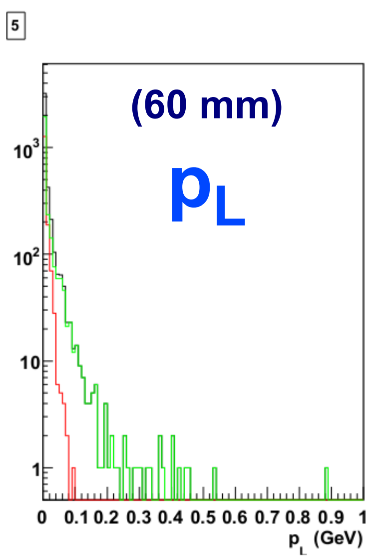
Thank you !

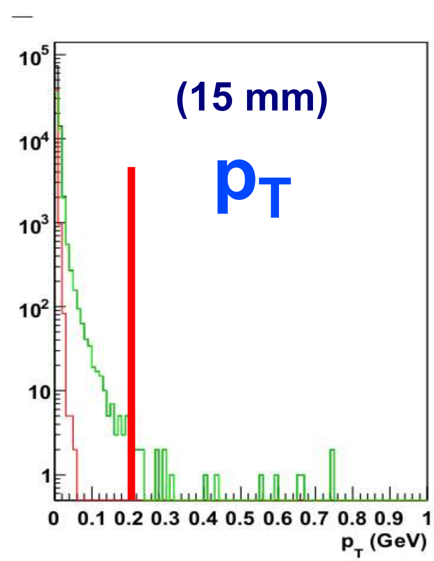
- Momentum distributions
  - From ILC note 2008 (Rita De Masi, PICSEL Group)
- Electrons/Positrons **p_T > 200 MeV**
  - 15 mm : order of magnitude 1/10000
  - 60 mm : order of magnitude 1/500
- Electrons/Positrons **p_T > 100 MeV**
  - 15 mm : order of magnitude : 1/4000
  - 60 mm : order of magnitude : 1/200

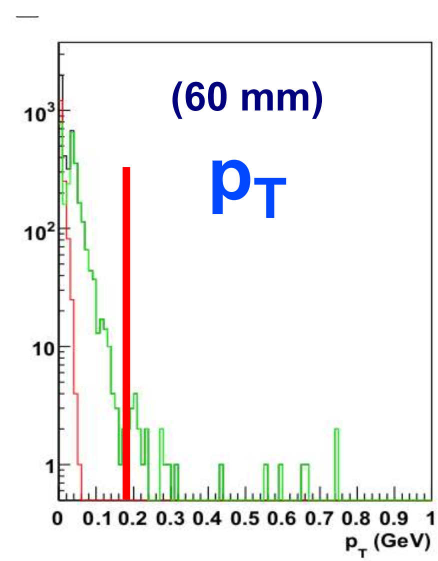












Statistic Estimation : High Momentum Beamstrahlung

DL	Hits/Readout/OR PT > 100 MeV	Readout / Seconde	Mvs/Seconde	Mvs/Minute	Mvs/Hour
1	0,05	97	5,30	318,27	**19096,19**
3	0,11	48	5,45	326,83	**19609,56**
DL	**Hits/Readout/OR PT > 200 MeV**	**Readout/ Seconde**	**Mvs/seconde**	**Mvs/Minute**	**Mvs/Hour**
1	0,02	97	2,12	127,31	**7638,48**
3	0,05	48	2,18	130,73	**7843,82**

- High statistic in small amout of time
  - P_T>100 MeV : Around 20000 MVs pairs in 1 hour !
  - P_T>200 MeV : Around 20000 MVs pairs in 3 hours !
- **BUT**
  - Can we select these high Pt tracks with mini-vectors ?
  - Can we reconstruct these helices/momentum ?
- Alignment resolution ?
- Next step : answer these questions.

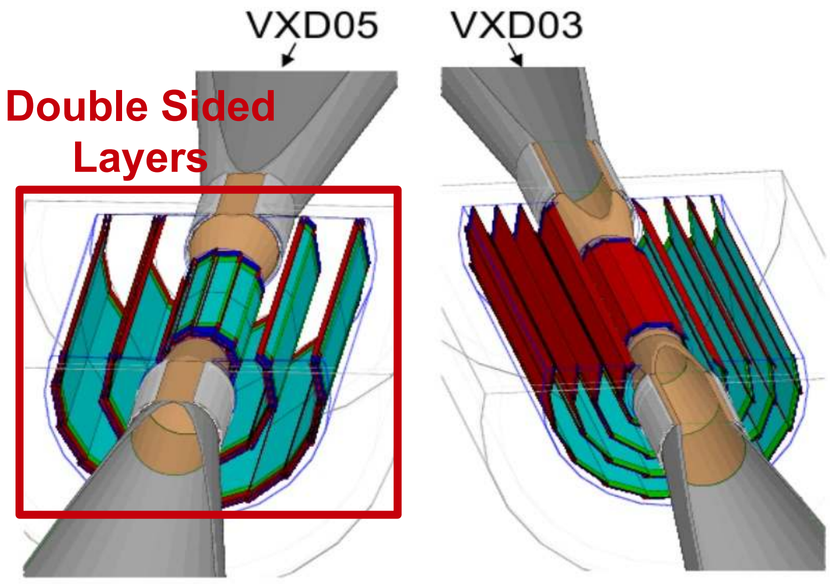
Motivations for double sided setup

- Context : ILC Vertex detector
- Requirement on the impact parameter :

$$\sigma_{ip} \leq 5 \oplus \frac{10}{p\beta \sin^{3/2}(\theta)} \mu m$$

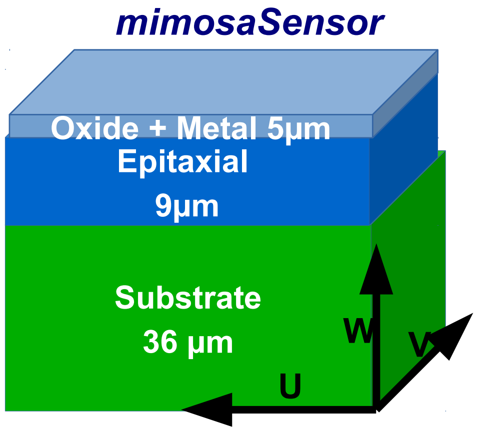
  - First layer resolution around 3 µm
  - Material budget :
    - 0.15 % X0 per layer.
    - 0.30 % X0 per double sided layer
- First layer occupation dominated by Beamstrahlung.
  - Low momentum particles
- Geometry of the vertex detector :
  - 5 single layers OR 3 double sided layers.
- Focus on 3 ***double sided layers***

- ***3 double sided layers***
  - ***Material budget reduction.***
    - 1 support for 2 layers.
  - 1 track → 2 hits → 1 mini-vector
  - ***Mini-vectors***
    - ***Potential improvment on tracking and alignment.***
- Goal : Studies of **alignment** with ***double sided ladders*** and ***mini-vectors***
- **With simulation tools**



Simulation : GEANT4

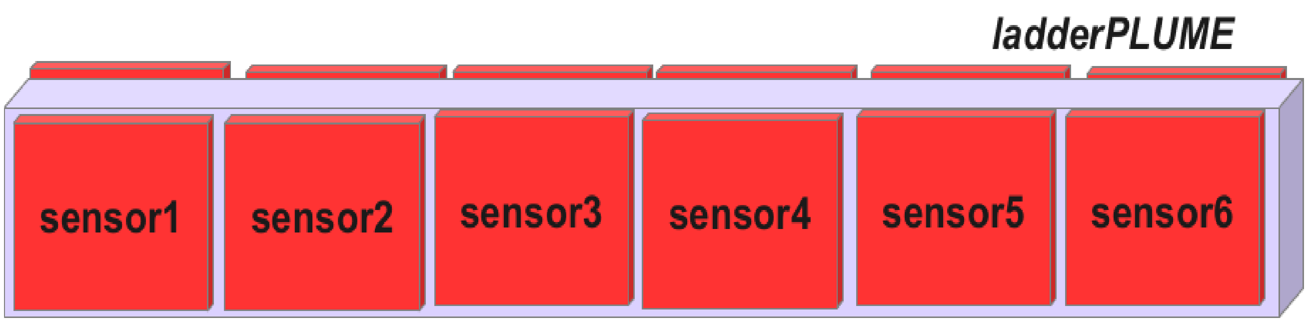
- ***CMOS sensors with GEANT4 :***
  - MIMOSA sensors : 3 layers design
    - **Substrate layer** (silicon) + **Epitaxial layer** (silicon) + **Oxide+Metal layer**
    - **Total thickness = 50 µm**
  - ***Energy deposition { Landau (MPV =80e⁻/µm) }***
  - Geometry modules :
    - ***Single sensor*** (MIMOSA-28 like)
    - ***Single and double sided ladders* (PLUME)**
    - ***Modular tool : New modules for a new geometries.***



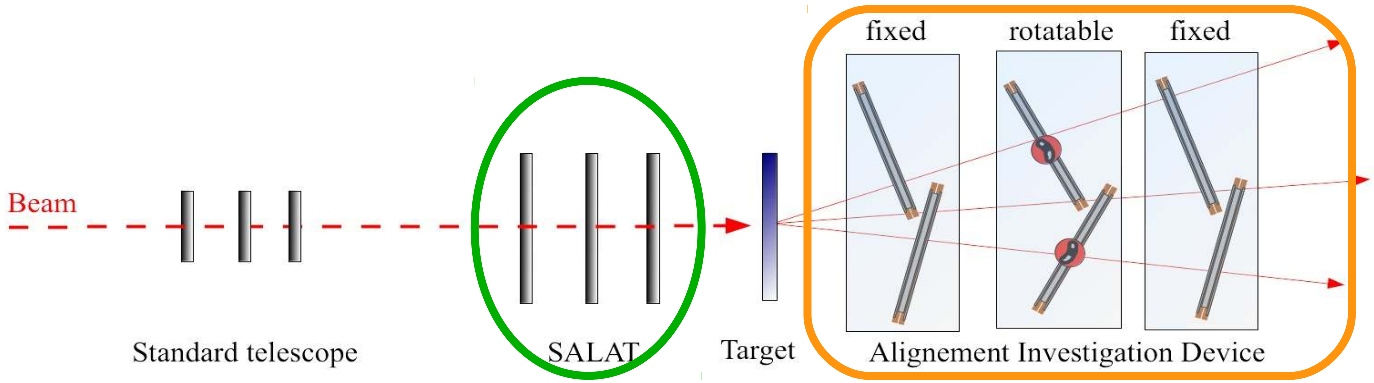
CMOS sensor simulated geometry

- Double sided ladder simulation : PLUME ladder (Pixel Ladders with Ultra-low Material Embedding)

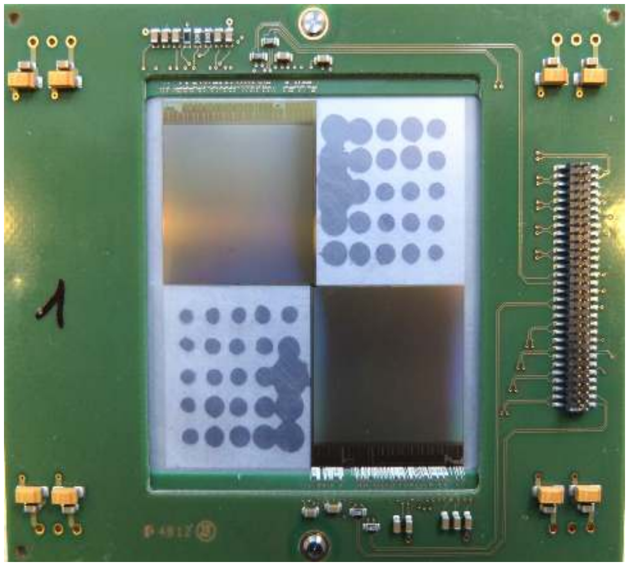
- Built by **12 sensors** MIMOSA-28 like
- 6 sensors per side
- Gap between two sensors = 420 µm
- *Support = **2 mm** SiC (Density 8 %)*



Thesis context : AIDA beam telescope

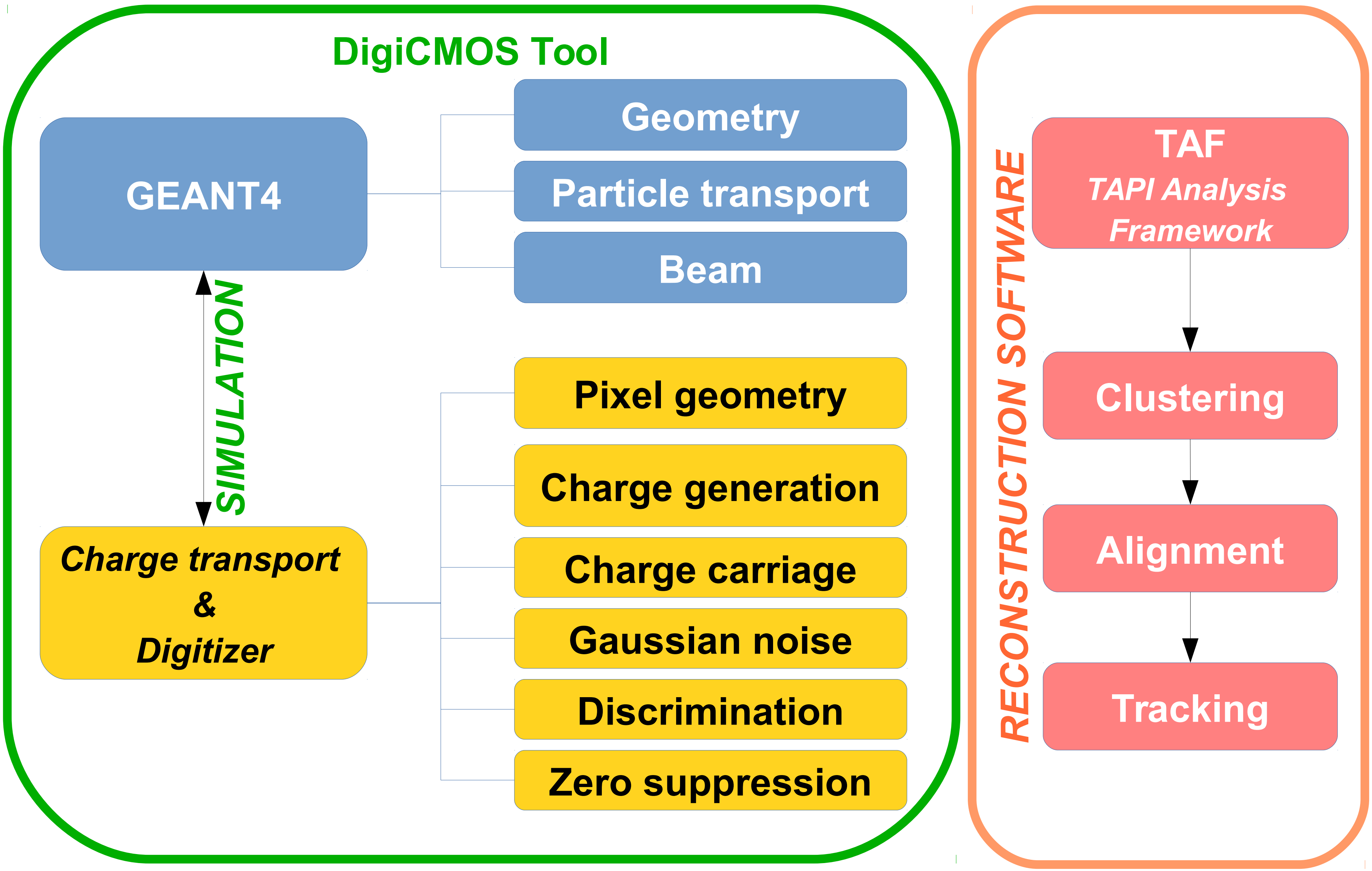


- AIDA : R&D futur detectors
- Vertex detector context → New beam telescope
- **SALAT : Single Arm Large Area beam Telescope**
- **AID box : Alignment Investigation Device**
  - Goal : ***Study of a vertex detector sector.***
  - Double sided ladders (PLUME, see latter)
- **Need a Monte Carlo simulation of these objects**
- **Studies on alignment**
  - Alignment of the whole ladder.
  - On the same layer, on the ***overlapping region*** between two consecutive ladders → ***With mini-vectors.***



A SALAT super-plane

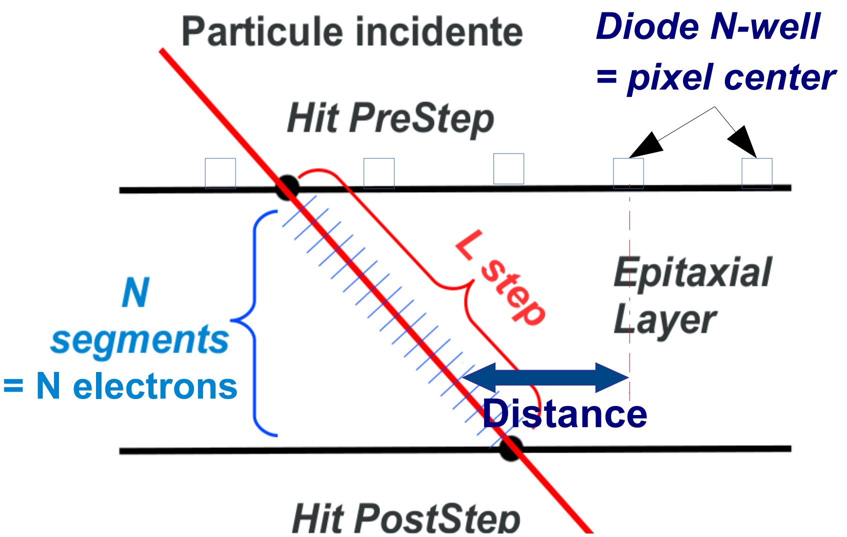
DigiCMOS tool (GEANT4) + TAF (Reconstruction)

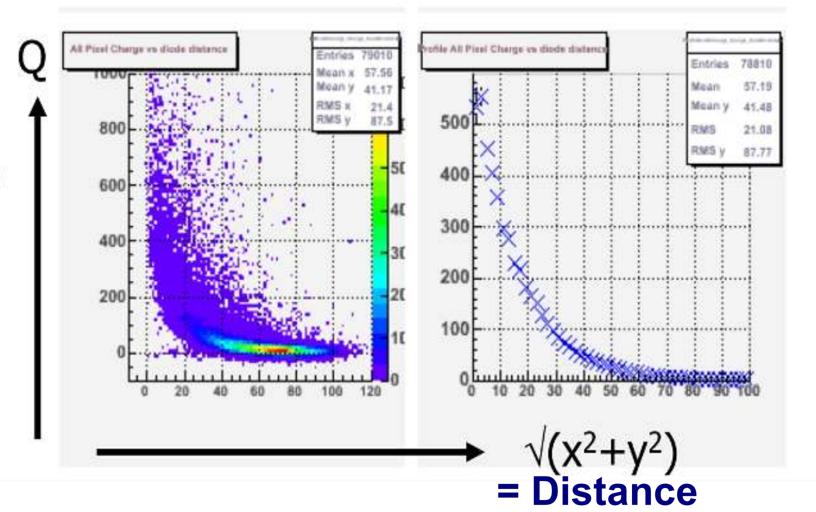


Charge transport simulation

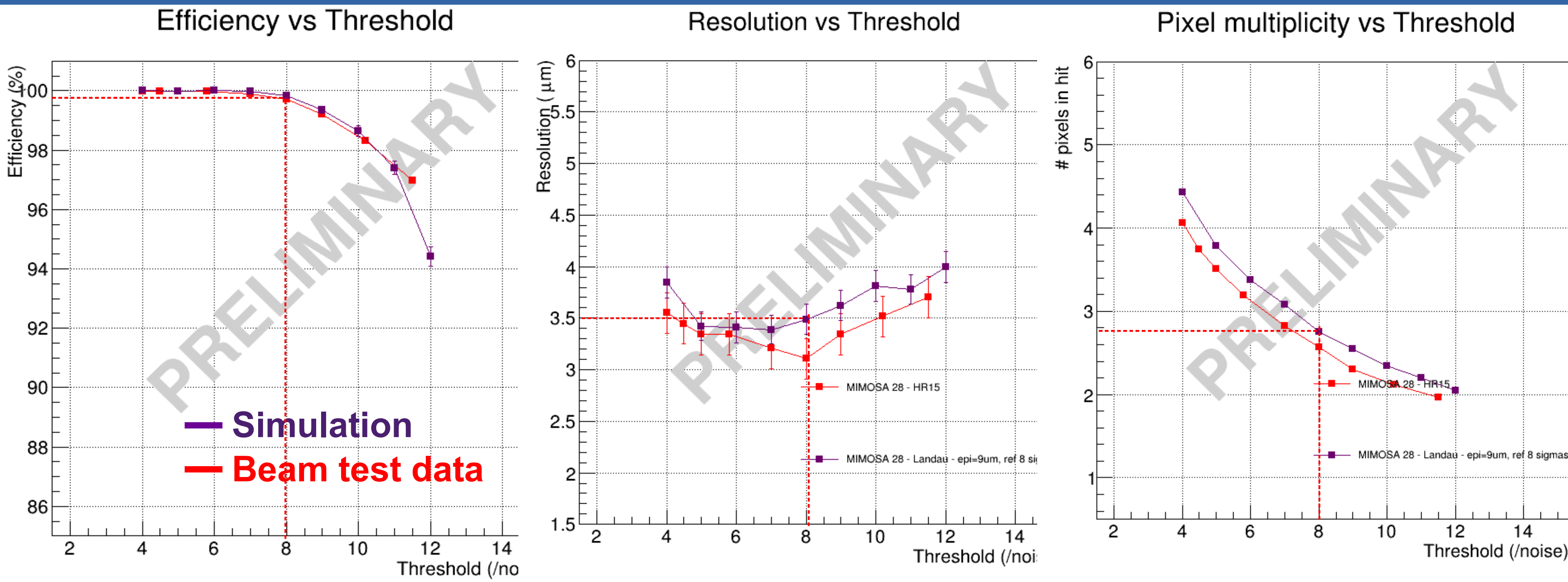
CMOS sensor response from energy deposition to digitization

- **Charge transport and digitizer**
  - **Pixels geometry** description
    - ***MIMOSA-28 : 20.7 x 20.7 µm²***
  - Very small depleted region → **thermal diffusion** of the charge carriers.
  - **Charge carriage simulation not possible** due to too many unknowns (doping profil, thicknees epi layer, etc ...)
  - **Data based charge transport model :**
    - from previous beam tests
    - Analog and digital output sensors
  - **Noise = *Gaussian noise*** (Mean = 13.7 e⁻)
  - ***Discriminator + Zero-suppresion***
    - pixel charge comparison with a threshold
    - Zero suppression
    - **Binary Output**





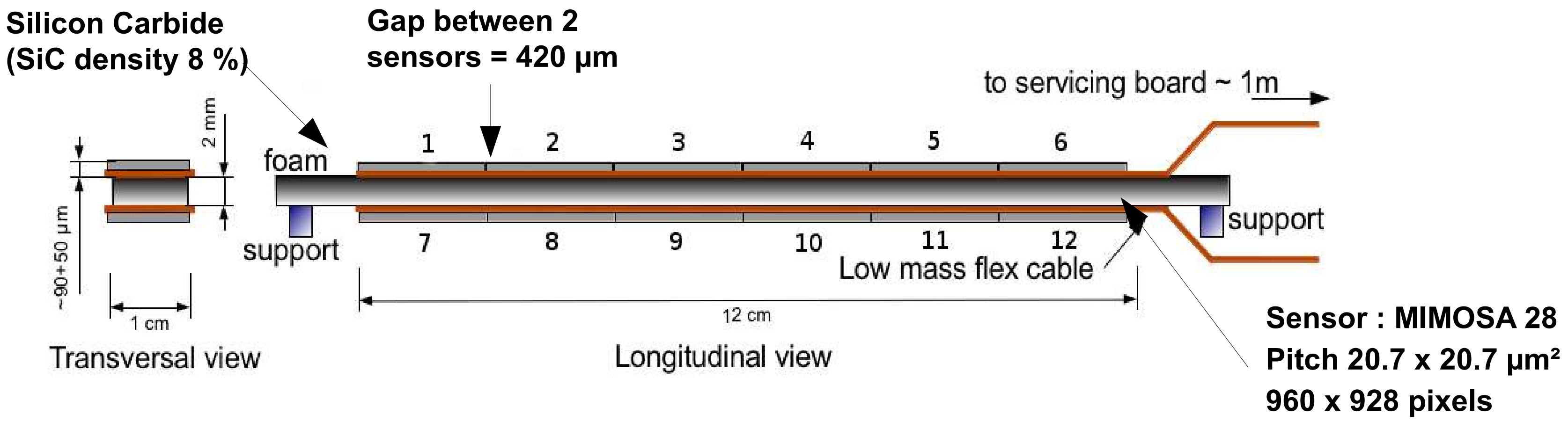
Simulation tool performances



- **Data based charge carriage** (Due to unknown on epi thickness, dopage profil, etc...)
- **Fine tuning of simulation parameters** (Energy distribution, epitaxial layer, charge transport, etc...)
- **Binary output (comparison with a threshold) + Zero suppresion**
- **Results :**
  - Comparison between simulation and test beam data of MIMOSA 28 HR15.
  - **Data and simulation agreement *better than 10 % (10 % for multiplicity)***.
  - ***Single sensor model response validated.***
  - Spatial resolution = **3.5 µm** (Normale incidence) | Efficiency > 99.5 %
  - Mean Cluster Mult.= 2.8 px (Normale incidence)

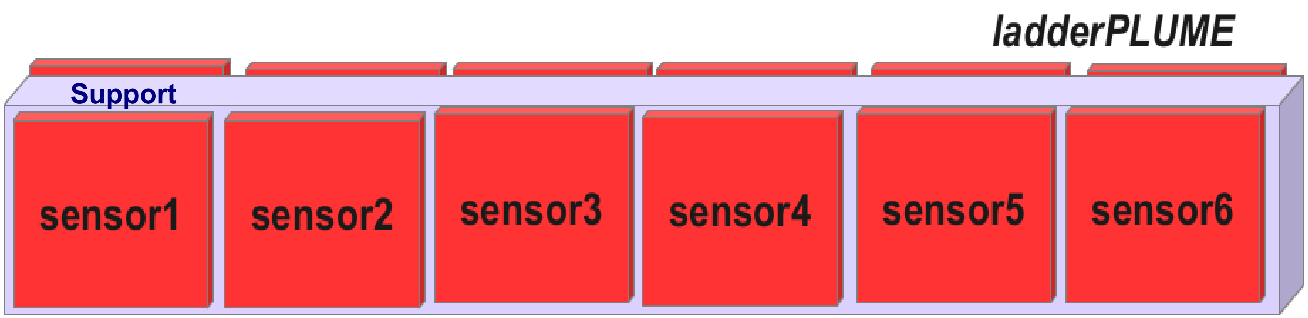
Simulations of double sided ladders

- Simulation of PLUME ladder (Pixel Ladders with Ultra-low Material Embedding)

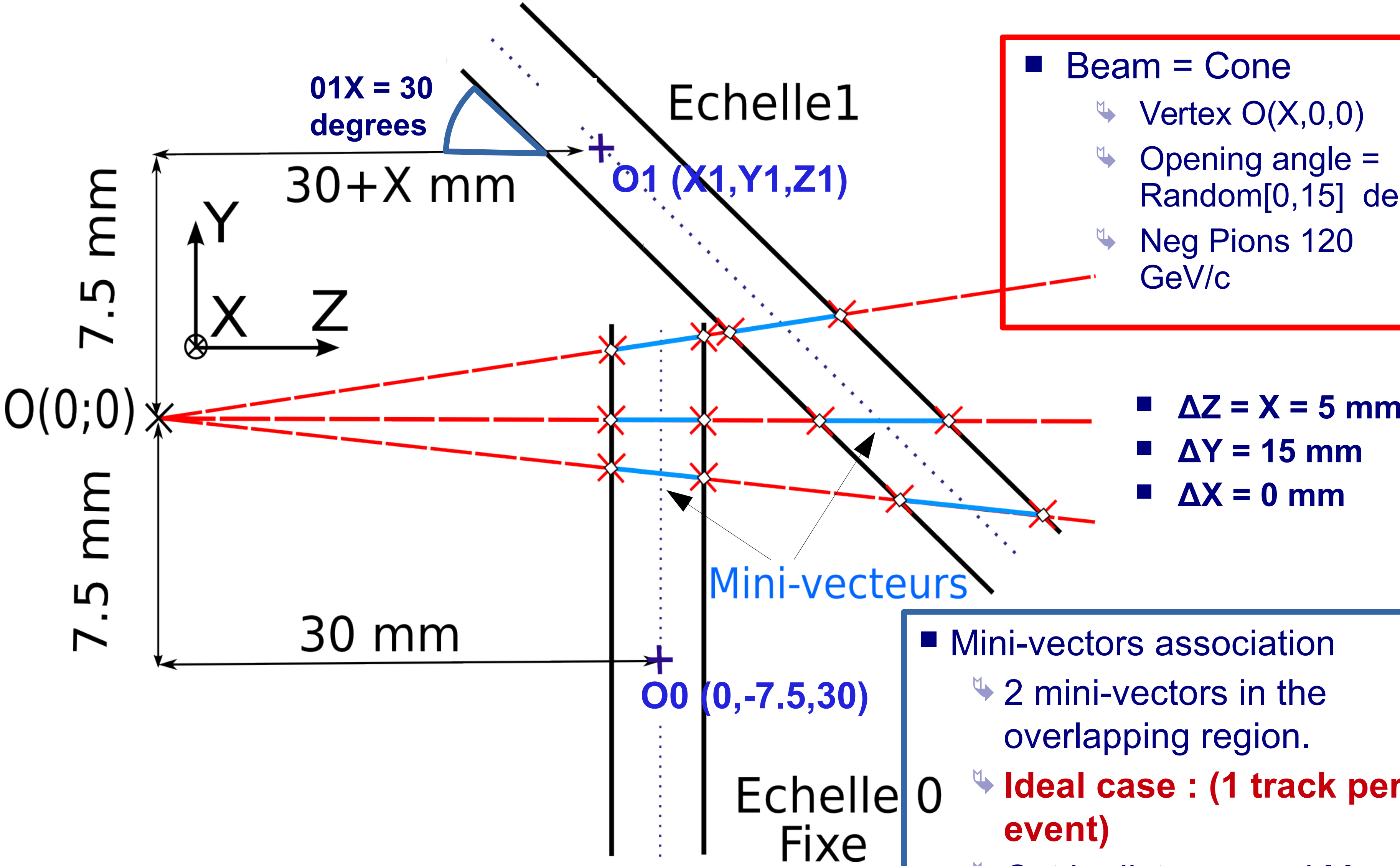


- 12 sensors MIMOSA-28 like simulated
- 6 sensor per side
- Gap between two sensors = 420 µm
- *Support = 2 mm SiC (Density 8 %)*

- *Resolution = 3.5 µm (Normal incidence)*
- *Efficiency > 99.5 %*
- *Mean Multiplicity = 2.8 px (Normal incidence)*



Configuration : Pions High Momentum (120 GeV/c)



- Beam = Cone
  - Vertex O(X,0,0)
  - Opening angle = Random[0,15] deg
  - Neg Pions 120 GeV/c

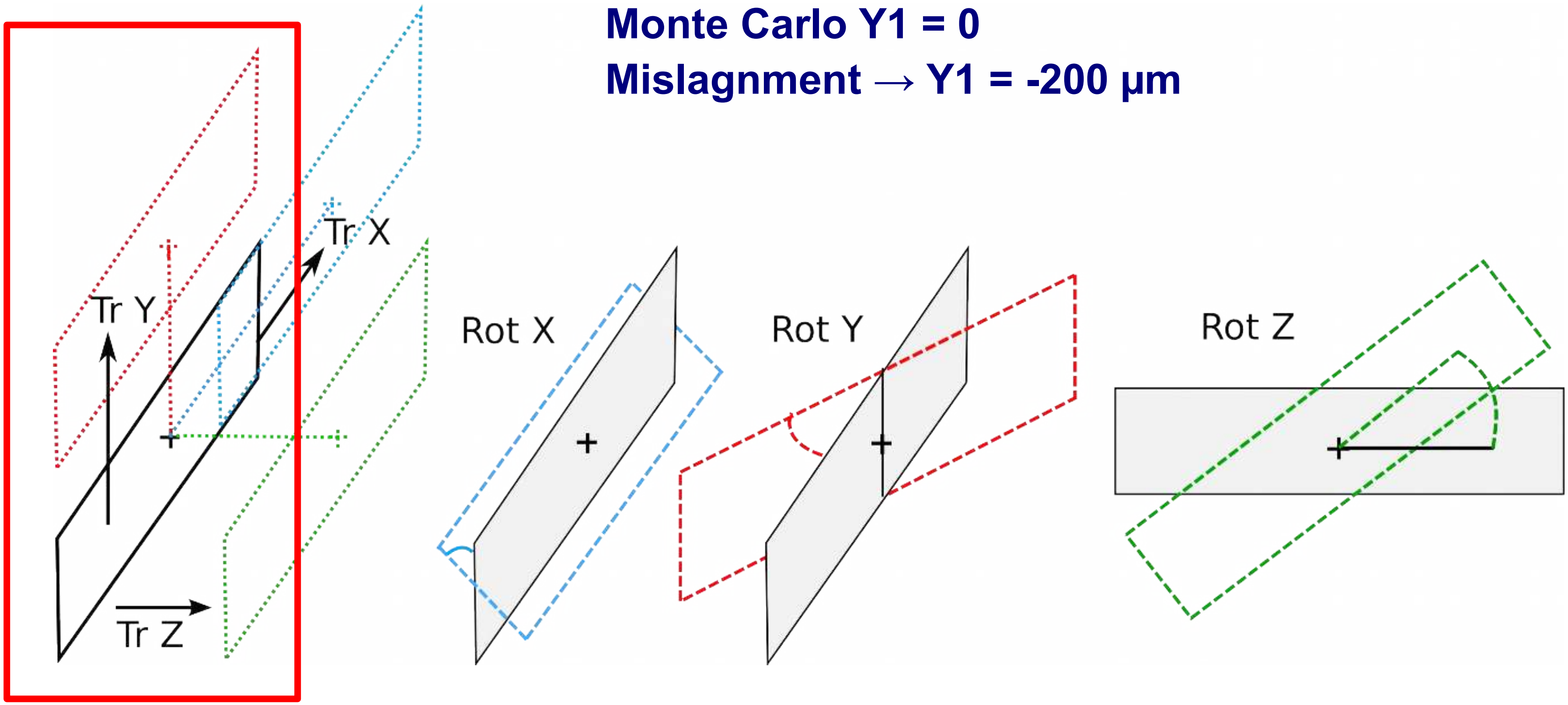
- Mini-vectors association
  - 2 mini-vectors in the overlapping region.
  - **Ideal case : (1 track per event)**
  - Cut in distance and Mvs tilts.

Parameter Y1

Translation Center C1 : Coordinate Y1

Monte Carlo Y1 = 0

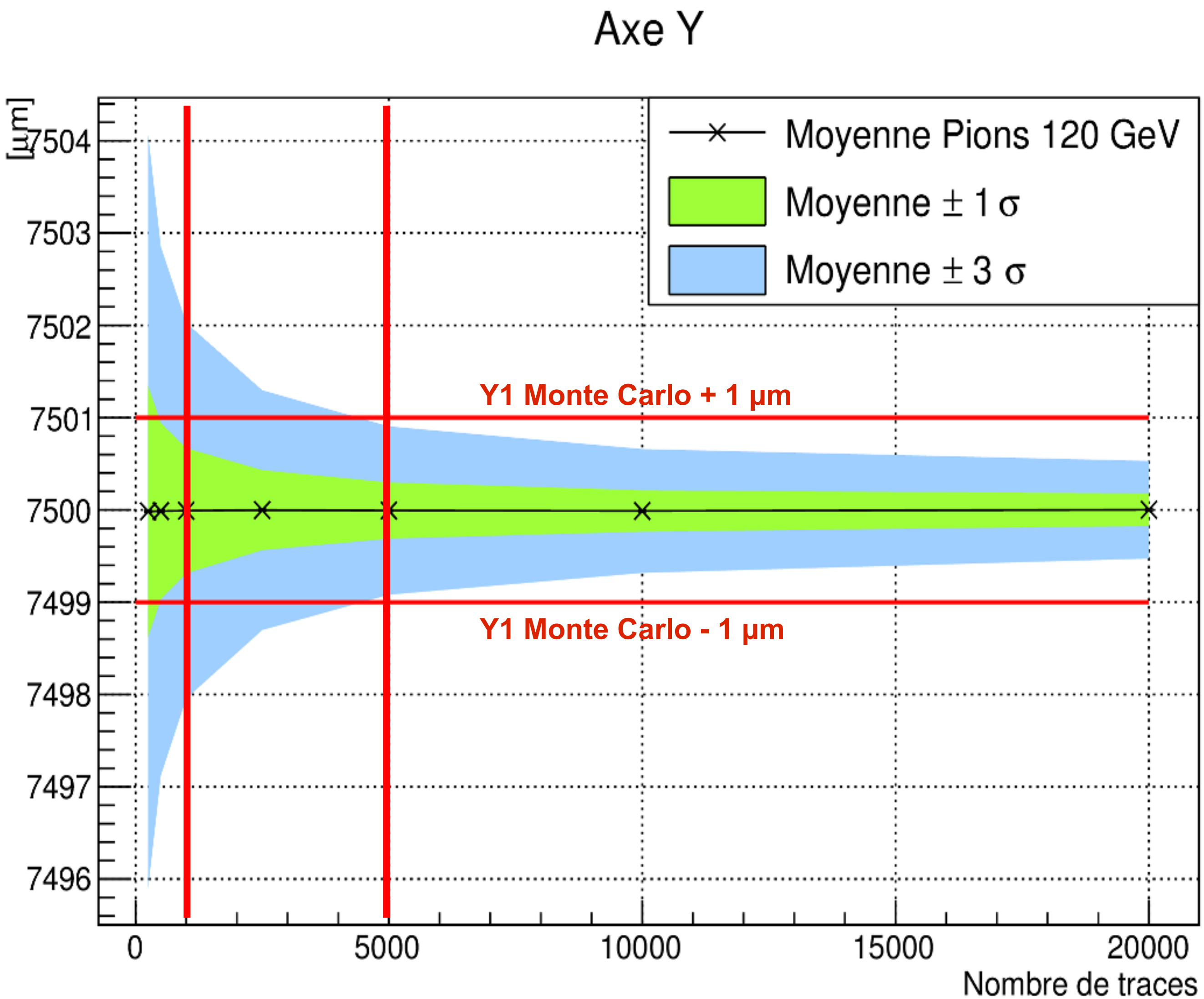
Mislagnment → Y1 = -200 µm



Alignment with mini-vectors : Results

- **Position Y1 :**
  - Monte Carlo Y1 = 0
  - Mean vs statistic (deviation from MC values)
  - Width vs statistic (method precision : ***± 1 σ***, ***± 3 σ .***)
- **1000** good couples of mini-vectors
  - ***precision (1 σ) better than 1 µm***
- **5000** good couples of mini-vectors
  - ***Precision (3 σ) better than 1 µm***

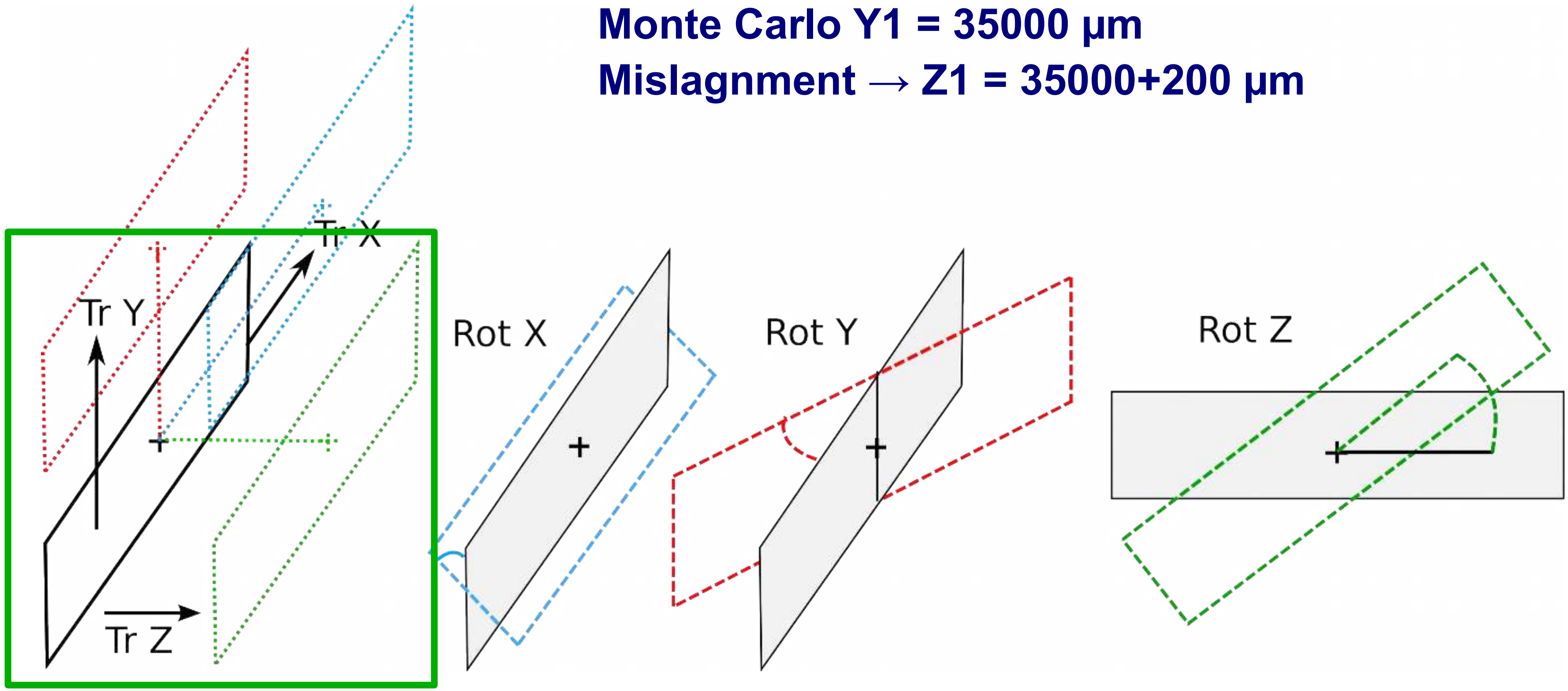
Position after minimisation in function of statistics



Good tracks = Good couples of mini-vectors

Parameter Z1

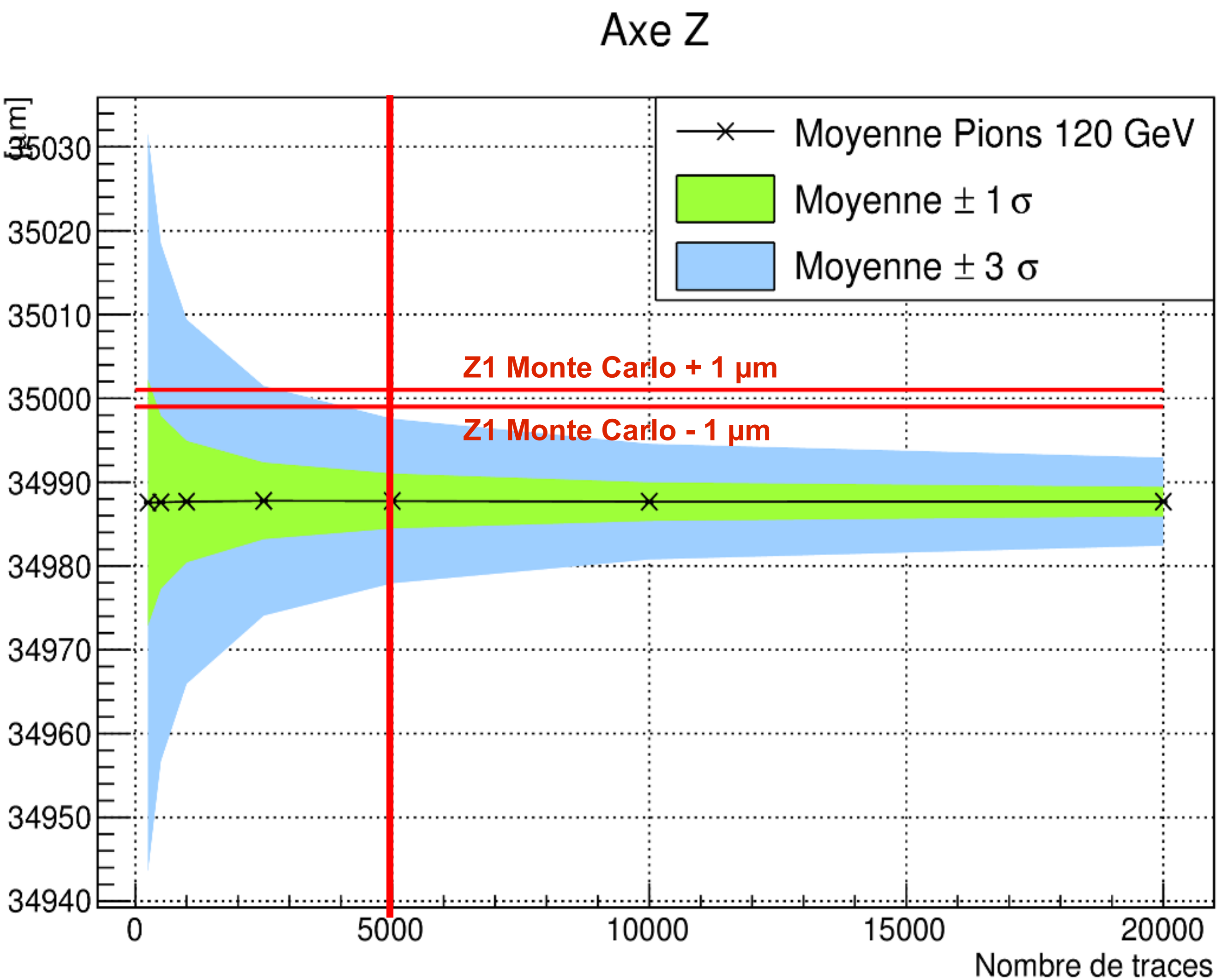
Translation Center O1 : Coordinate Z1
Monte Carlo Y1 = 35000 µm
Mislagnment → Z1 = 35000+200 µm



Alignment with mini-vectors : Results

- **Position Z1 :**
  - Monte Carlo Z1 = 0
  - Mean vs statistic
  - Width vs statistic (*± 1 σ*, *± 3 σ* .)
- Mean = ***Bias*** around ***-10 µm.***
  - Result of a ***weak mode***
  - Constant bias → can be sustracted
- ≥ 5000 couples of MVs
  - ***Width (3 σ) = ± 10 µm***
- Bias reduction :
  - More tilt in Y direction for Mini-vectors
  - Bias suppresion
  - Precision *(1 σ)* < 2µm with 1000 couples

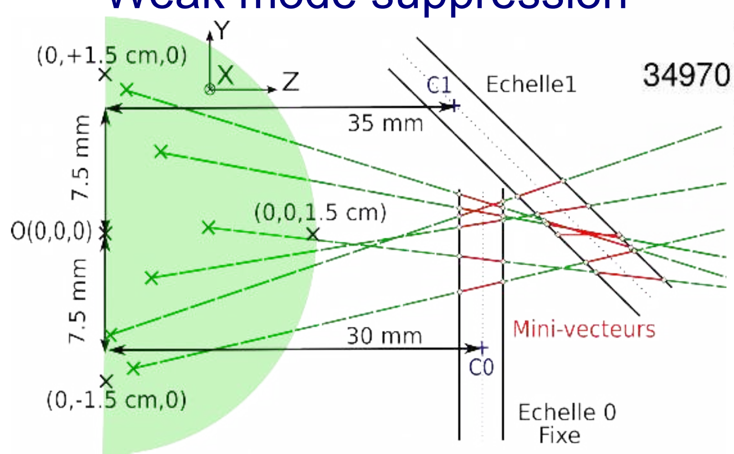
Position after minimisation in function of statistics

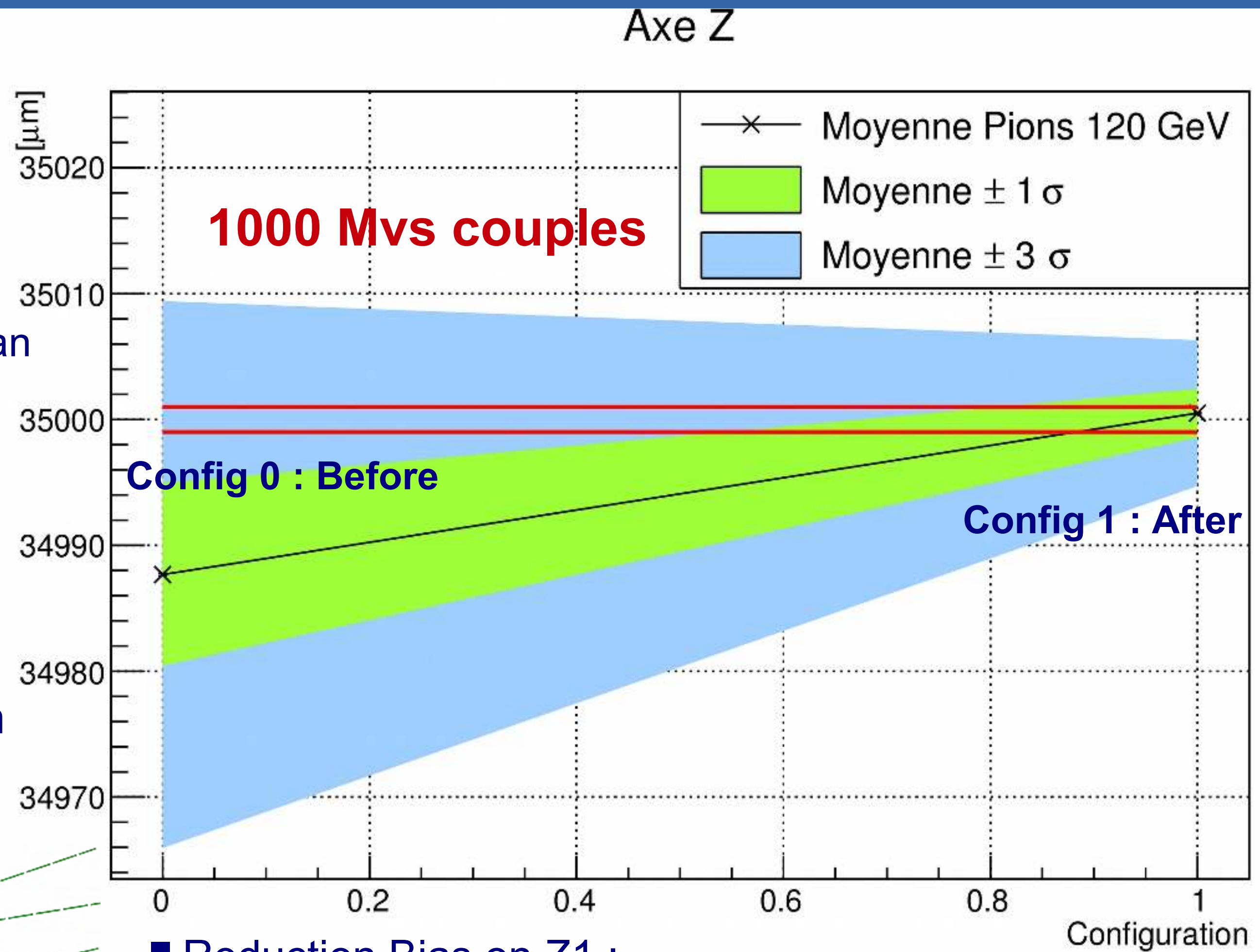


Good tracks = Good couples of mini-vectors

Bias reduction : Z axis

- **Bias on Z1**
- **Configuration 0**
  - As before (1000 Mvs couples)
- **Configuration 1**
  - Cone Vertex : start in an half cylinder of radius 15 mm.
  - MVs TiltY more important
  - 1000 Mvs couples
- **Bias reduction**
- Weak mode suppression

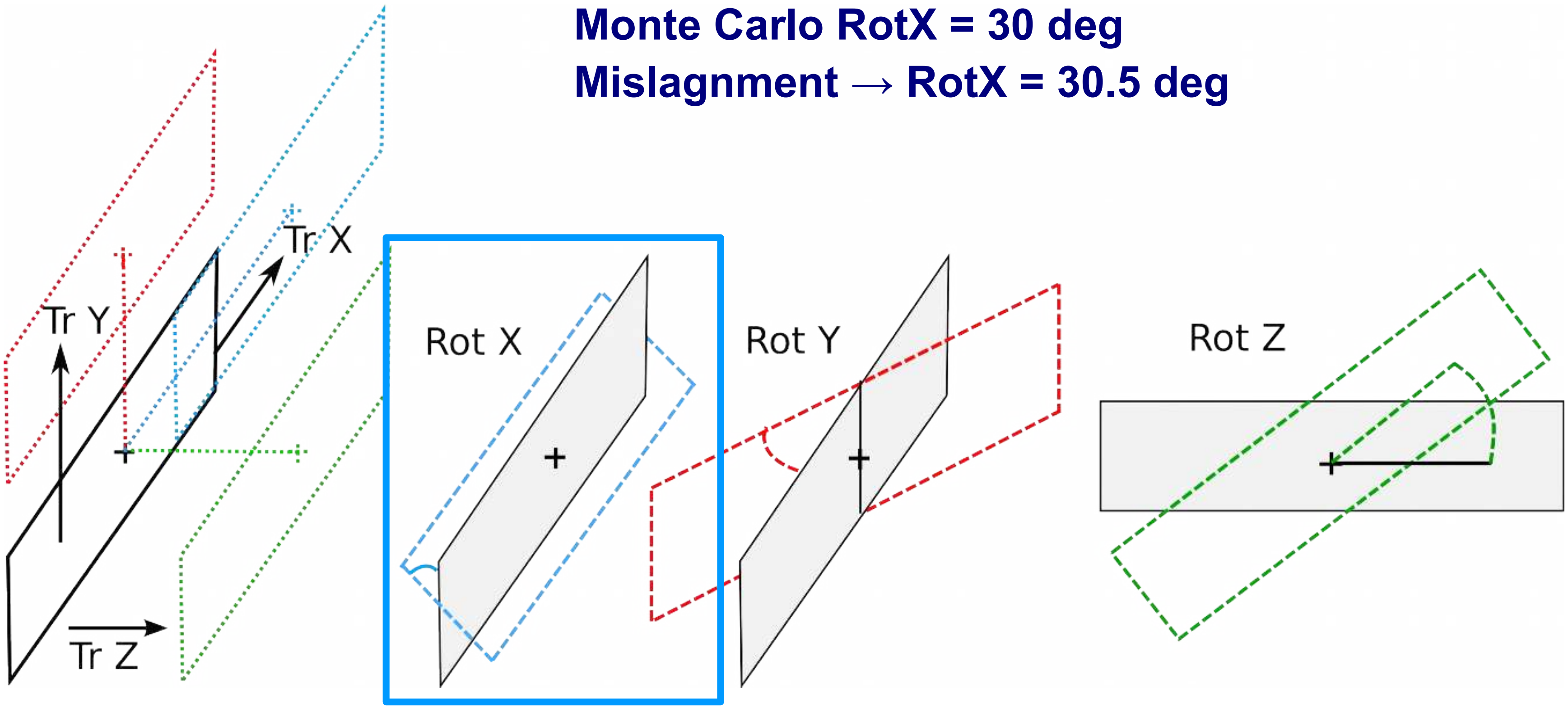




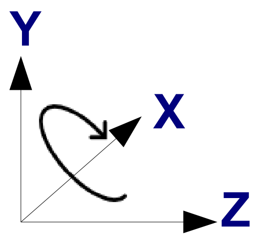
- Reduction Bias on Z1 :
  - With 1000 MVs couples → precision 1.5 µm
- And : Best precision in rotation O1Y
  - With 1000 MVs couples : precision (3 σ) : 3.5 mrad → 1.2 mrad

Parameter RotX

Rotation Center C1 : Rotation C1X
Monte Carlo RotX = 30 deg
Mislagnment → RotX = 30.5 deg

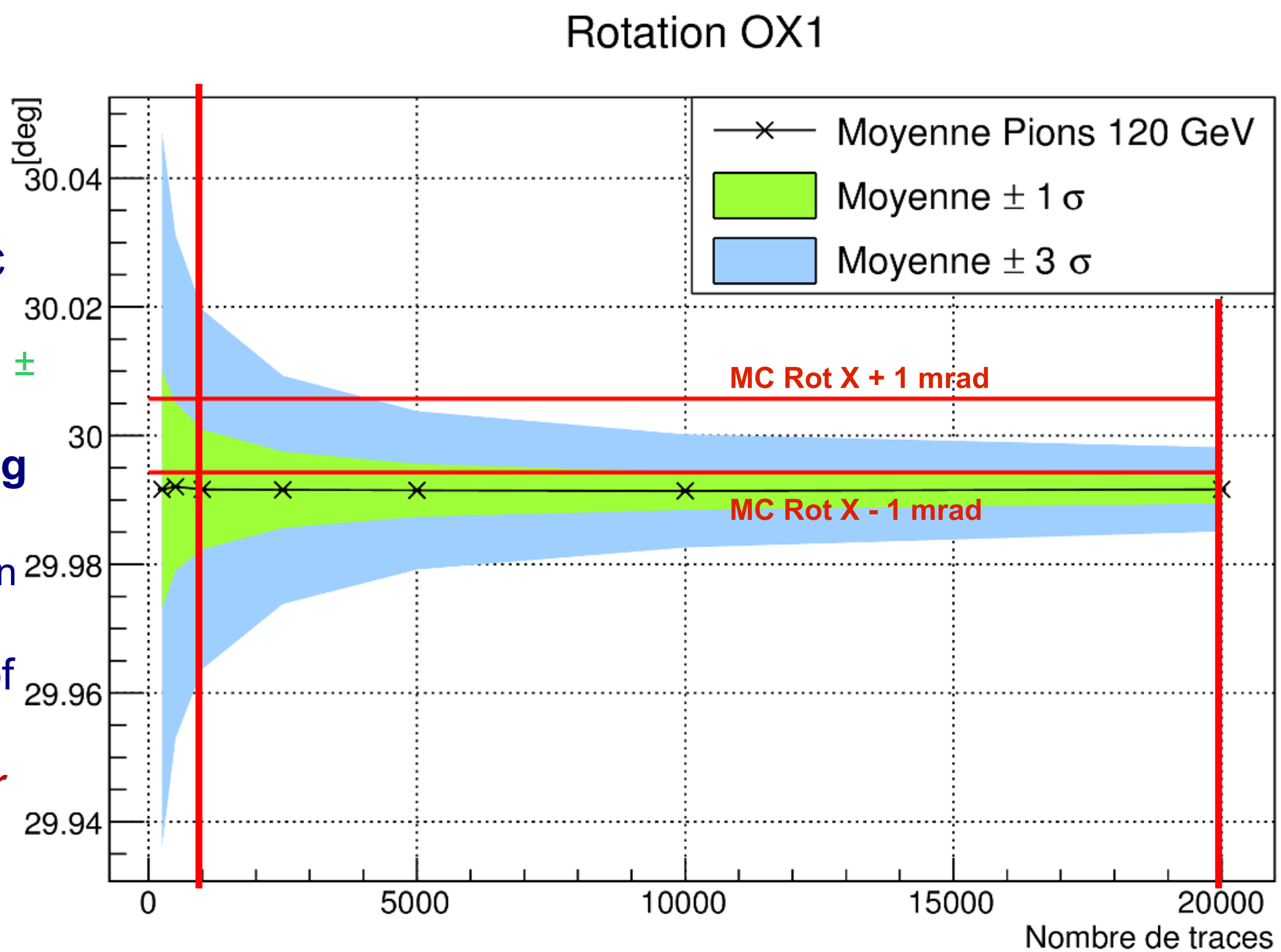


Alignment with mini-vectors : Results



- **Rotation 01X** :
  - Deviation from MC values vs stat
  - method precision : ± *1 σ*, ± *3 σ*.
- **Small bias : 0.01 deg**
  - Small weak mode.
  - Constant bias : can be substracted
- **1000** good couples of mini-vectors
  - ***Width (1 σ) better than 1 mrad***
- **20 000** good couples of mini-vectors
  - ***Width (3 σ) better than 1 mrad***

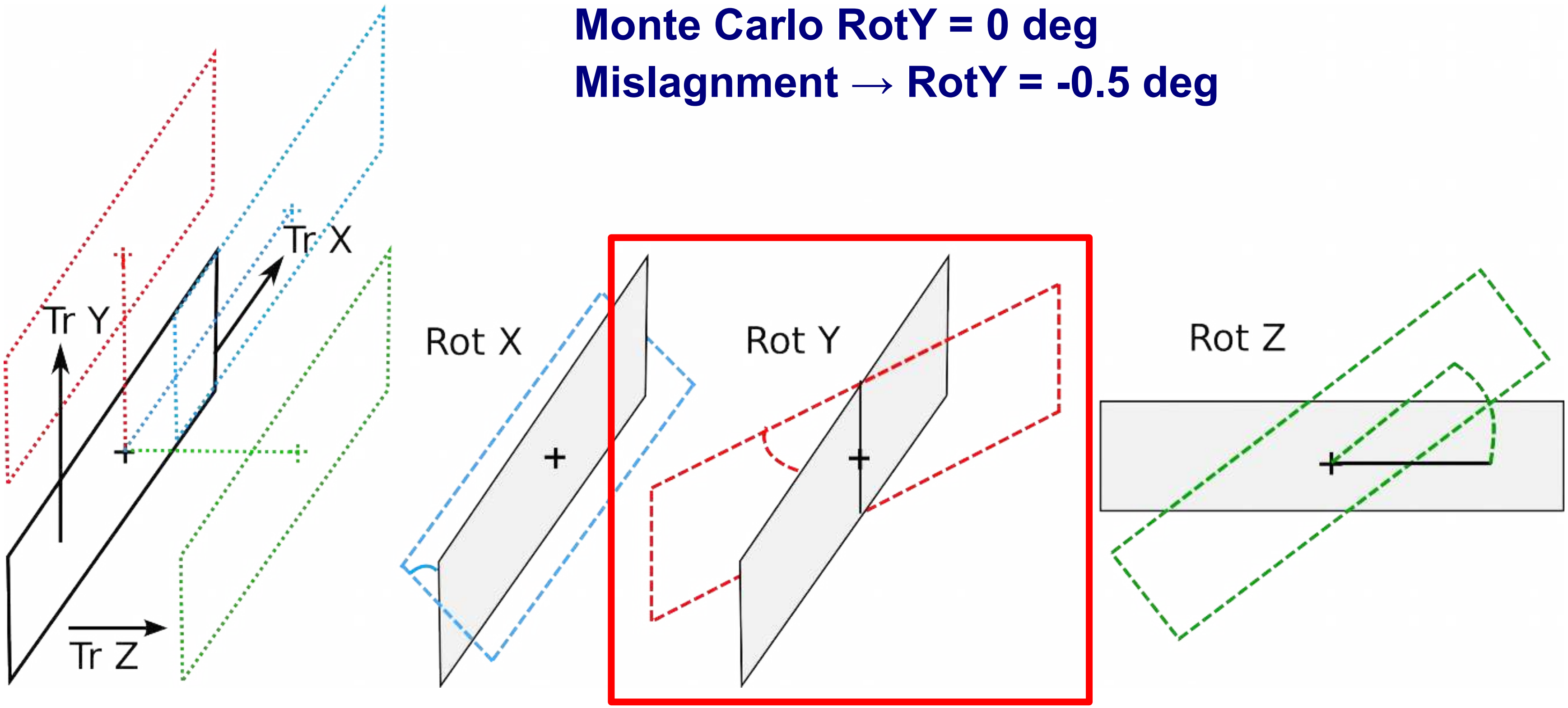
Position after minimisation in function of statistics



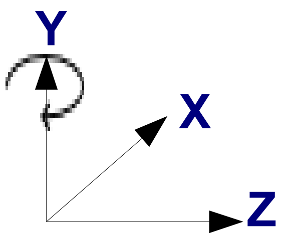
Good tracks = Good couples of mini-vectors

Parameter RotY

Rotation Center C1 : Rotation C1Y
Monte Carlo RotY = 0 deg
Mislagnment → RotY = -0.5 deg

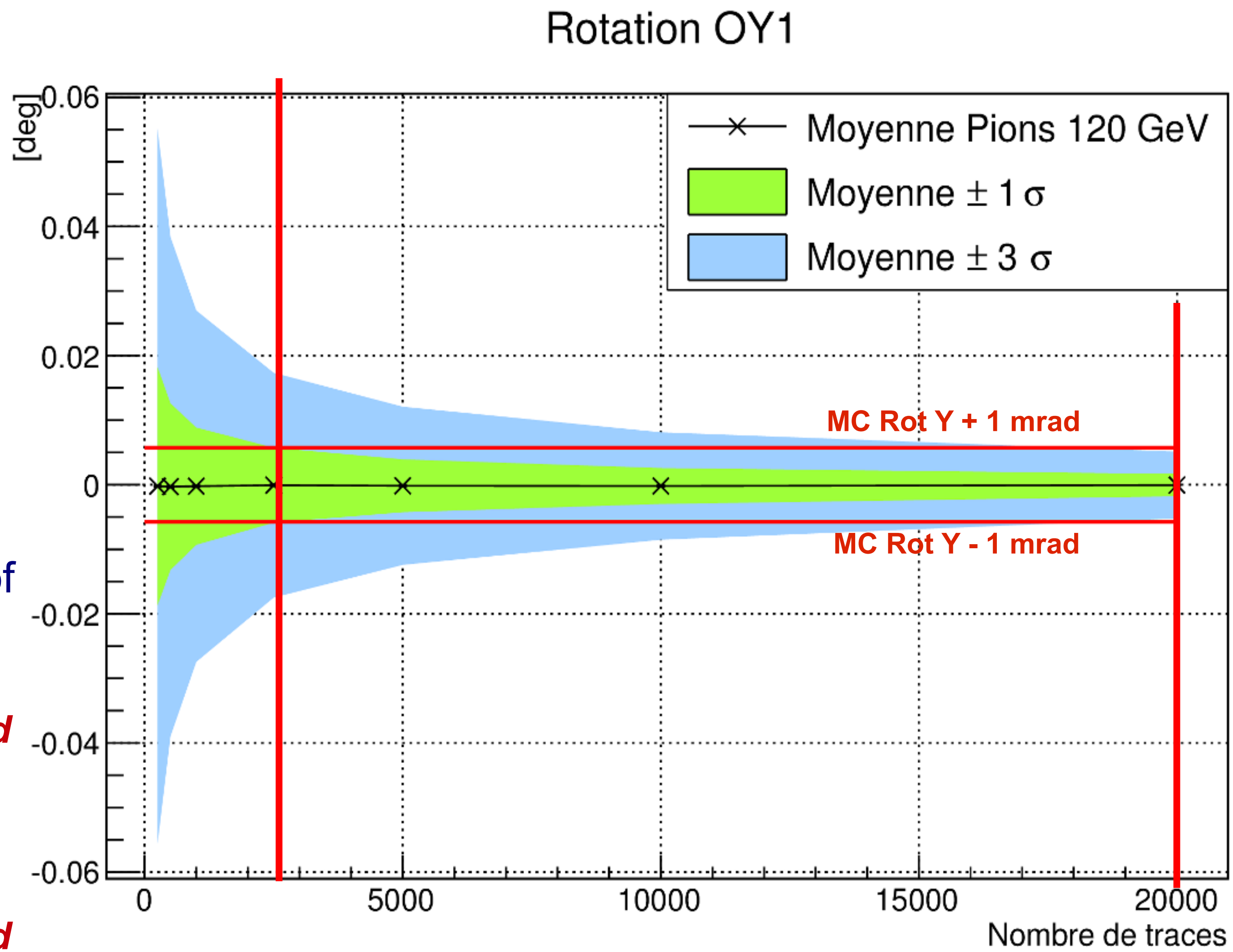


Alignment with mini-vectors : Results



- **Rotation 01Y :**
  - Mean vs statistic (deviation from MC values)
  - Width vs statistic (method precision : ± *1 σ*, ± *3 σ* .)
- **2 500** good couples of mini-vectors
  - ***precision (1 σ) better than 1 mrad***
- **20 000** good couples of mini-vectors
  - ***Precision (3 σ) better than 1 mrad***

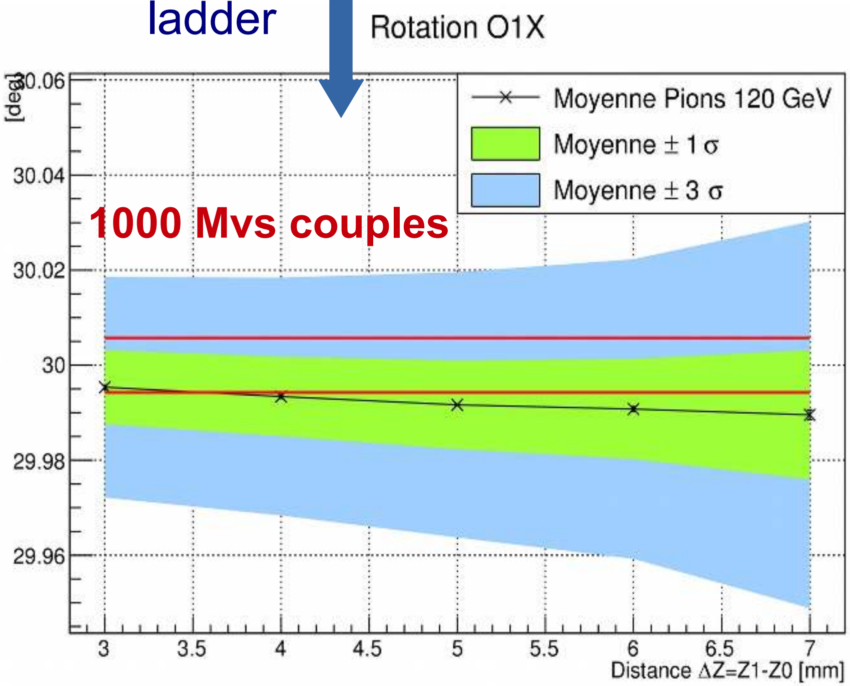
Position after minimisation in function of statistics

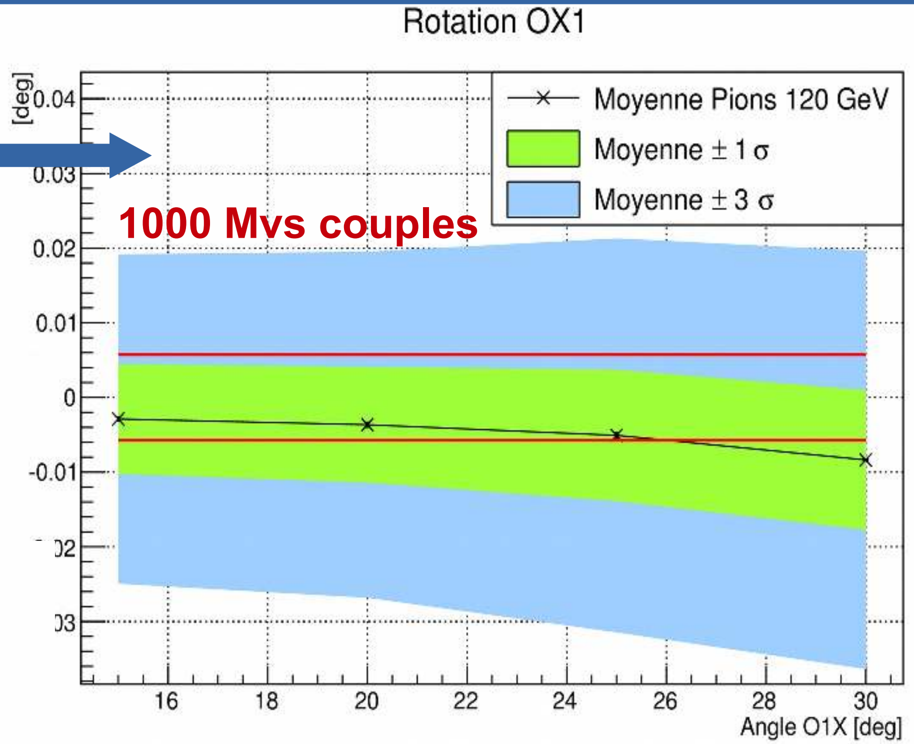


Good tracks = Good couples of mini-vectors

Bias reduction : Rotation O1X

- Bias on rotation O1X
- Reduction of the ladder1 tilt on O1X
  - Smaller distance between the two ladder
- Reduction of the distance between the 2 centers
  - Smaller distance between the two ladder



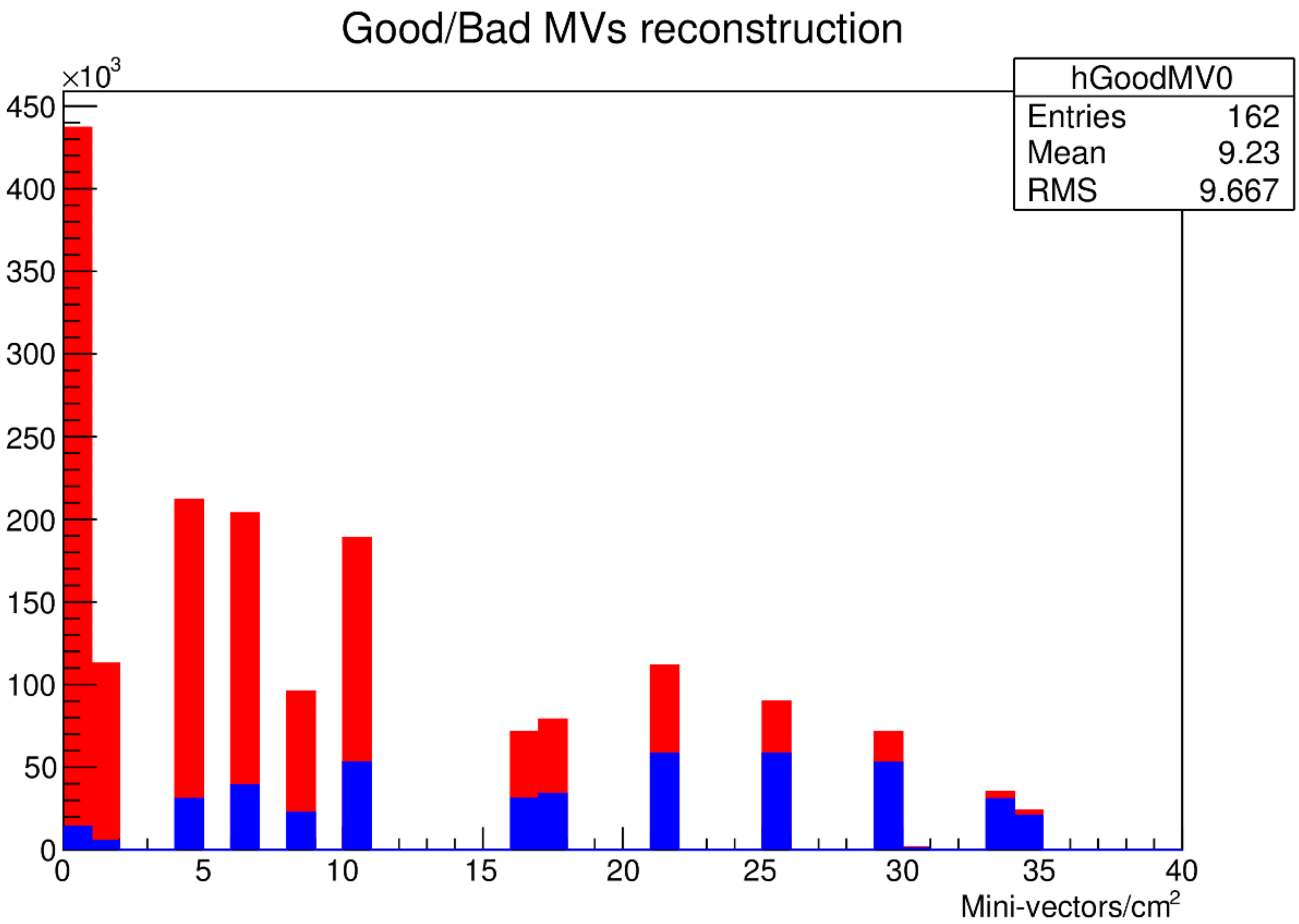


- Small bias reduction
  - Always a small weak mode
- Other solution :
  - Increase the overlapping region (In progress).
- Bias reduction strategy
  - Mixing these three solutions

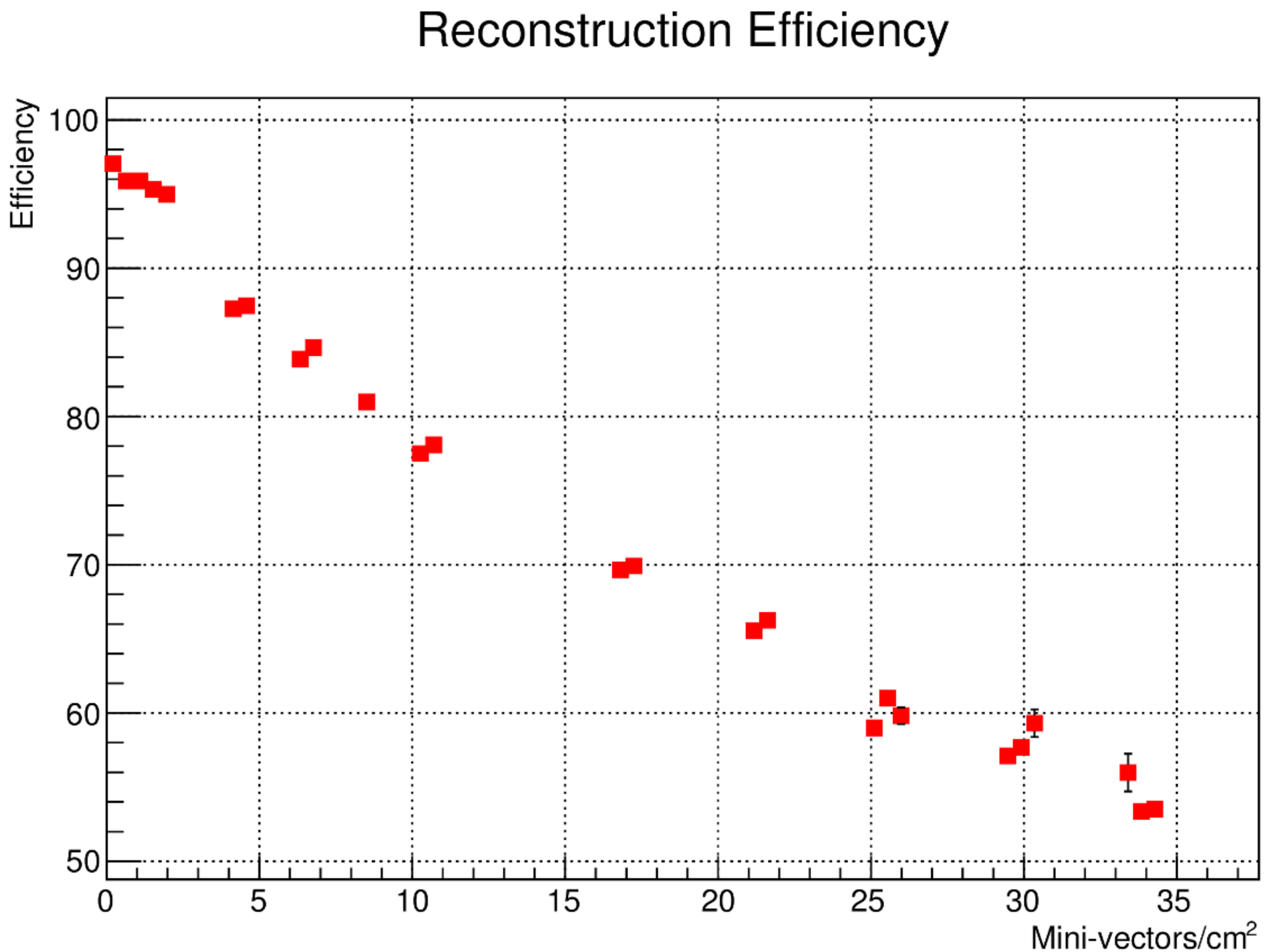
Alignment with mini-vector

- **Alignment** on the **overlapping region** with **high momentum particles** (Pions 120 GeV/c)
- Alignement precision
  - **Ladder center : precison < 1 µm** with 5000 Good couples of mini-vectors (X1, Y1)
  - **Ladder tilts : precision < 1 mrad** with 20000 couples of mini-vectors
  - Bias on Z1 = -10 µm.
- Bias reduction
  - **Z1 precision < 2 µm** with 20 000 good pairs of mini-vectors and optimized configuration
- **Low momentum particles (Electron 200 MeV) + B=0**
  - **Small impact of multiple scattering**
  - No bias or very small bias
  - Just a lower precision
- **Principle proof : *validated***
- **Step 2 : Standalone alignment with beamstrahlung (optimistic option)**
- Let's see the statistic ...

Mini-vectors reconstruction



Mini-vectors reconstruction



SIT

- 2 Double Layer
- Rin = 153 mm 2 double layers 7.0µm
- Rout = 300 mm Si-strip sensors ±7.0µm
- z = 644 mm
- Ptmin = 80.5 MeV
- Ptmax = 157.5 MeV

Statistic estimations : geometry

DBD/TDR values

Double Layer	Layer	Radius (mm)	|z| (mm)	|cos(θ)|	σ(μm)	Readout time (μs)
1	1	16	62,5	0,97	2,8	50
	2	18	62,5	0,96	6	10
2	3	37	125	0,96	4	100
	4	39	125	0,95	4	100
3	5	58	125	0,91	4	100
	6	60	125	0,9	4	100

Double Layer	Layer	Surface (cylinder) (cm²)	Circumference (mm)	Ladders per double sided layer	Ladder Height (mm)	Angle (degree)
1	1	62,83	100,53	10	10	36
	2	70,69	113,10	10	10	36
2	3	290,60	232,48	12	20	30
	4	306,31	245,04	12	20	30
3	5	455,53	364,42	18	20	20
	6	471,24	376,99	18	20	20

Statistic estimations : (Order of magnitude only)

Processus	Cross Section (fb)	Lumi $cm^{-2}.s^{-1}$	N.sigma
$e^+ e^- \rightarrow \mu^+ \mu^-$ (500 GeV)	500	1,8x1034	0,009
Δt Bunches (μs)	**Bunches per train**	**Trains per sec**	**Surface ZR (% Ladder)**
0,552	1312	5	10

Layer Number	Hits/BX	Hits/cm²/BX	BX/Readout	Hits/cm²/Readout	Hit/OR/Readout
1	1,37E-06	2,18E-08	90	1,97E-06	1,23E-06
2	1,37E-06	1,94E-08	18	3,49E-07	2,18E-07
3	1,37E-06	4,72E-09	181	8,55E-07	2,14E-06
4	1,37E-06	4,48E-09	181	8,11E-07	2,03E-06
5	1,37E-06	3,01E-09	181	5,45E-07	1,36E-06
6	1,37E-06	2,91E-09	181	5,27E-07	1,32E-06

Layer Number	Per Sec	Per Day	Per Week	Per Month	Per Year
1	8,84E-05	**7,64**	53,48	229,22	2781,18
OR = 10 % 2	7,95E-05	**6,87**	48,07	206,01	2499,63
Ladder 3	7,69E-05	**6,64**	46,51	199,34	2418,71
Surface 4	7,30E-05	**6,30**	44,13	189,12	2294,67
5	4,91E-05	**4,24**	29,67	127,17	1542,97
6	4,74E-05	**4,10**	28,68	122,93	1491,54

Statistic Estimations (Order of magnitude only)

Processus	Cross Section (fb)	Lumi $cm^{-2}.s^{-1}$	N.sigma
$e^+ e^- \rightarrow qq$ (500 GeV)	3000	$1,8x10^{34}$	0,054
Δt Bunches (μs)	**Bunches per train**	**Trains per Sec**	**Surface ZR (% Ladder)**
0,552	1312	5	10

Layer Number	Evts/BX	Hits/cm²/BX	BX/Readout	Evts/cm²/Readout	Evt/OR/Readout
1	8,23E-06	1,31E-07	90	1,18E-05	7,37E-06
2	8,23E-06	1,16E-07	18	2,10E-06	1,31E-06
3	8,23E-06	2,83E-08	181	5,13E-06	1,28E-05
4	8,23E-06	2,69E-08	181	4,86E-06	1,22E-05
5	8,23E-06	1,81E-08	181	3,27E-06	8,18E-06
6	8,23E-06	1,75E-08	181	3,16E-06	7,90E-06

Layer Number	Per Seconde	Per Day	Per Week	Per Month	Per Year
1	5,31E-04	**45,84**	**320,91**	1375,31	16687,07
2	4,77E-04	**41,20**	**288,42**	1236,08	14997,77
3	4,61E-04	**39,87**	**279,08**	1196,06	14512,24
4	4,38E-04	**37,82**	**264,77**	1134,73	13768,02
5	2,94E-04	**25,43**	**178,03**	763,01	9257,81
6	2,85E-04	**24,59**	**172,10**	737,57	8949,22

OR = 10 % Ladder Surface

Statistic Estimations (Order of magnitude only)

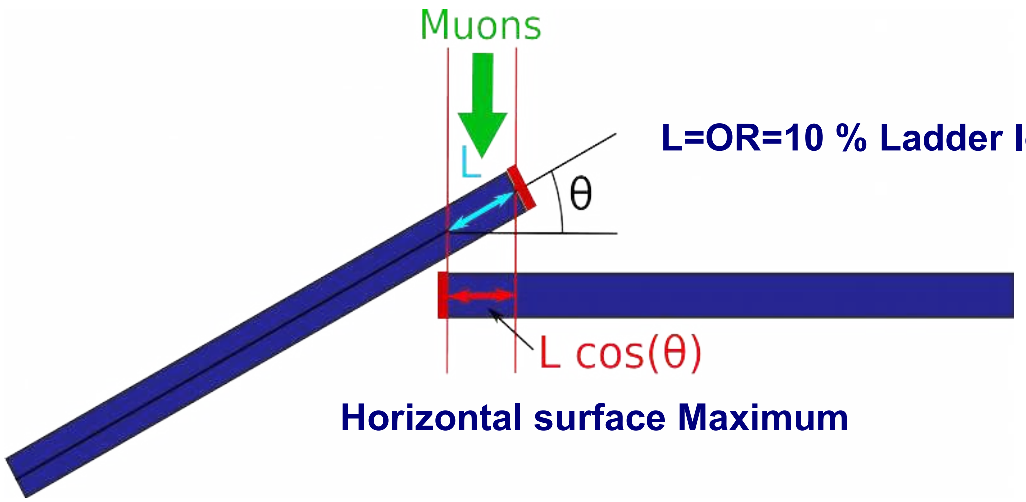
Processus	Cross Section (fb)	Lumi $cm^{-2}.s^{-1}$	N.sigma
$e^+ e^- \rightarrow \mu\mu$ (Z Pole)	1020000	$1x10^{33}$ (10^9 Z Per Year)	1,02
Δt Bunches (µs)	**Bunches per train**	**Trains per Sec**	**Surface ZR (% Ladder)**
0,552	1312	5	10

Layer number	Evt/BX	Evt/cm²/BX	BX/Readout	Evt/cm²/Readout	Evt/OR/Readout
1	1,55E-04	2,47E-06	90	2,23E-04	6,96E-05
2	1,55E-04	2,20E-06	18	3,96E-05	1,24E-05
3	1,55E-04	5,35E-07	181	9,68E-05	1,21E-04
4	1,55E-04	5,08E-07	181	9,19E-05	1,15E-04
5	1,55E-04	3,41E-07	181	6,18E-05	7,72E-05
6	1,55E-04	3,30E-07	181	5,97E-05	7,47E-05
Layer number	**Per Seconde**	**Per Day**	**Per Week**	**Per Month**	**Per Year**
1	5,01E-03	432,97	3030,77	**12989,03**	157600,28
2	4,50E-03	389,14	2723,96	**11674,09**	141645,68
3	4,36E-03	376,54	2635,77	**11296,17**	137060,18
4	4,13E-03	357,23	2500,60	**10716,88**	130031,46
5	2,78E-03	240,21	1681,44	**7206,18**	87434,94
6	2,69E-03	232,20	1625,39	**6965,97**	84520,45

OR = 5 % Ladder Surface

Cosmic Muons (Order of magnitude only)

Cosmic rate muons/m²/s	Ladder Length (cm)	Ange (deg)	Ladders number
150	1	36	10
Cosmic rate muons/cm²/s	2	30	12
0,015	2	20	18



- Cosmic Muons : **Vertical direction**
  - **Horizontal surface**
- Statistic : only for the maximum surface
- Significant statistic in few days
- **BUT :**
  - Same direction
  - So : Weak mode
- **Bad track sample to align with mini-vectors**

OR = 10 % Ladder Surface

Layer number	Surface/OR Max (cm²)	Muons/ OR/Sec	Muons/OR /Minute	Muons/OR /Heure	Muons/OR /Jour
1	0,51	0,01	0,46	27,30	**655,30**
2	2,17	0,03	1,95	116,91	**2805,92**
3	2,35	0,04	2,11	126,86	**3044,60**

Statistic : Beamstrahlung (Order of magnitude)

From TDR
(A. Vogel DESY)

Energy (GeV)	Lumi ($cm^{-2}.s^{-1}$)	Bunches per train	Δt Bunches	Trains/s
500	$2x10^{34}$	2625	0,369	5

Layer Number	Hits/cm²/BX (TDR)	Error (Stat)	Hits/cm²/BX Max	BX/Readout
1	6,320	1,763	8,083	135
2	4,009	1,176	5,185	27
3	0,250	0,109	0,359	271
4	0,212	0,094	0,306	271
5	0,048	0,031	0,079	271
6	0,041	0,026	0,067	271

Layer Number	Hits/cm²/Readout	Hits/Ladder/Readout	Hits/Readout/OR	Factor x2 (Syst. Errors)
1	1091,21	**6820,03**	**341,00**	682
2	140,00	**874,97**	**43,75**	87,50
3	97,29	**2432,23**	**121,61**	243,22
4	82,93	**2073,15**	**103,66**	207,32
5	21,41	**535,23**	**26,76**	53,52
6	18,16	**453,93**	**22,70**	45,39

5 %

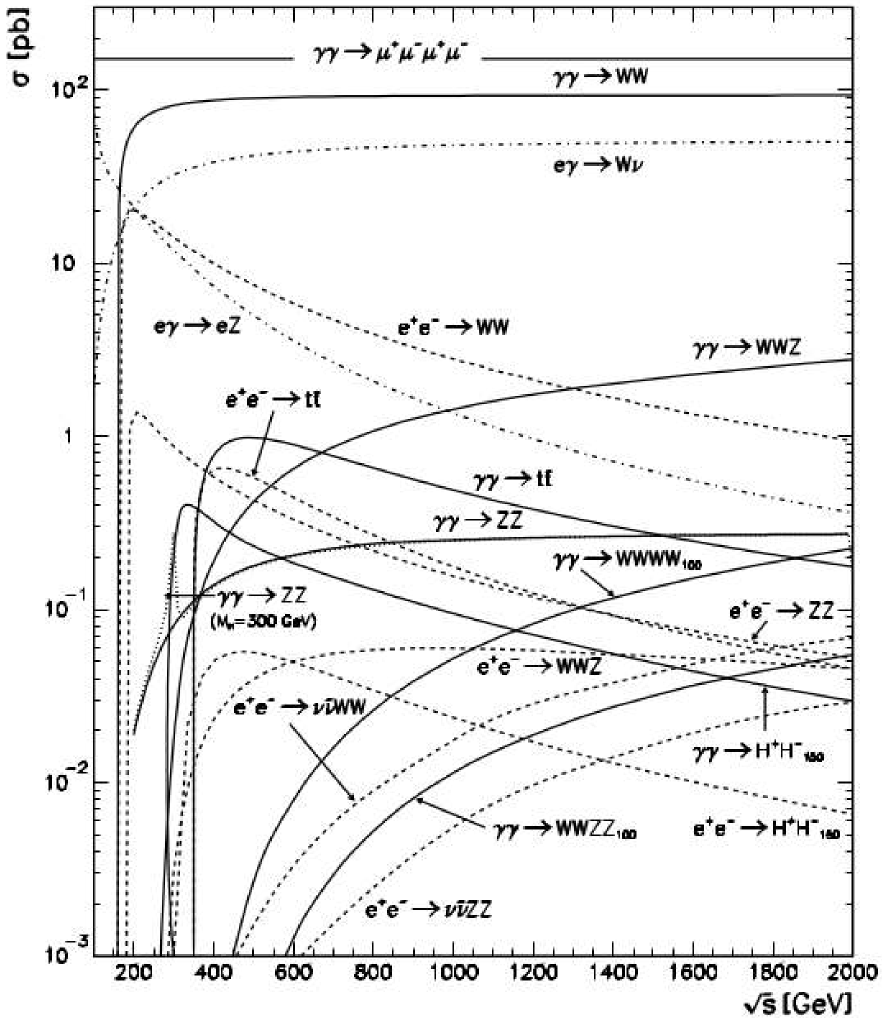
Occupation Rate (1/2)

Numéro couche	Lecture (µs)	Pitch Ligne	Pitch Colonne
1	50	17	17
2	10	85	17
3	100	34	34
4	100	34	34
5	100	34	34
6	100	34	34
Numéro couche	**Lecture ligne (ns)**	**Lignes**	**Taille Capteur (µm)**
1	100	500	10000
2	100	100	10000
3	100	1000	20000
4	100	1000	20000
5	100	1000	20000
6	100	1000	20000

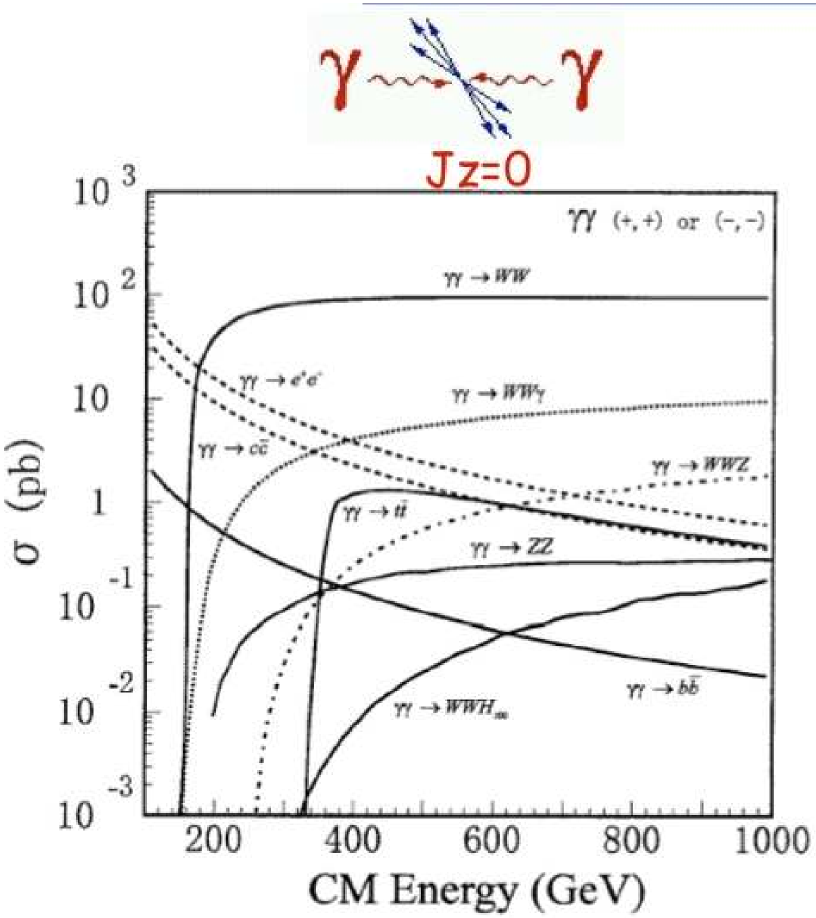
Occupation Rate (2/2)

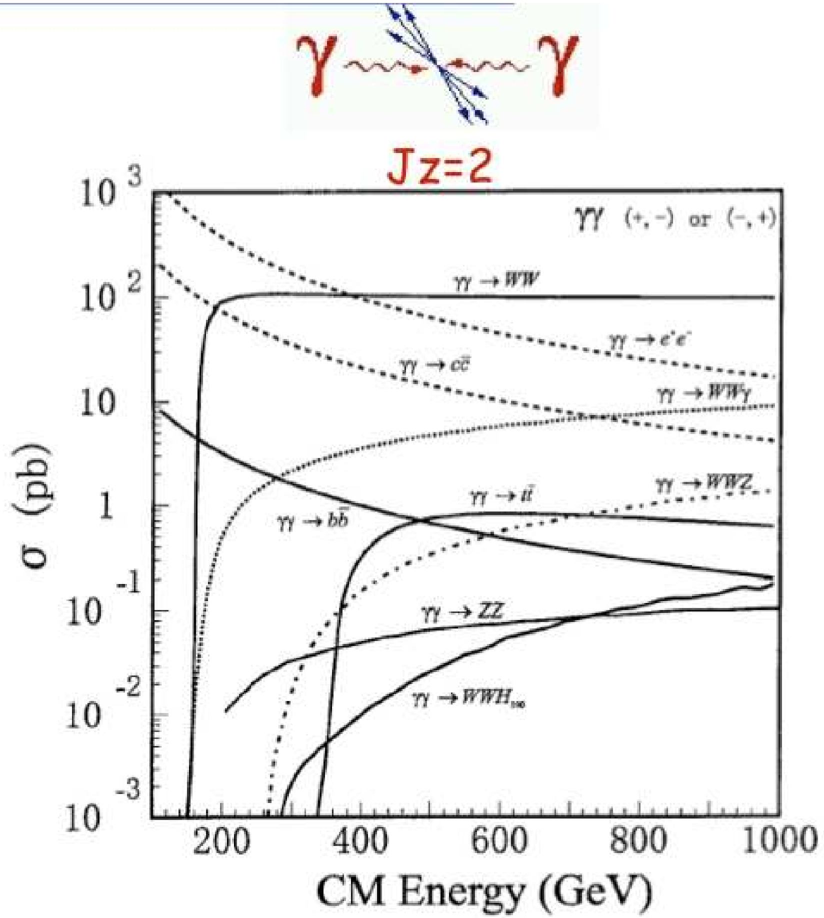
Numéro couche	Colonnes	Pixels	Surface Capteur (cm²)
1	588	294000	1,000
2	117	11700	0,995
3	588	588000	1,999
4	588	588000	1,999
5	588	588000	1,999
6	588	588000	1,999
Numéro couche	**Occupation (%)**	**Multiplicité Moy.**	
1	1,855	5	
2	5,908		
3	0,165		
4	0,139		
5	0,036		
6	0,031		

Photon collider



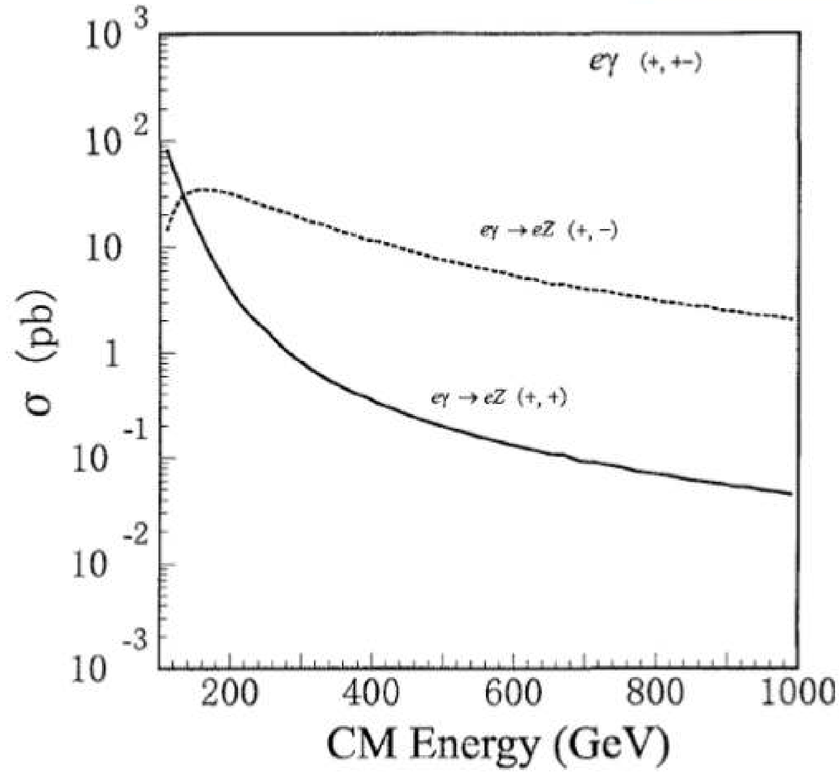
Photon Collider cross sections

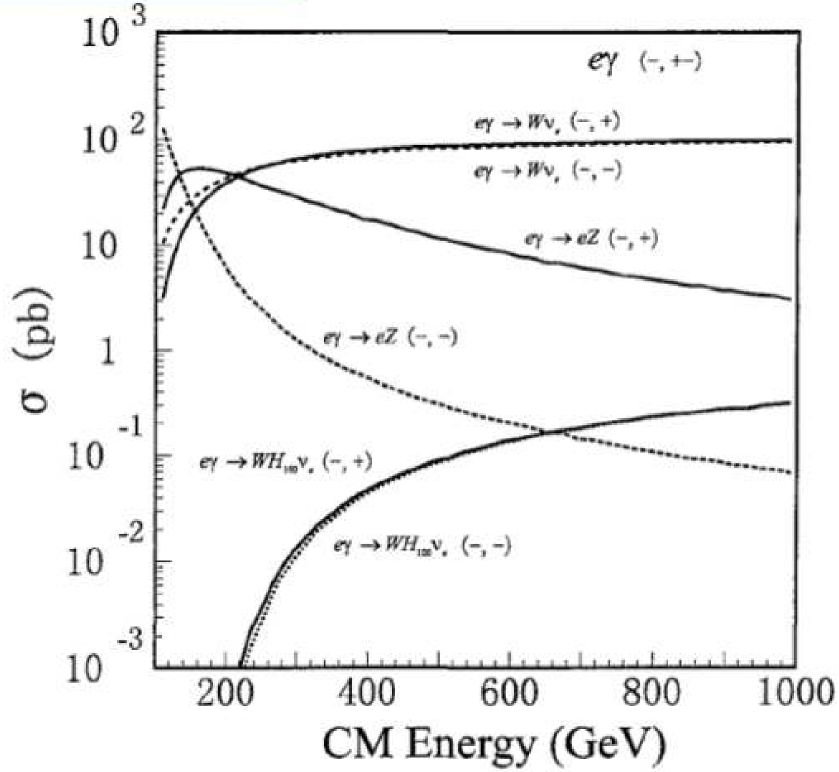




Collider e-photon : cross sections

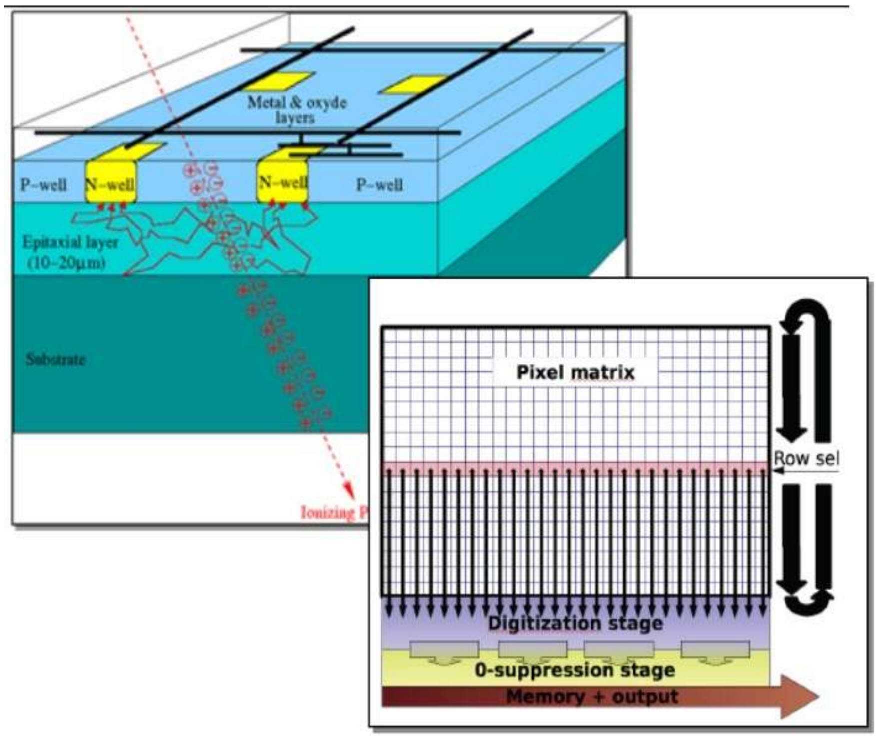
eγ cross sections





MIMOSA CMOS sensors

- Operating principle
  - Signal in the epitaxial layer ≈ 1000 e-.
  - Thermal diffusion (very small depleted region)
  - Reflection at interfaces
  - Continuous collection of charges (no dead time)
- Advantage
  - Granularity : 3-4 µm with pitch of 20 µm
  - Material budget : sensors thinned down to 50 µm.
  - CMOS = Industrial process



- Readout time, power consumption.
  - Rolling shutter mode → T = T(row) * Number of Row
  - Low power consumption (≈ µW per pixel)
- Digitization and zero suppression
  - Digitization (end column)
  - Zero suppression (end column)

Chi2

$$\chi^2 = \sum_{Traces} \left(\frac{(U_{ext} - U_{MV1})^2}{\sigma_U^2} + \frac{(V_{ext} - V_{MV1})^2}{\sigma_V^2} + \frac{(\Delta R_X)^2}{\sigma_{R_X}^2} + \frac{(\Delta R_Y)^2}{\sigma_{R_Y}^2} \right)$$

$$R_X = \frac{x_2 - x_1}{z_2 - z_1} = \frac{\Delta x}{\Delta z} \qquad \sigma_{R_X}^2 = \frac{2\sigma_{\Delta x}^2}{(\Delta z)^2} + \frac{(\Delta x)^2 \sigma_{\Delta z}^2}{(\Delta z)^4}$$

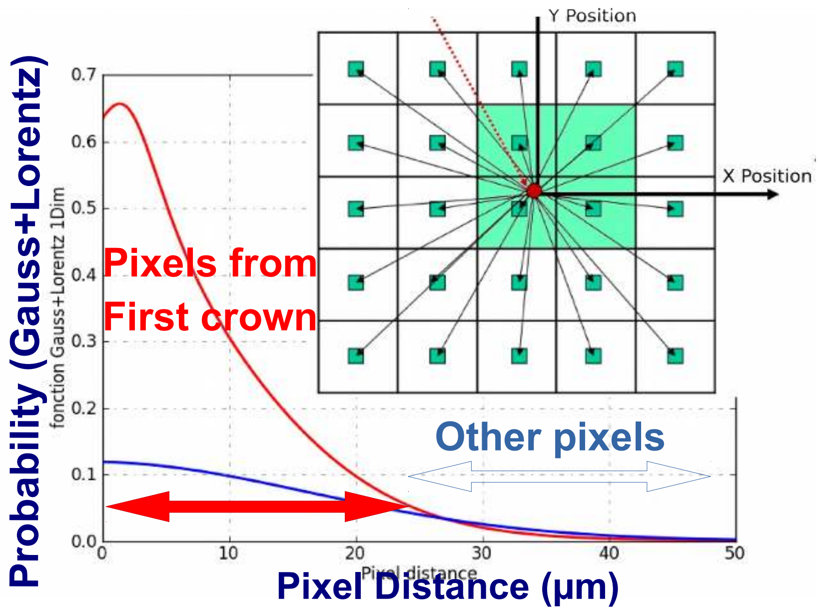
$$R_X = \frac{y_2 - y_1}{z_2 - z_1} = \frac{\Delta y}{\Delta z} \qquad \sigma_{R_Y}^2 = \frac{2\sigma_{\Delta y}^2}{(\Delta z)^2} + \frac{(\Delta y)^2 \sigma_{\Delta z}^2}{(\Delta z)^4}$$

→ σ_U = 3.5 µm (Nomal incidence) or value at incidence θu

→ σ_V = 3.5 µm (Nomal incidence) or value at incidence θv

→ Δx, Δy, Δz = mini-vector size in x, y and z.

Digitizer


Y Position
X Position
Probability (Gauss+Lorentz)
fonction Gauss+Lorentz 1Dim
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
Pixels from
First crown
Other pixels
Pixel distance
Pixel Distance (µm)

Alignment

- *TAF* : **Framework for *test beam analysis* and *simulated data analysis*.**
- ***Alignment of double sided objects* like PLUME ladders.**
- **2 possible strategies of alignment :**
  - ***Alignment sensor by sensor*** in a composite object
  - ***Alignment of the whole object*** with relative sensor position fixed.
  - Example : alignment of PLUME ladders or SALAT super-plans.
- **Alignment description :**
  - ***Track based alignment*** (straight tracks).
  - ***Local Chi² alignment.***
  - Chi² = sum(residuals(u,v)/resolution(u,v))² over tracks
  - Chi² minimisation.