

Das OPERA–Experiment – Status nach dem CNGS–Strahlbetrieb 2009

– Gruppenbericht –
DPG Frühjahrstagung 2010, Bonn



bmb+f - Förderschwerpunkt

OPERA

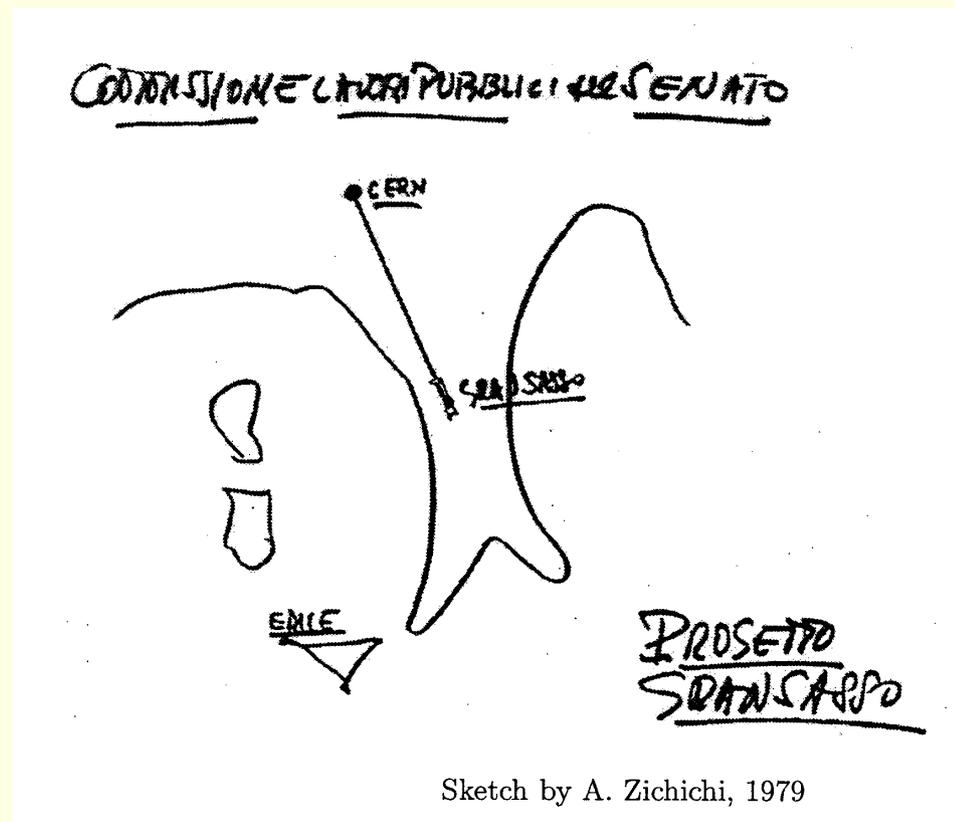
Großgeräte der physikalischen
Grundlagenforschung

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Institut für Experimentalphysik
Universität Hamburg

- Das OPERA–Experiment:
 - CNGS–Strahl
 - Detektor
 - Datennahme
- CNGS–Strahlbetrieb 2009
- Status der Daten–Analyse
- Ausblick
- Zusammenfassung

Oscillation Project with Emulsion tRacking Apparatus

- **Ziel:** Direkter Nachweis von $\nu_{\mu} \rightarrow \nu_{\tau}$ Oszillationen (Appearance)
- **Konzept:** long baseline ν_{μ} -Strahl \rightarrow Nachweis des τ -Leptons
- **Anforderung:** Große Targetmasse und μm -Ortsauflösung
- **Lösung:** Blei und Fotoemulsionen (Emulsion Cloud Chambers) + elektronische Detektoren

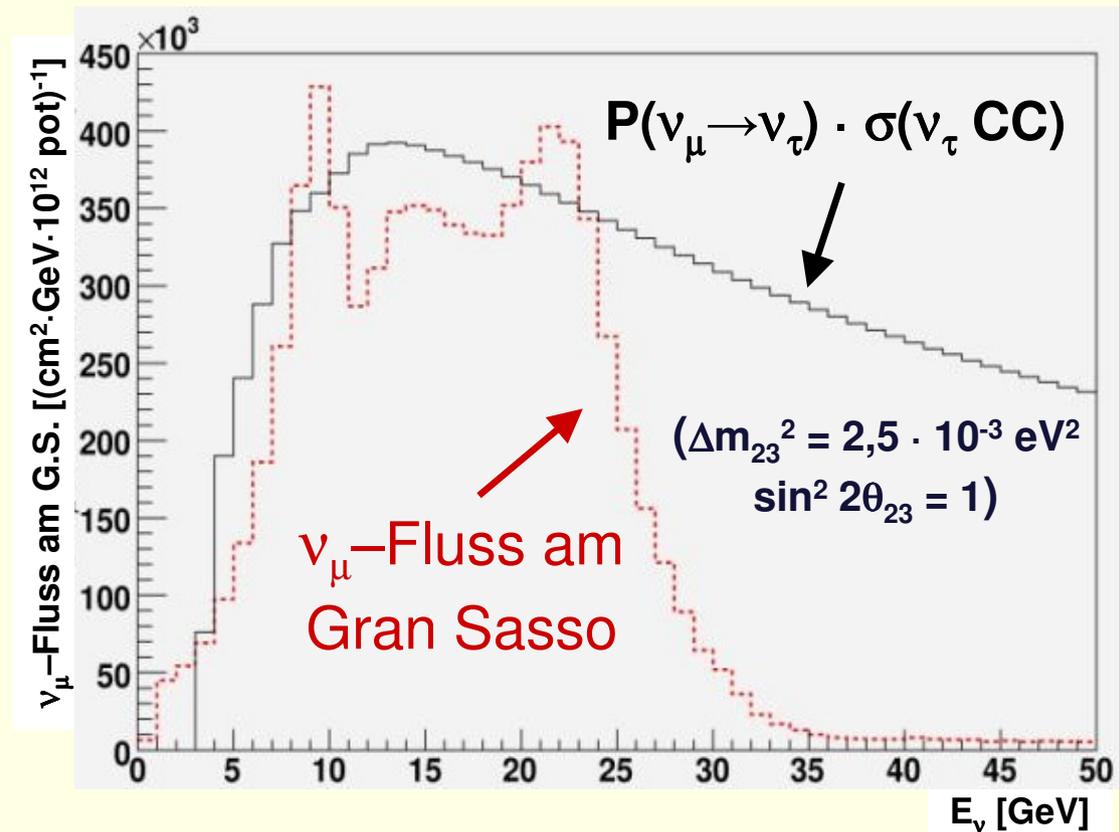


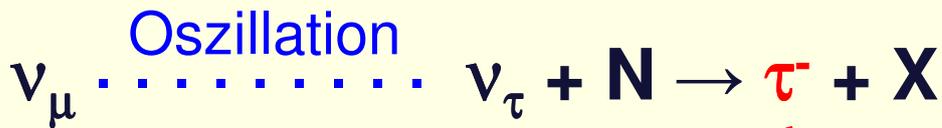
CERN Neutrinos to Gran Sasso



- Strahl optimiert für ν_τ –Appearance am Detektor

Strahlkontamination	
$(\nu_e + \bar{\nu}_e) / \nu_\mu$	0,87 %
$\bar{\nu}_\mu / \nu_\mu$	2,1 %
ν_τ / ν_μ	$< 10^{-4}$ %





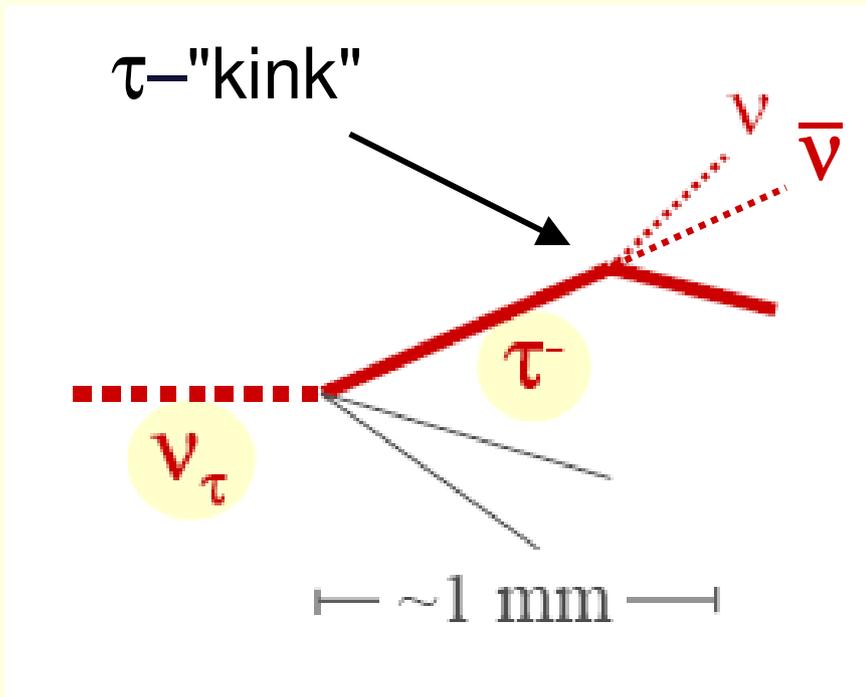
Tau-Zerfall

1-prong-Zerfallskanäle:

$h^- + \nu_\tau + (n\pi^0)$	BR 49,5 %
$e^- + \nu_\tau + \bar{\nu}_e$	BR 17,8 %
$\mu^- + \nu_\tau + \bar{\nu}_\mu$	BR 17,7 %

3-prong-Zerfallskanäle:

$h^- + h^- + h^+ + \nu_\tau + (n\pi^0)$	BR 15,0 %
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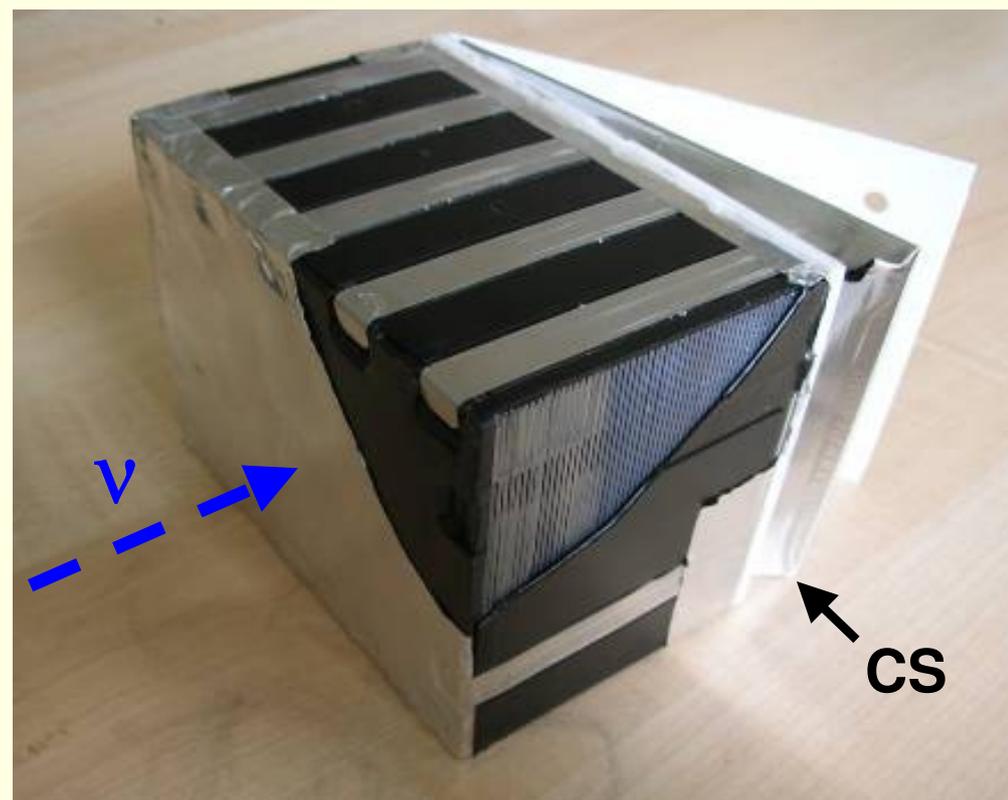
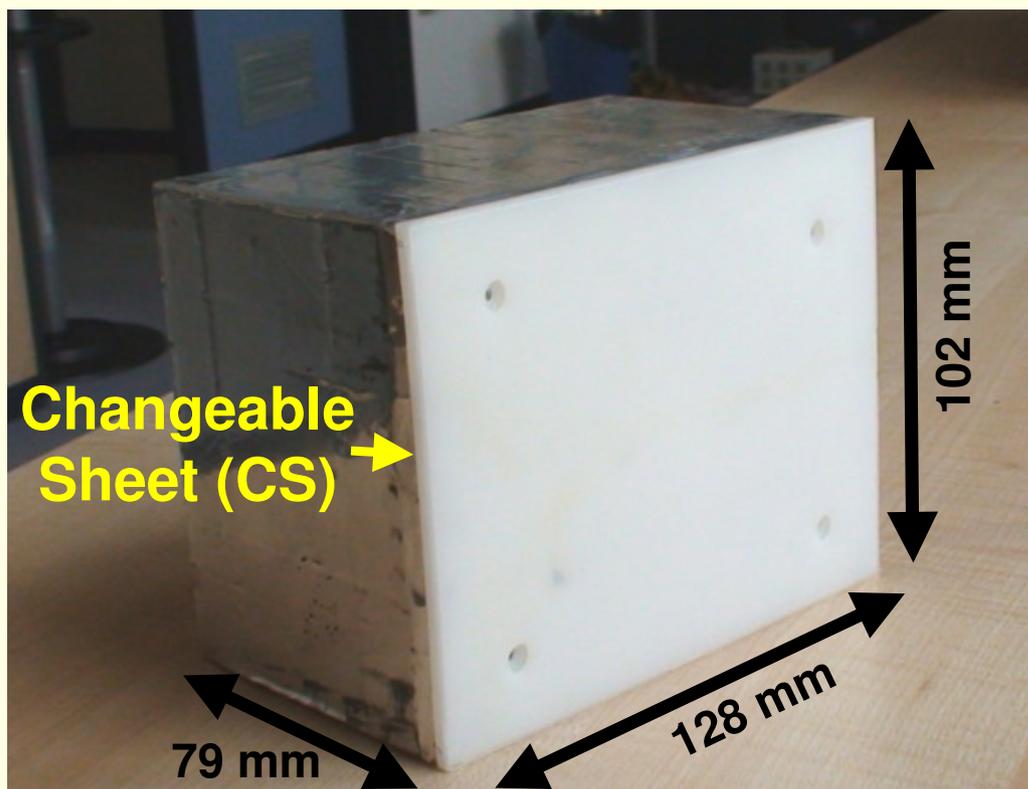
- Mittlere Tau-Zerfallslänge:
~ 600 μm

Target–ECC–Bricks

- 57 + 2 Emulsionsfilme ($\sim 0,3$ mm)
- 56 Bleischichten (1 mm)

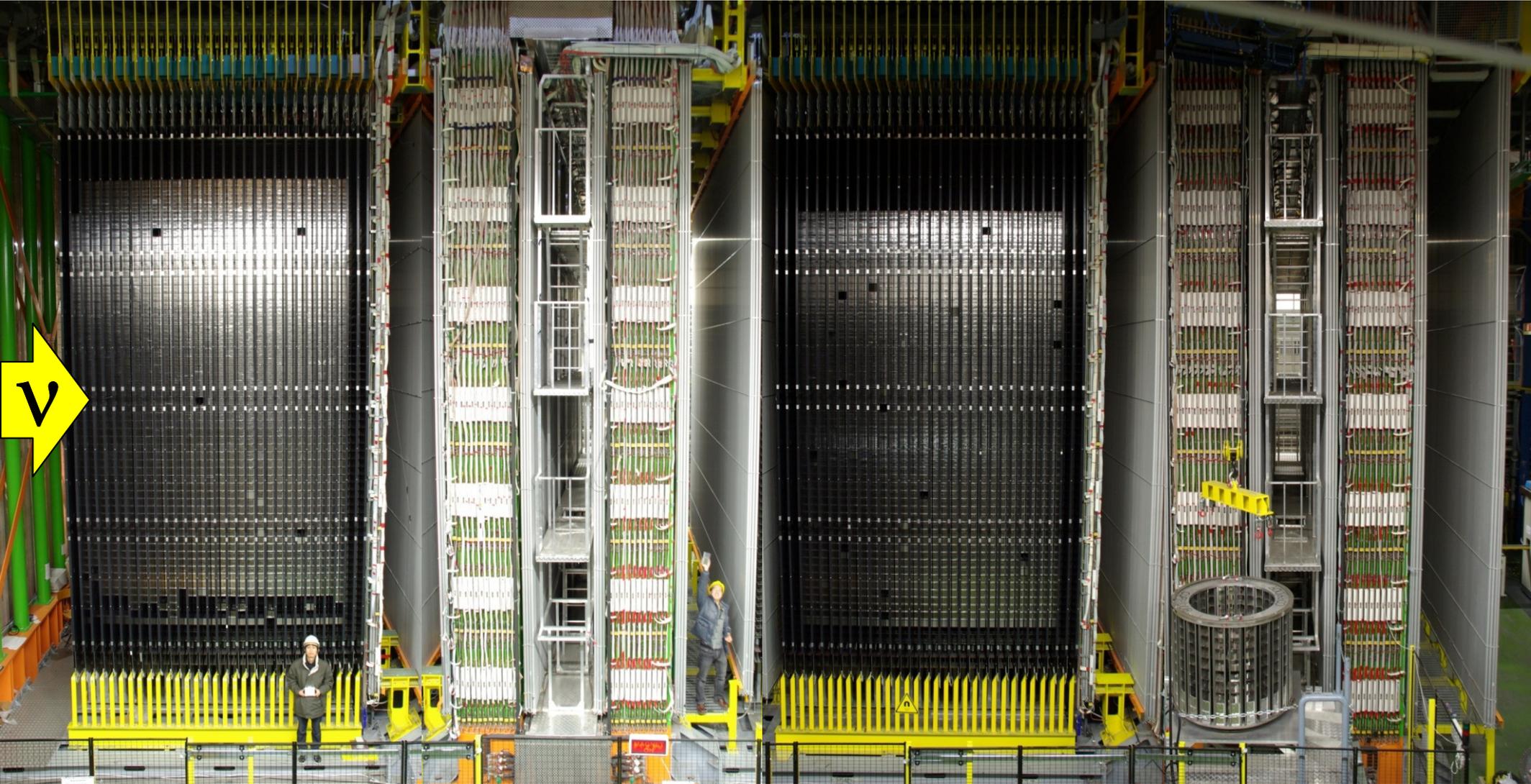
ca. 150.000 Bricks
à 8,3 kg

→ **ca. 1,25 kt
Targetmasse**



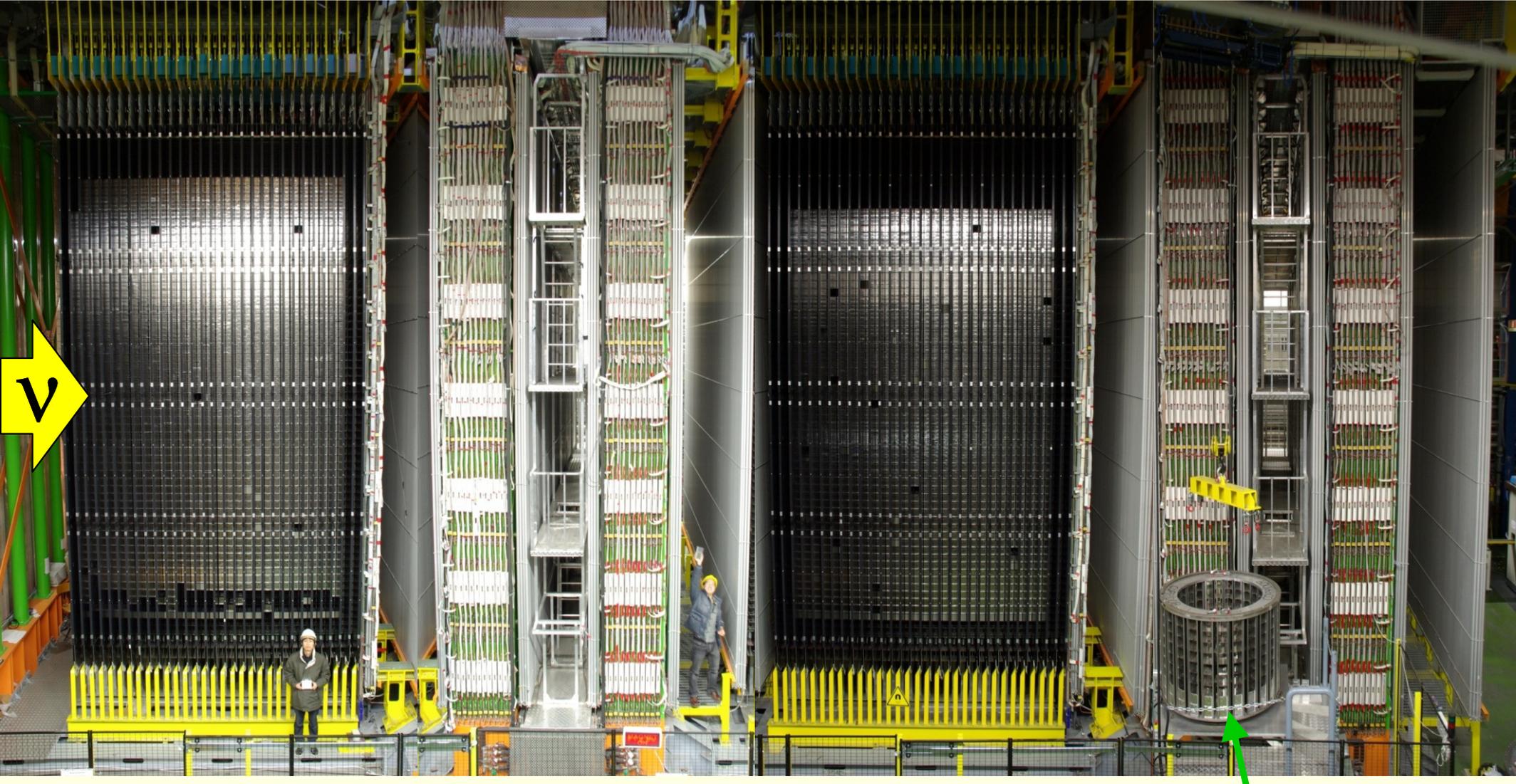
← SM1

SM2 →

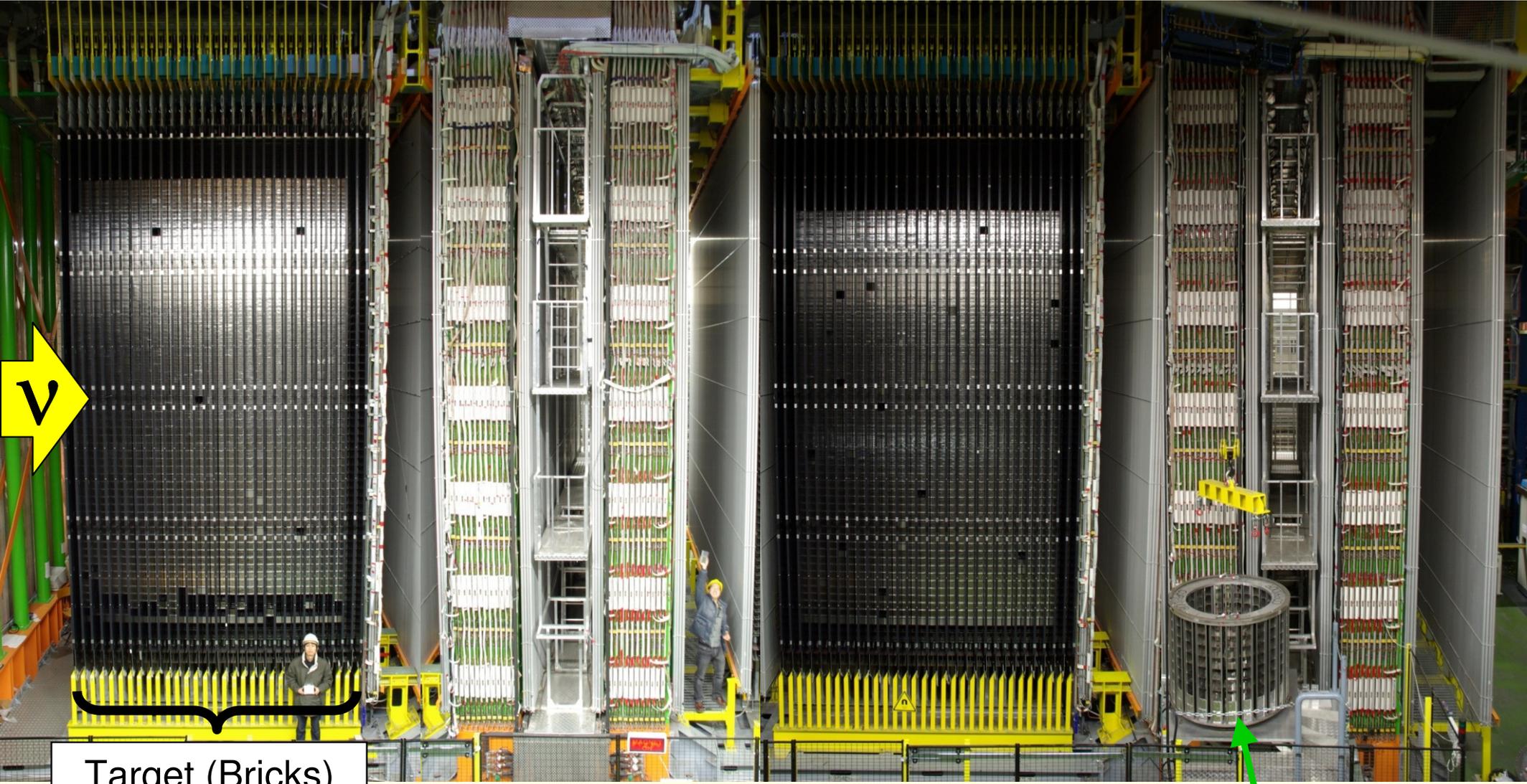
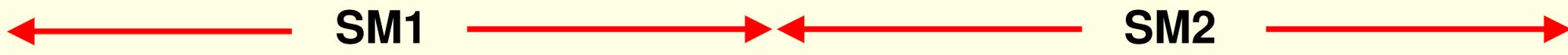


← SM1

SM2 →

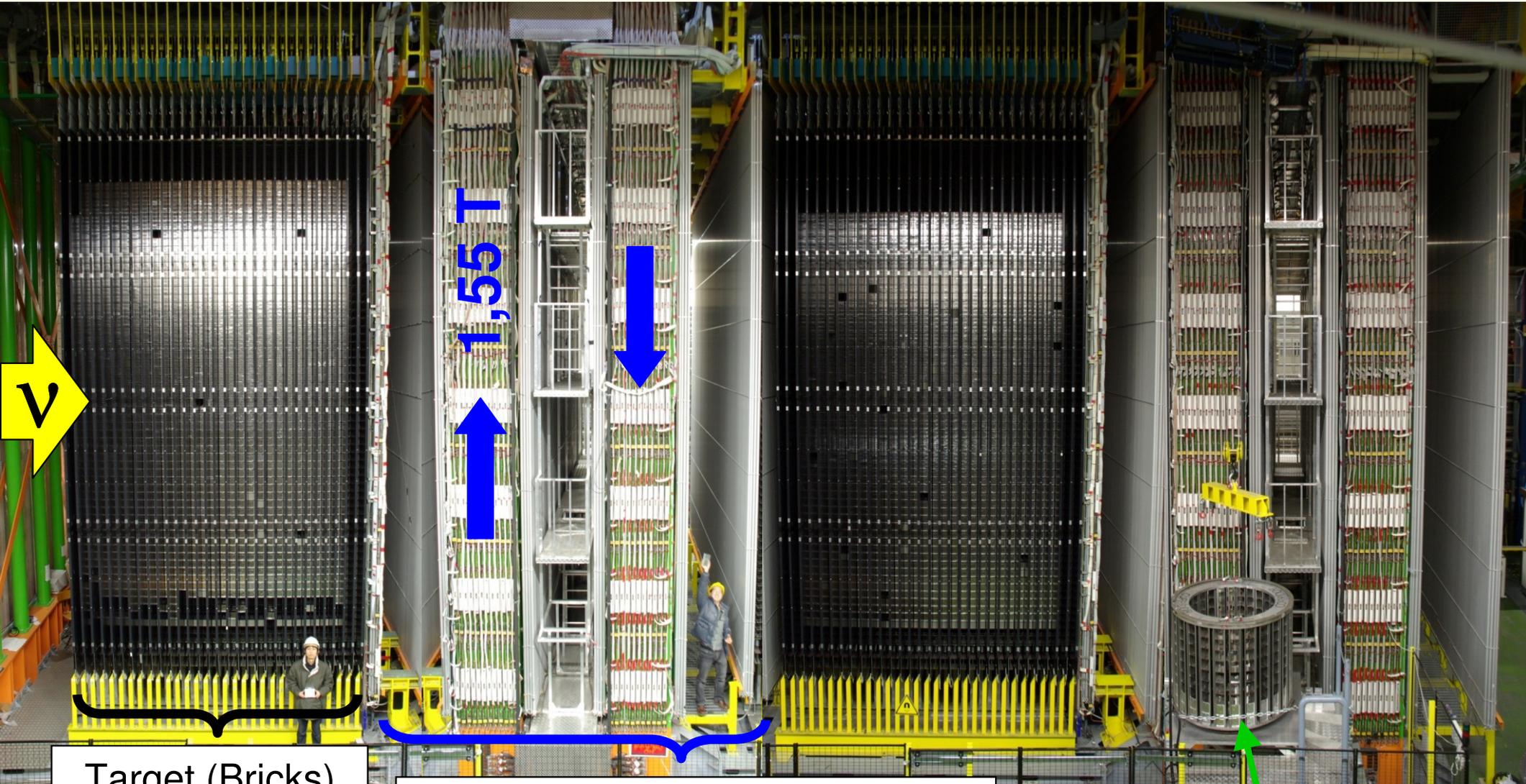
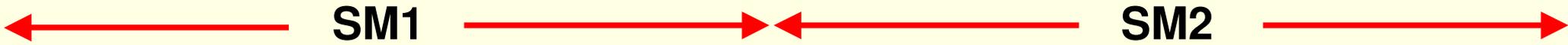


Brick Manipulator System



Target (Bricks)
+ Target Tracker

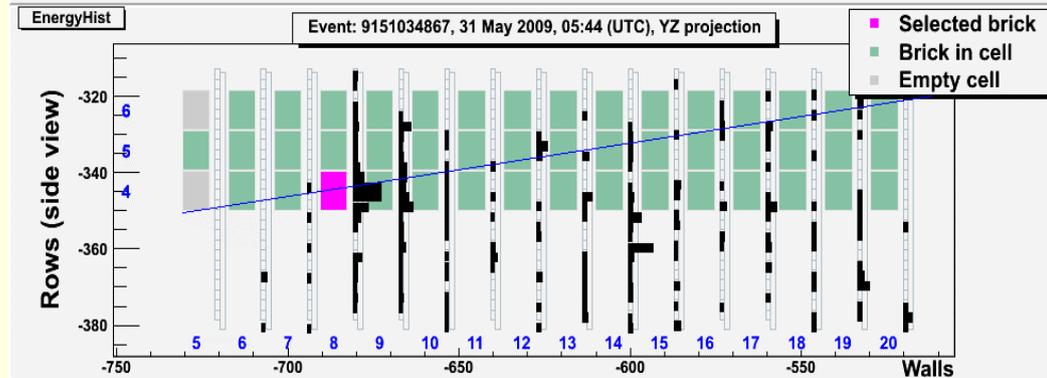
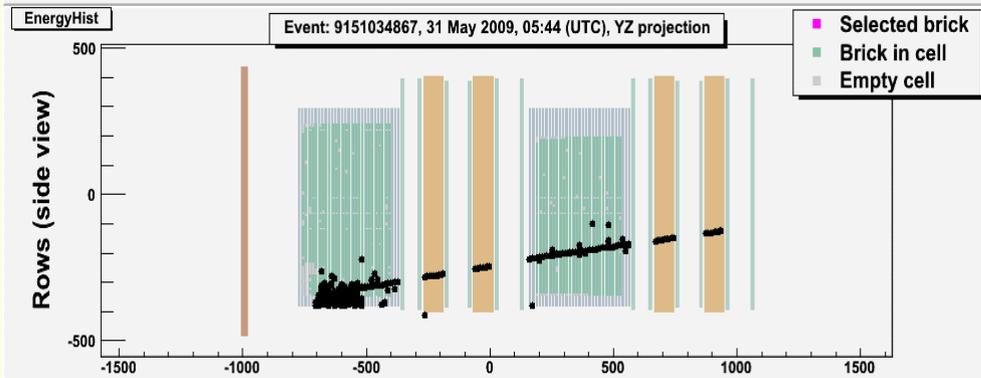
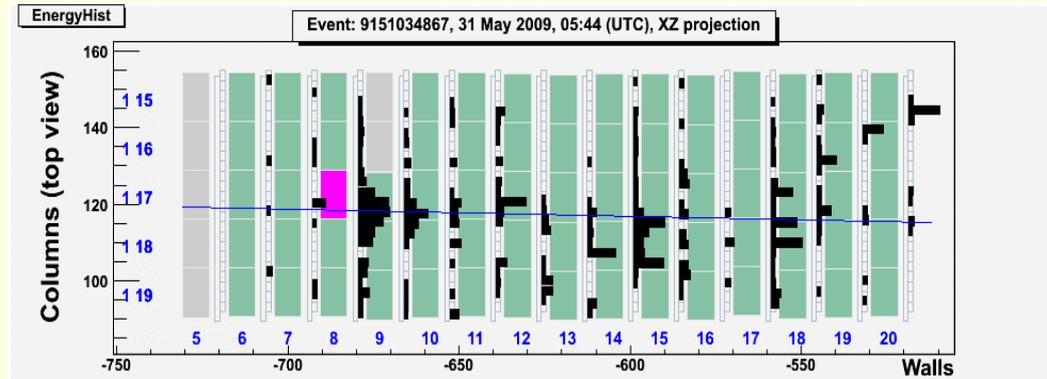
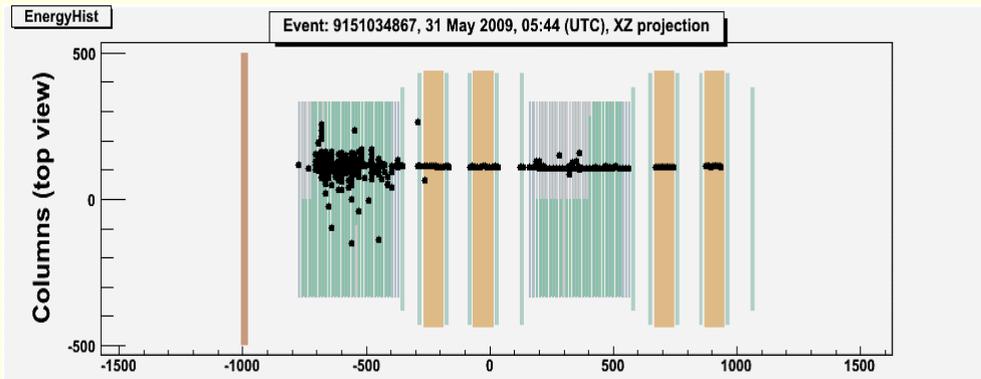
Brick Manipulator System



Target (Bricks)
+ Target Tracker

Myonspektrometer:
Magnet, RPCs, Precision Tracker

Brick Manipulator System



Brick finding information: Super module 1

BrickId	Wall	Side	Column	Row	Prob	CS x	CS y
brick 1:	1005281	8	1	17	4	0.91	21.6 62.2
brick 2:	1025547	8	1	18	4	0.07	149.6 62.2
brick 3:	1069021	7	1	17	4	0.01	24.8 42.8

Muon track parameters: Mu+

Momentum: 9.051 GeV/c

Angle XZ (rad): -0.018+/-0.006

Angle YZ (rad): 0.138+/-0.006

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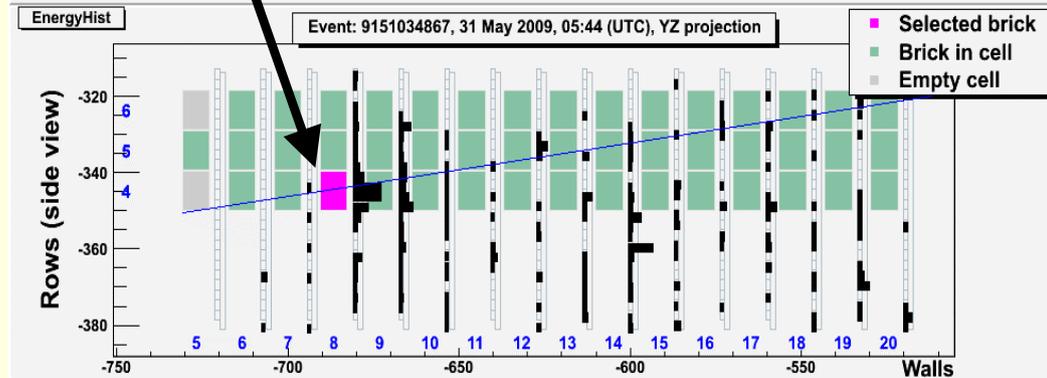
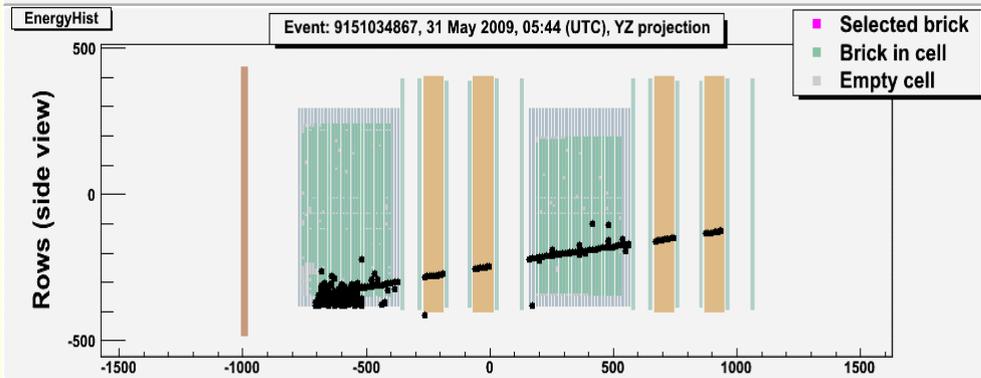
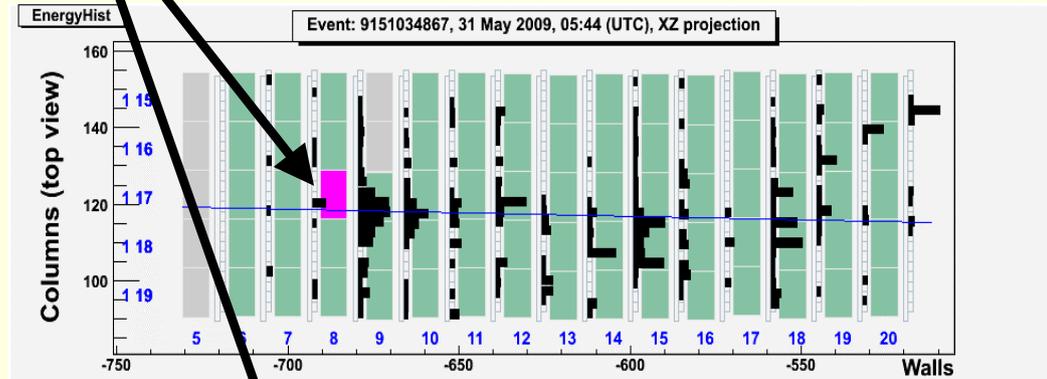
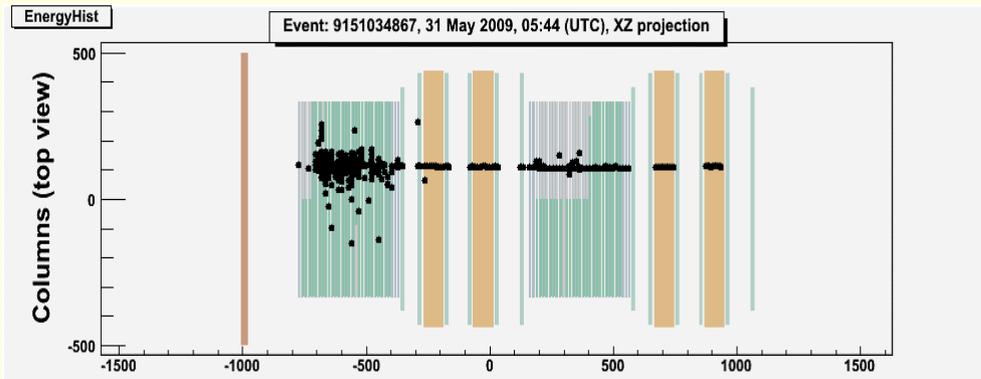
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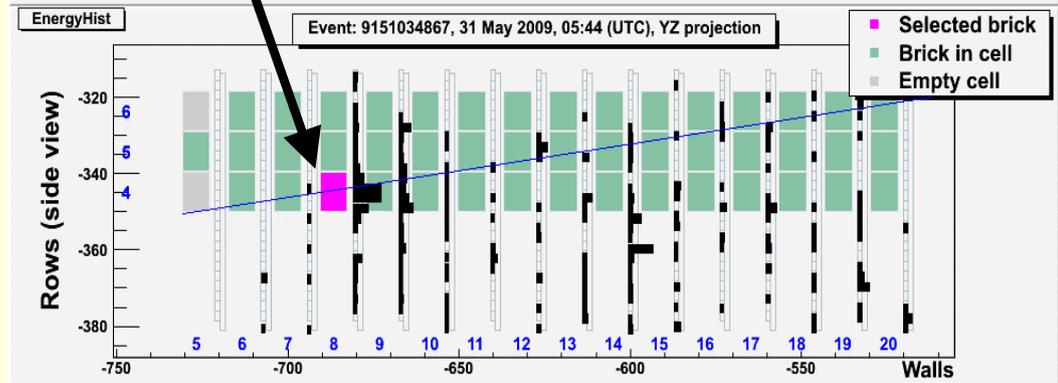
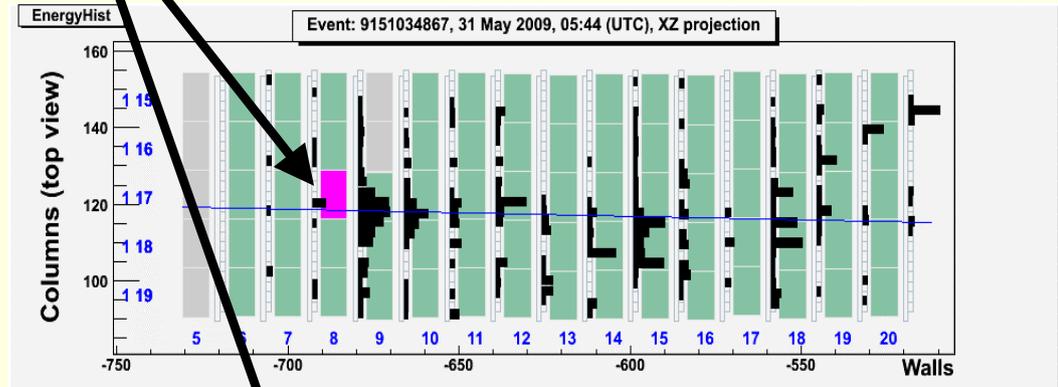
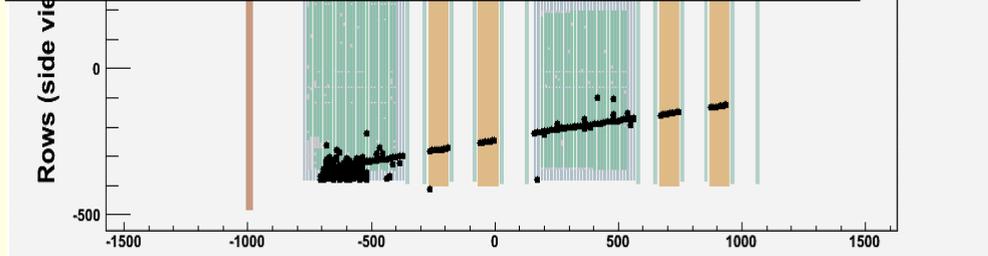
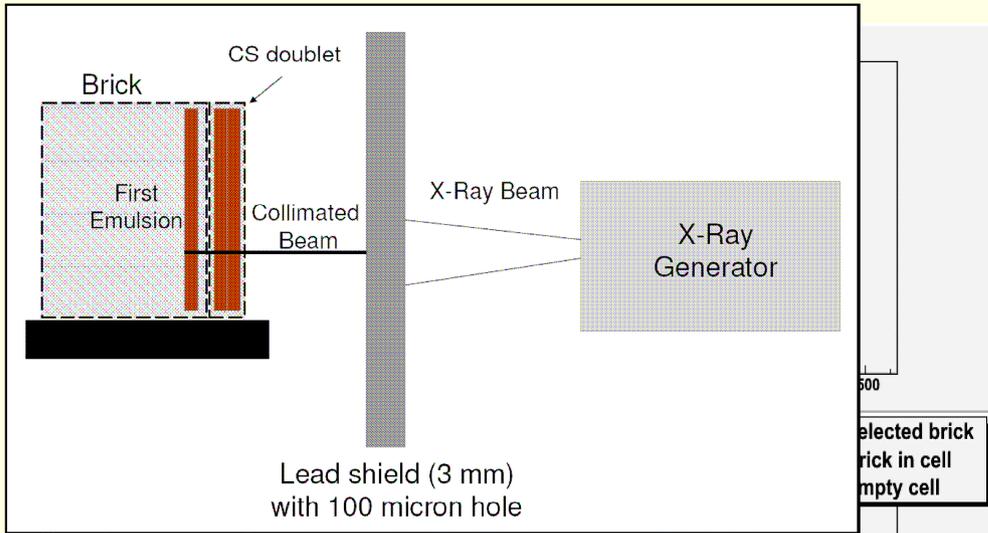
Brick wird zur Analyse entnommen



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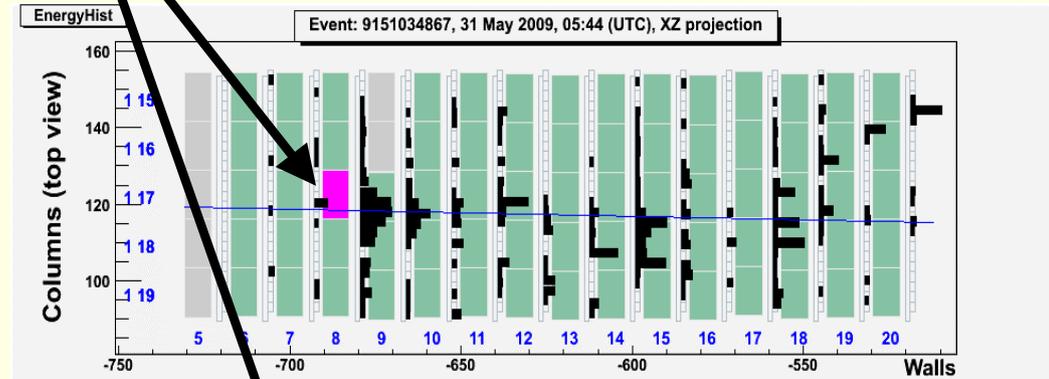
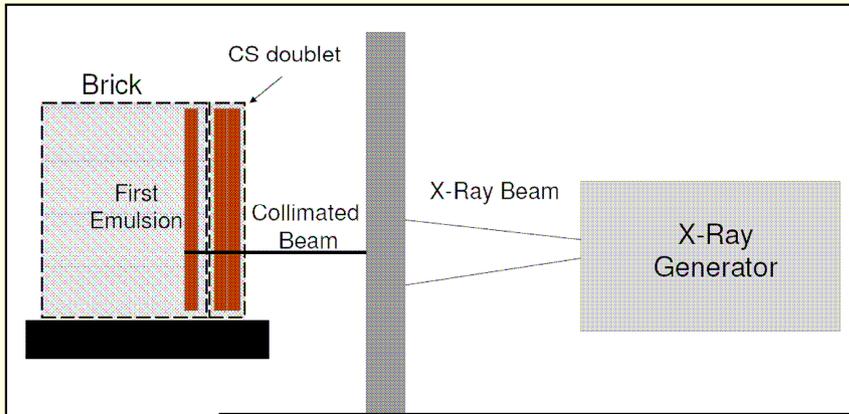
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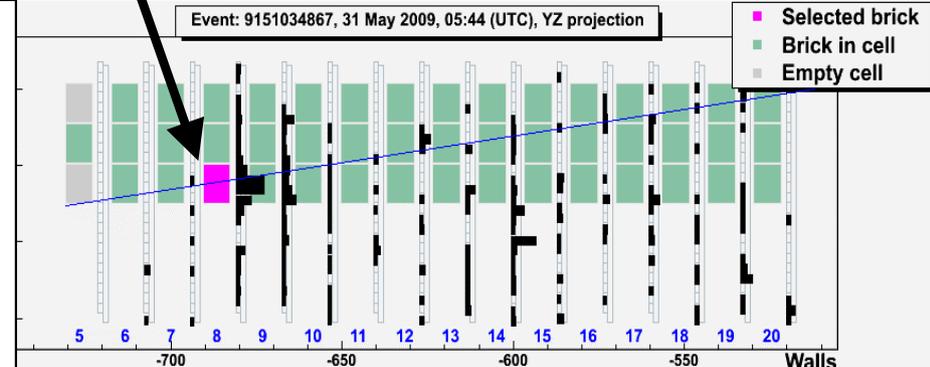
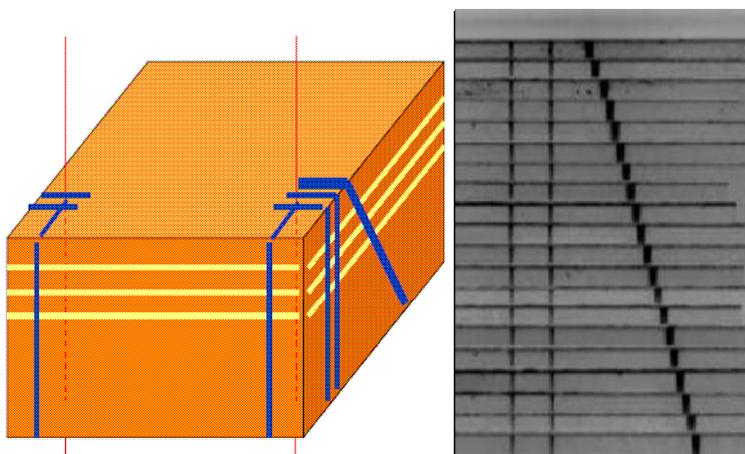
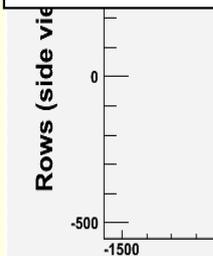
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Brick wird zur Analyse entnommen



Röntgenmarkierungen + Bestrahlung durch kosmische Myonen



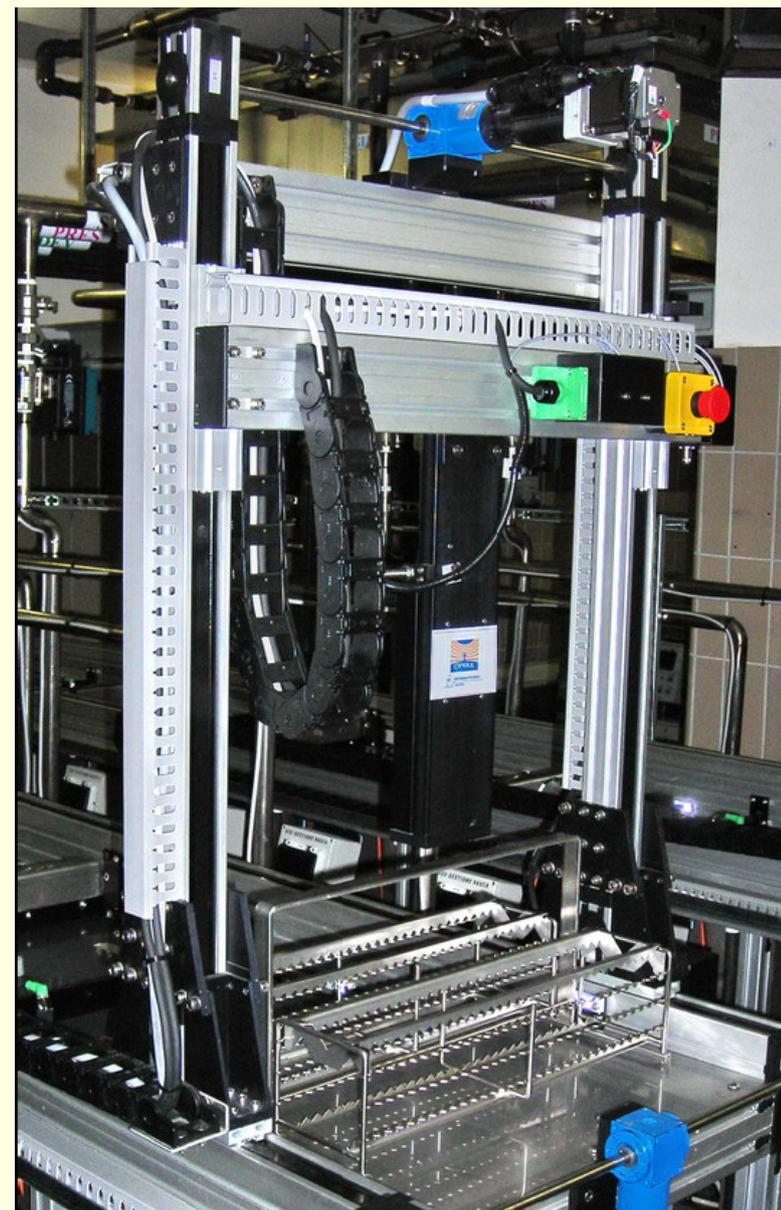
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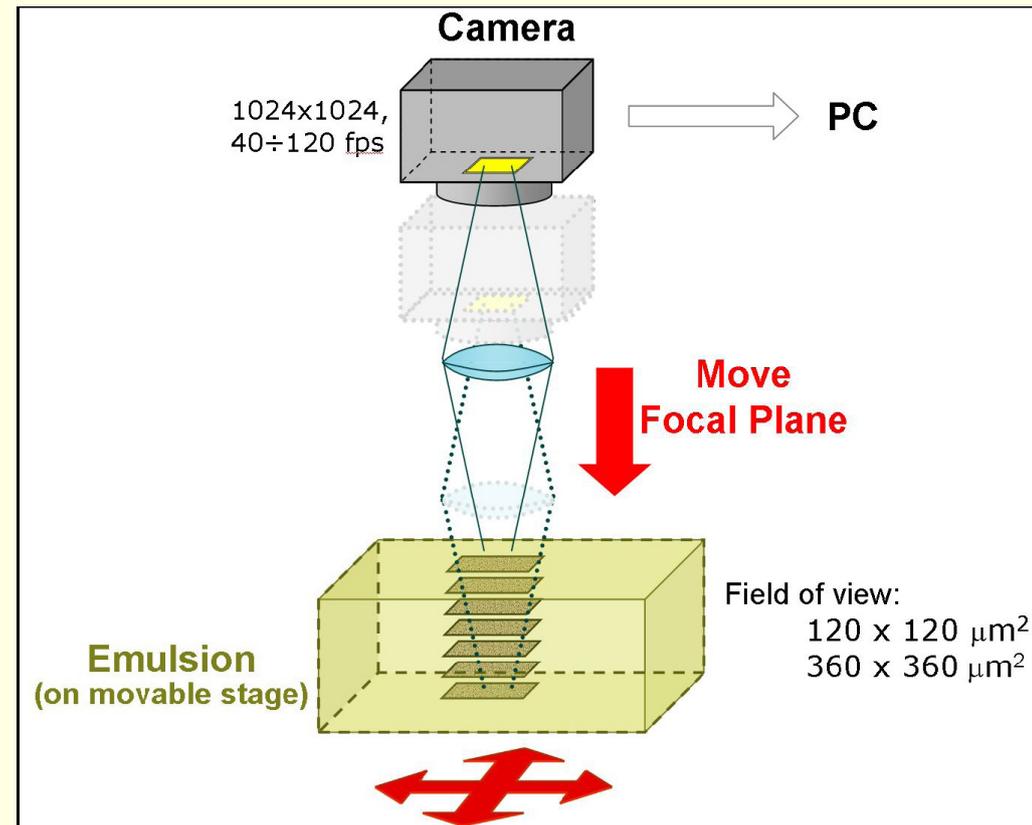
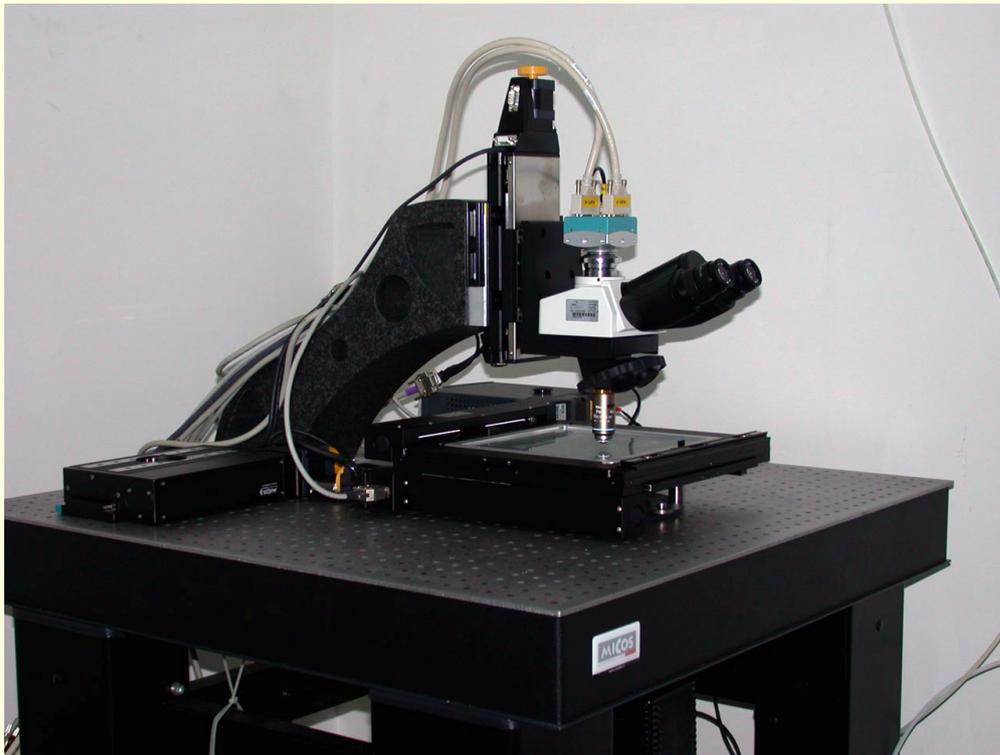
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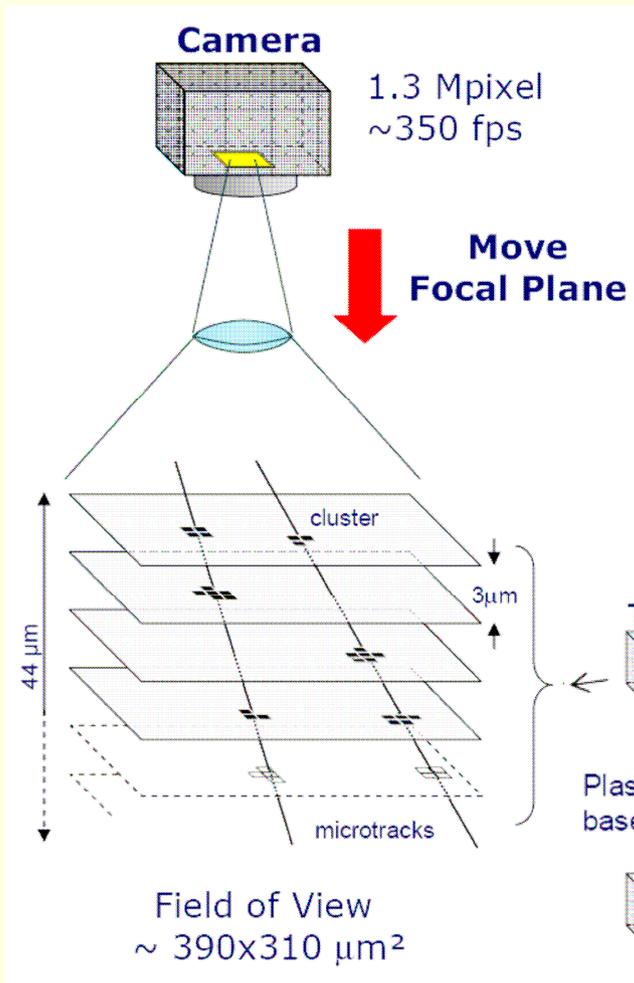
- Fotochemische Entwicklung der Emulsionen



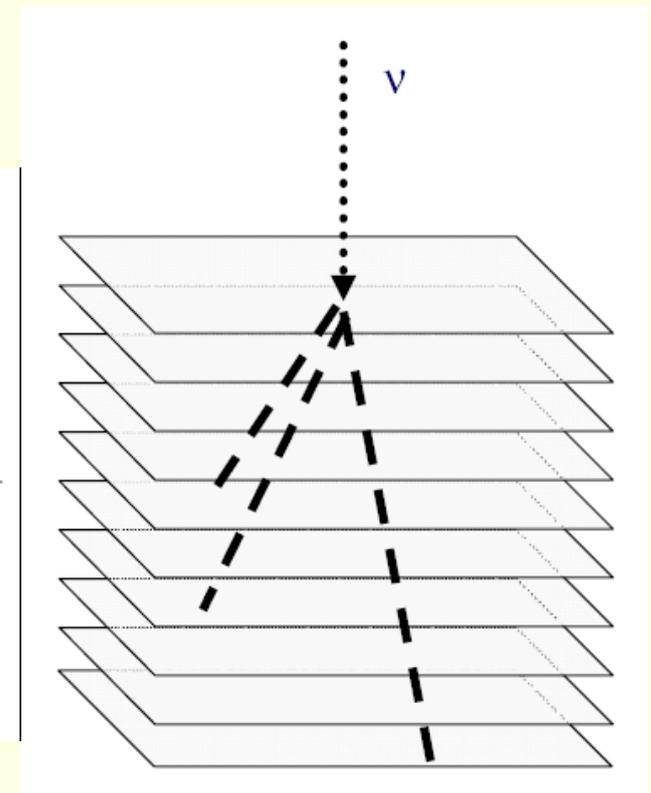
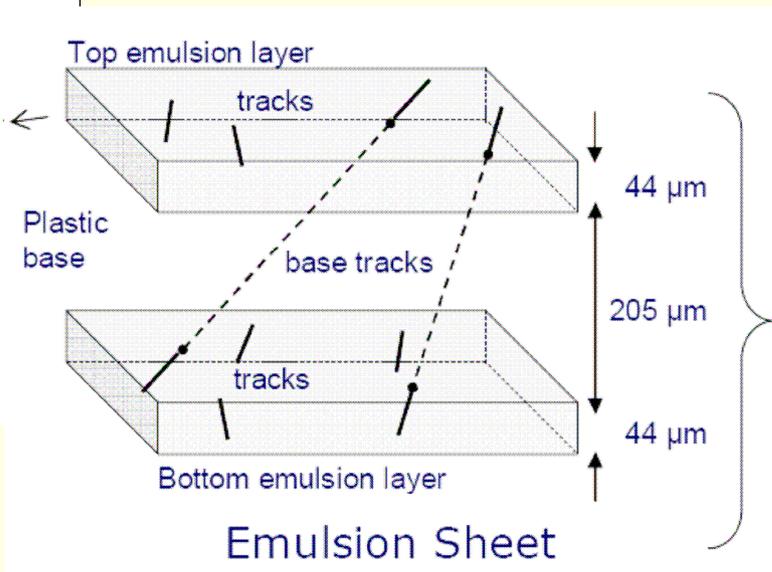
Digitalisierung

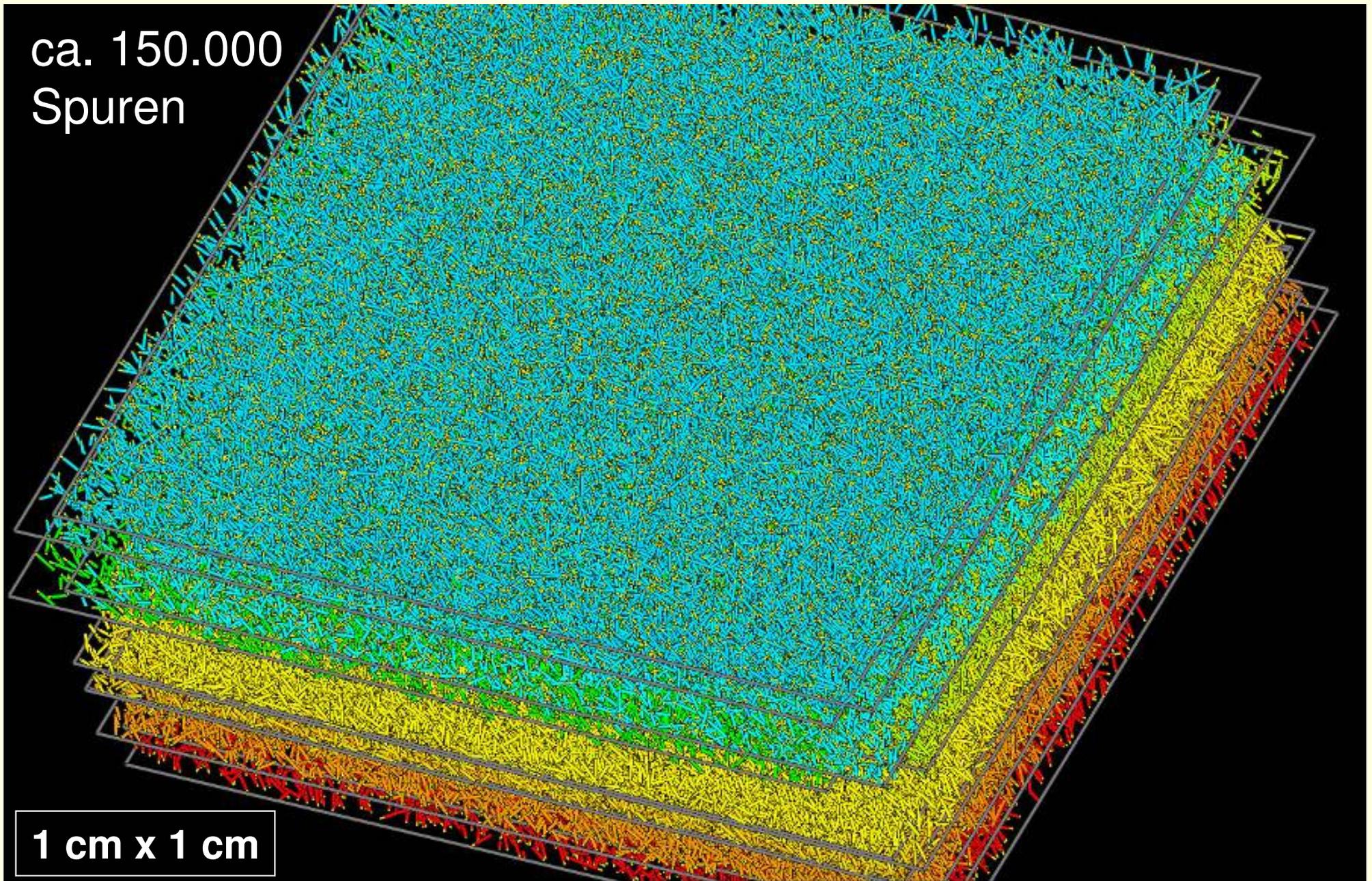
- ~ 40 Scanning-Mikroskope in Europa und Japan
- ca. 20 – 75 cm² Emulsionsoberfläche je Mikroskop und Stunde



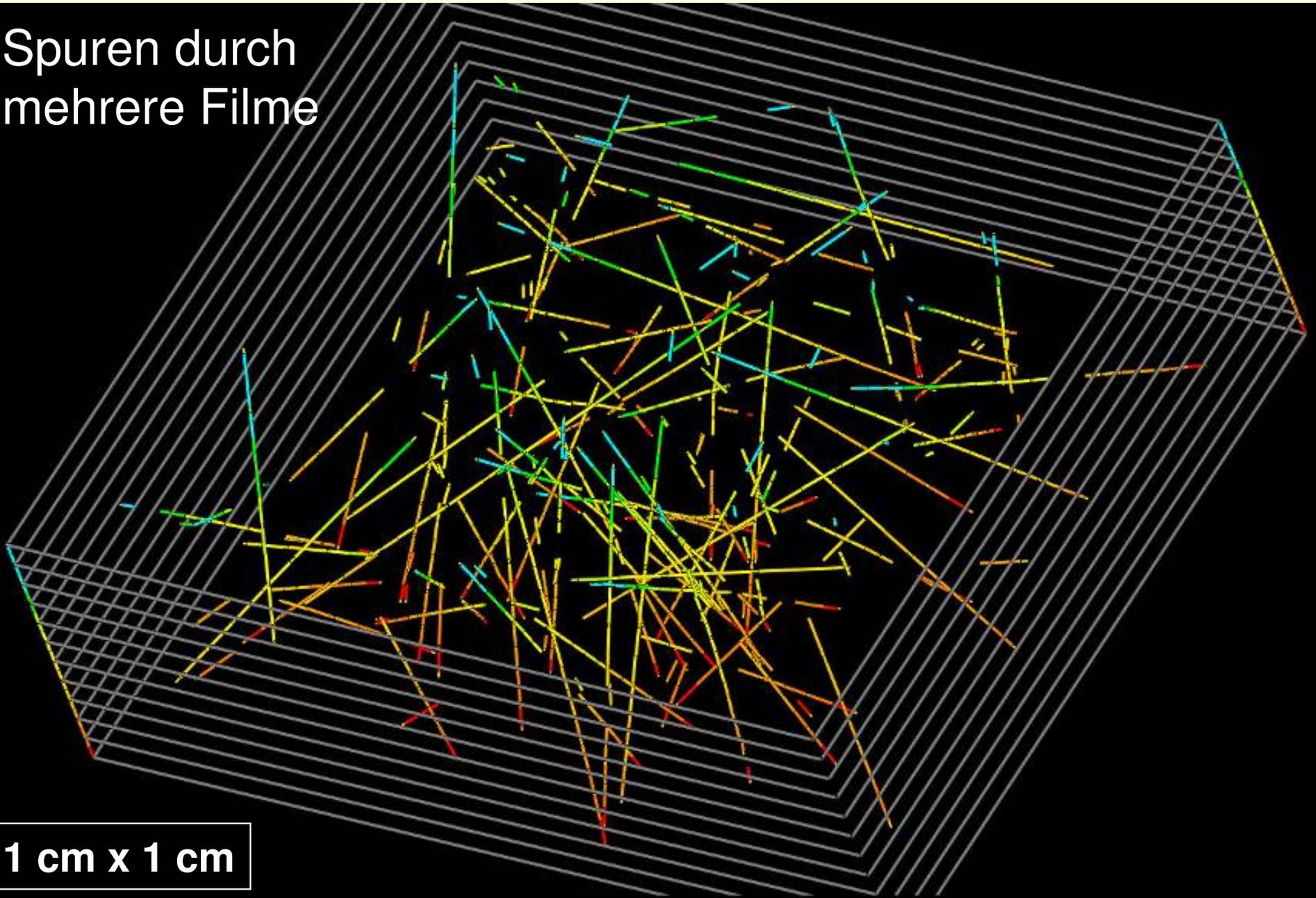


- "Micro-Tracks" aus 6 – 16 Punkten (cluster) innerhalb einer Emulsionslage
 → "Base-Tracks" innerhalb eines Films
 → Teilchenspuren



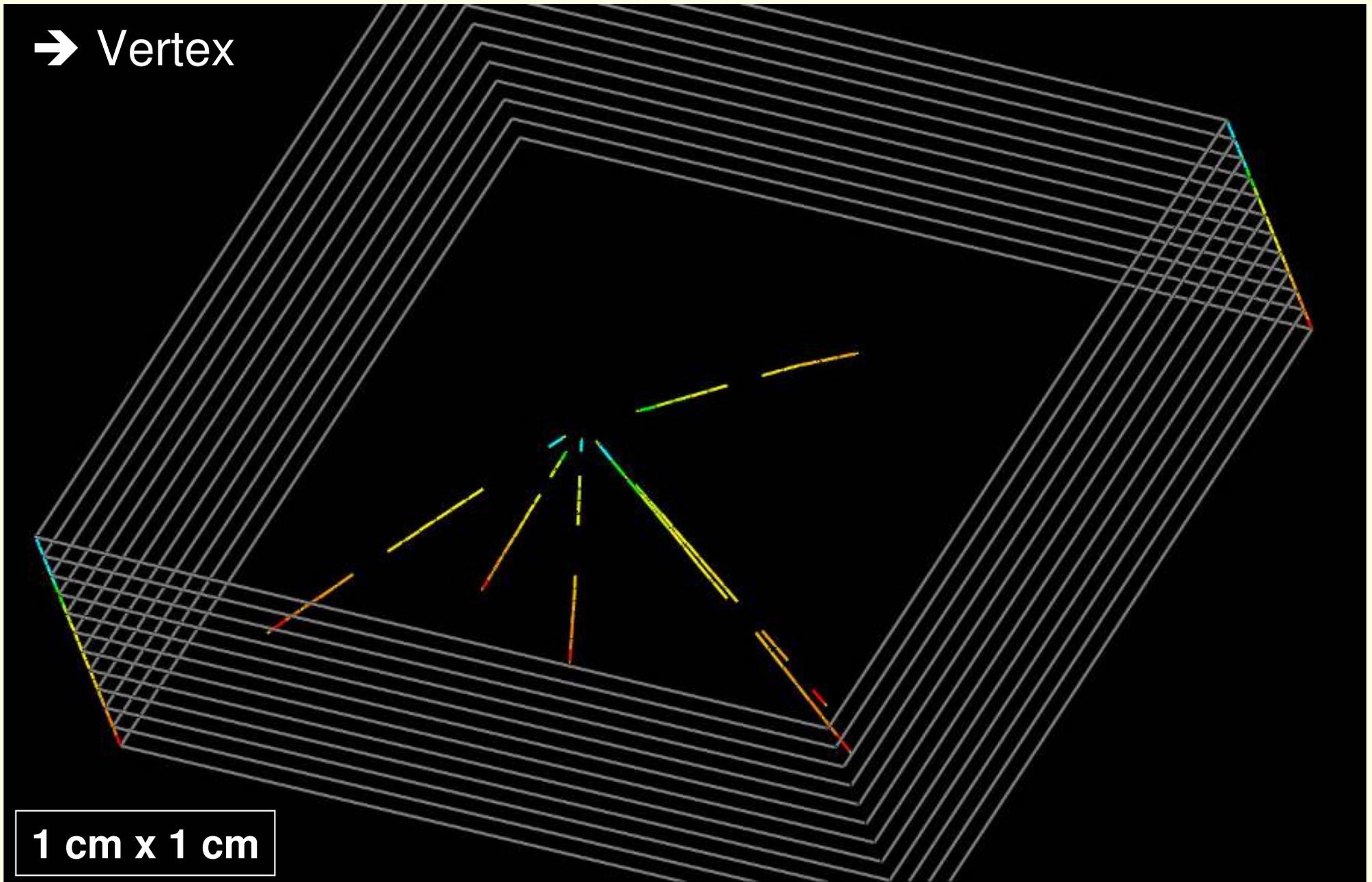


Spuren durch
mehrere Filme

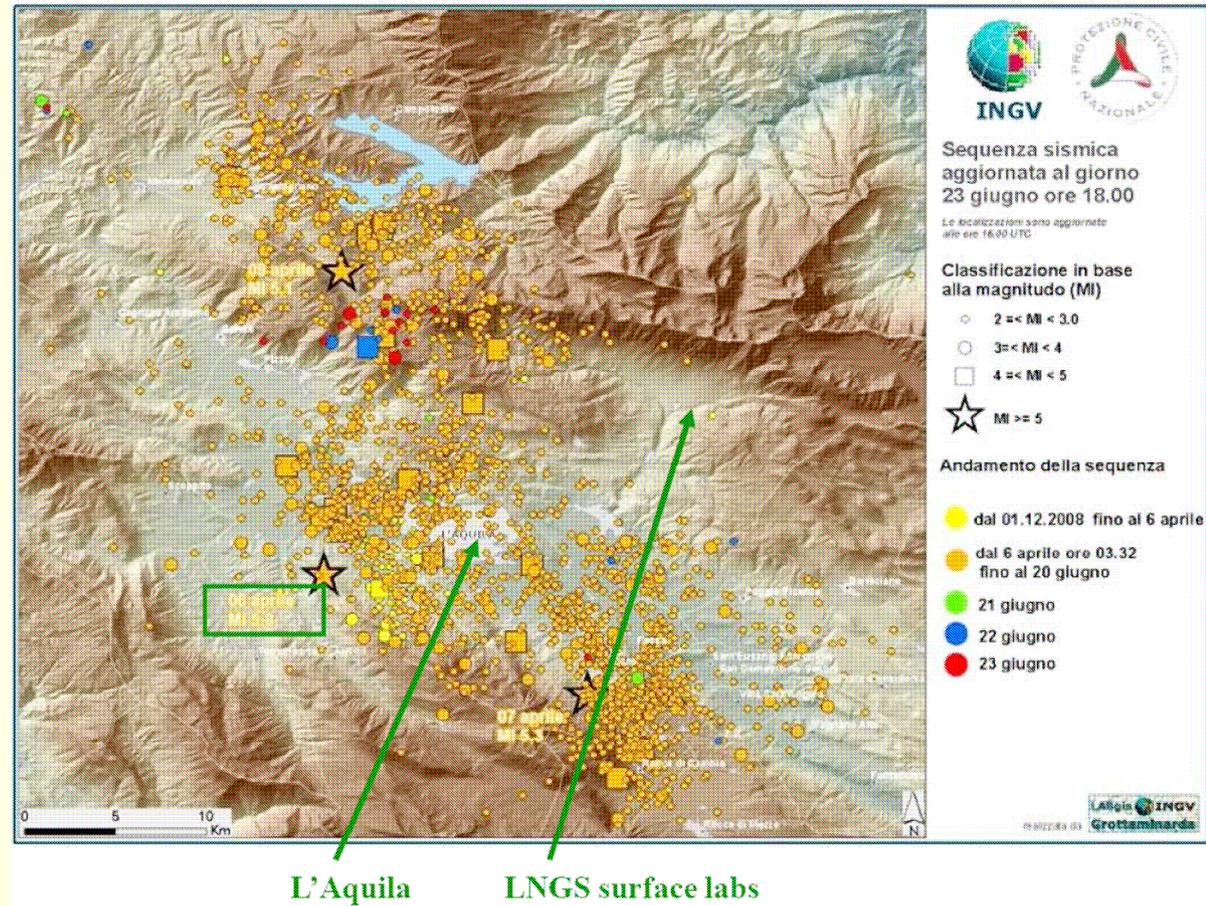


1 cm x 1 cm

→ Vertex

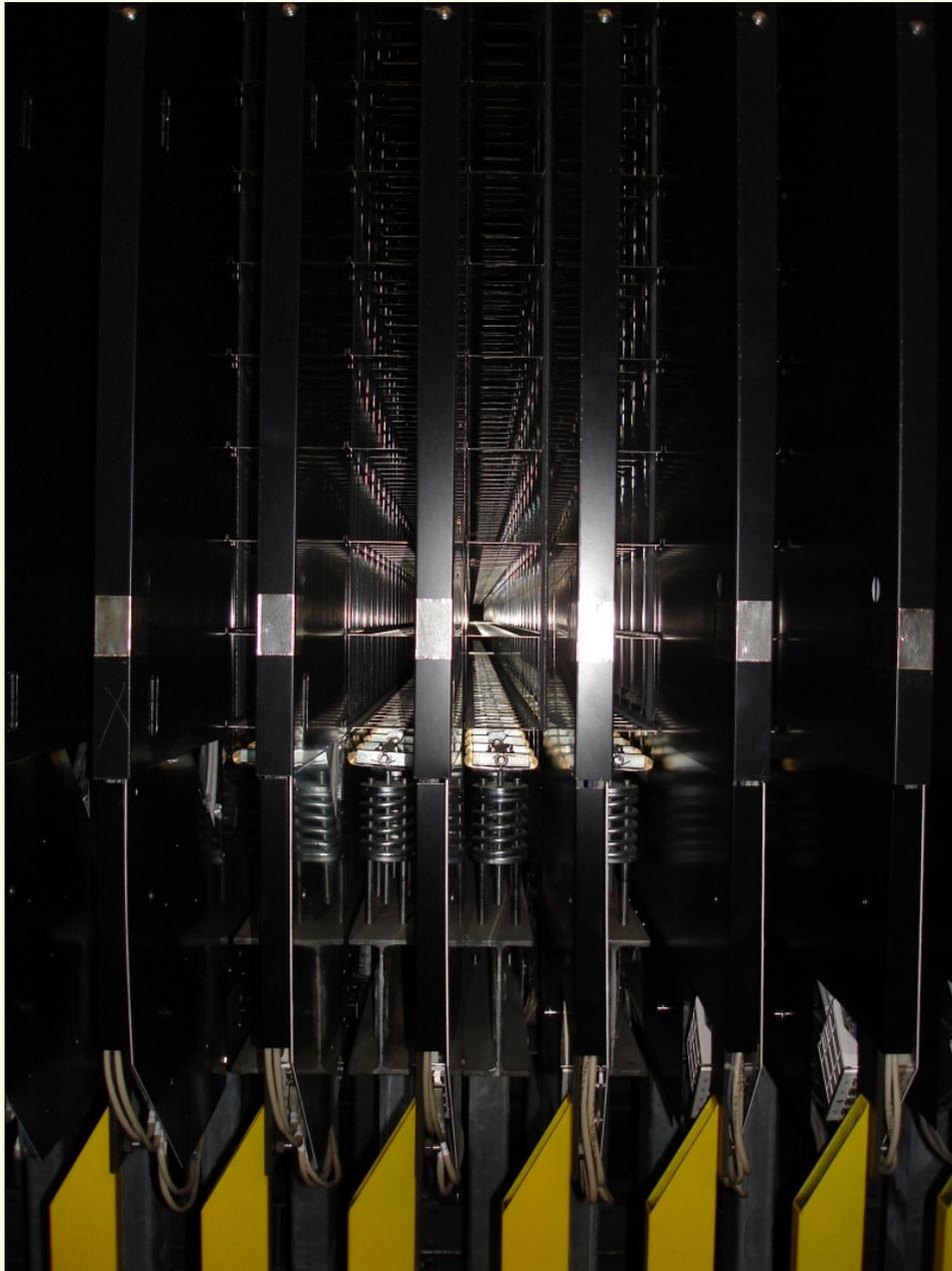


- 6. April 2009
- Stärke: $M_W = 6,3$
- über 300 Todesopfer,
1.600 Verletzte,
65.000 Obdachlose



Höchste Beschleunigungswerte:

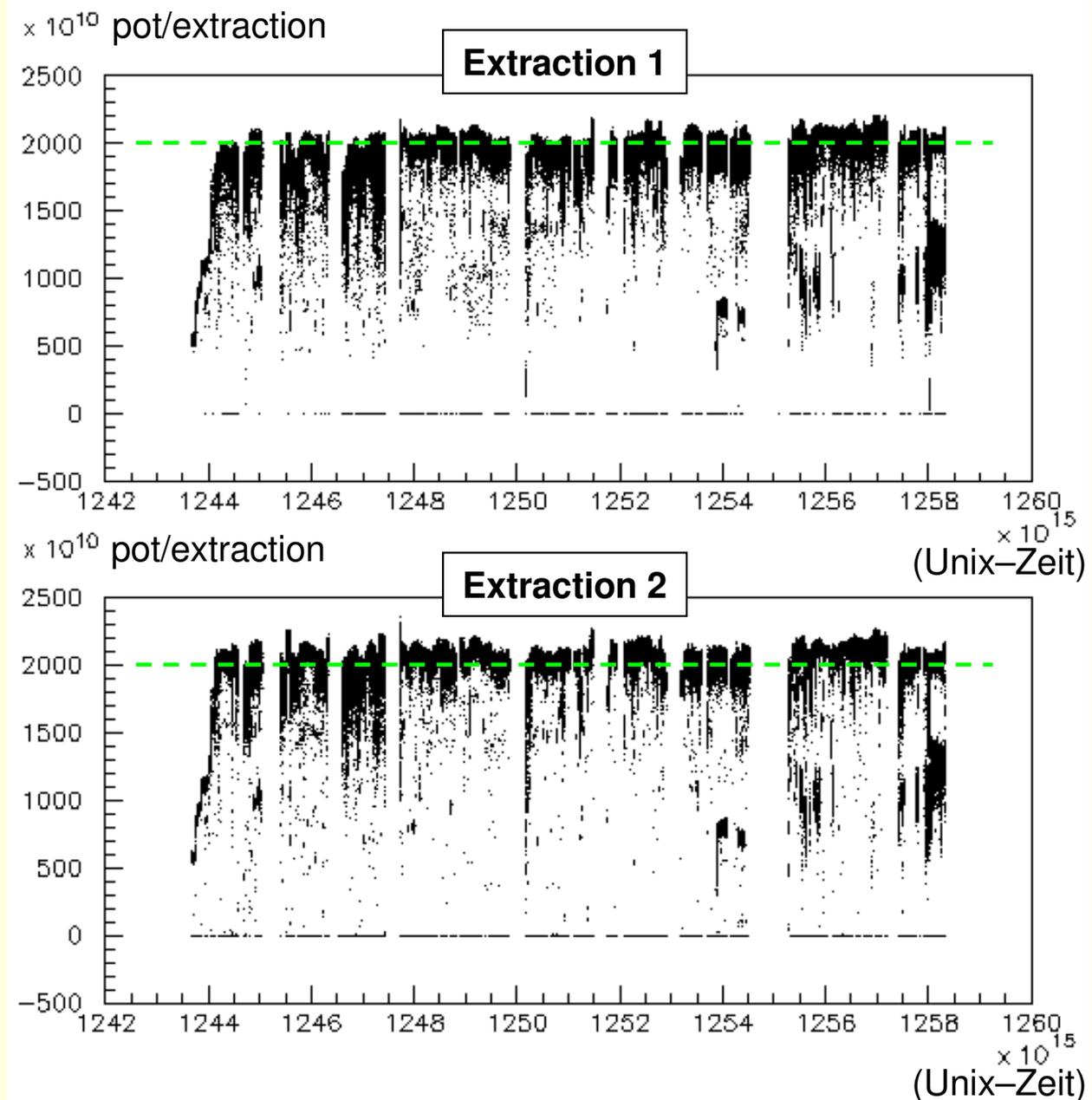
- L'Aquila: 0,64 g
- externes Labor: 0,15 g
- Untergrundlabor: 0,03 g



➔ Keine Auswirkung auf das Detektor-Alignment

- 30.5. – 23.11.2009
- $3,522 \cdot 10^{19}$ pot
(protons on target)
- ca. 21.400 CNGS–
Ereignisse im
Detektor
- ca. 3.700 Vertices
im OPERA–Target

(2008: $1,782 \cdot 10^{19}$ pot)

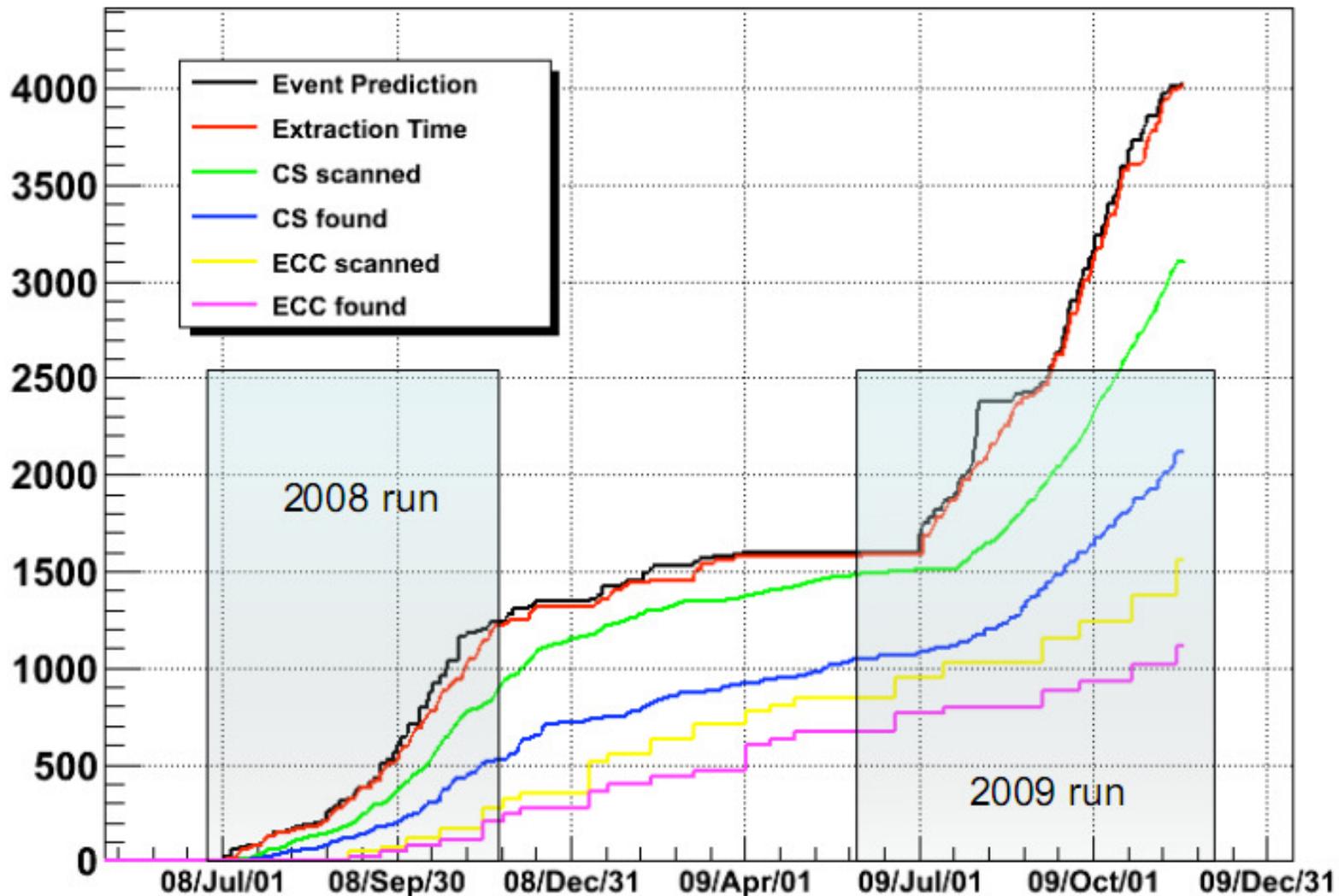


- Anzahl erwarteter Tau–Ereignisse nach 5 Jahren Messzeit bei $4,5 \cdot 10^{19}$ pot/Jahr:

τ -Zerfalls- kanal	B.R. (%)	Signal ($\Delta m^2 = 2,5 \cdot 10^{-3} \text{ eV}^2$)	Background
$\tau \rightarrow \mu$	17,7	2,9	0,17
$\tau \rightarrow e$	17,8	3,5	0,17
$\tau \rightarrow h$	49,5	3,1	0,24
$\tau \rightarrow 3h$	15,0	0,9	0,17
Summe		10,4	0,75

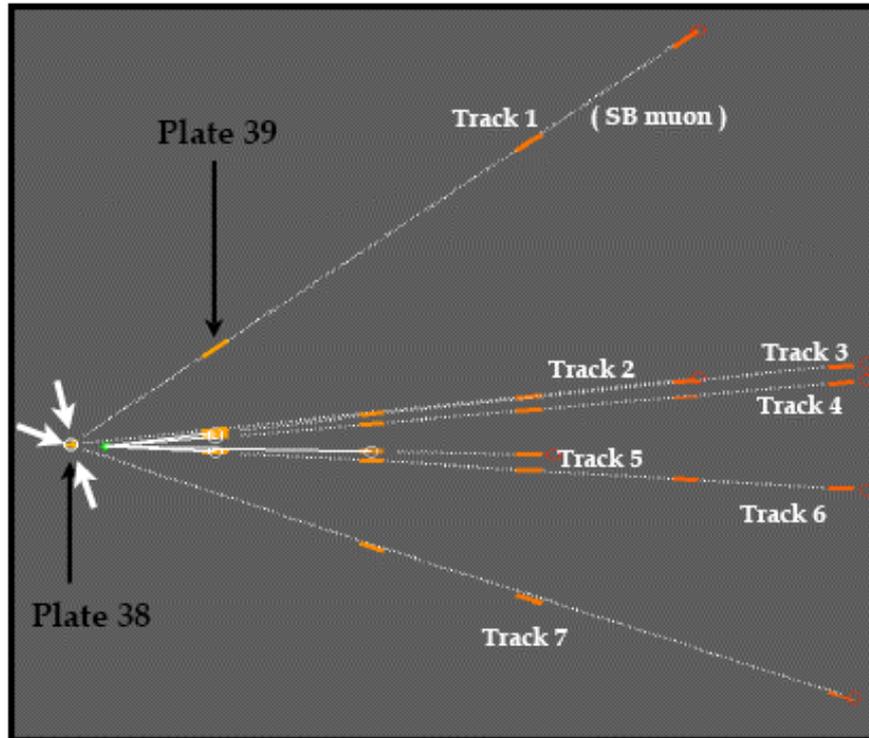
➔ nach Analyse aller Daten von 2008 und 2009: ca. 2,5 τ

2008+2009 Run



Event 234654975

Brick 85405



VERTEX 1

	Impact Parameter
Track 1	1,36
Track 2	0,88
Track 7	0,51

Primärer Vertex

X	66716,60
Y	49892,8
Z	90,9

VERTEX 2

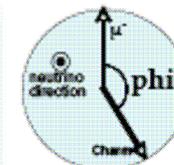
	Impact Parameter
Track 3	1,13
Track 4	1,81
Track 5	1,99
Track 6	1,39

Zerfallsvertex

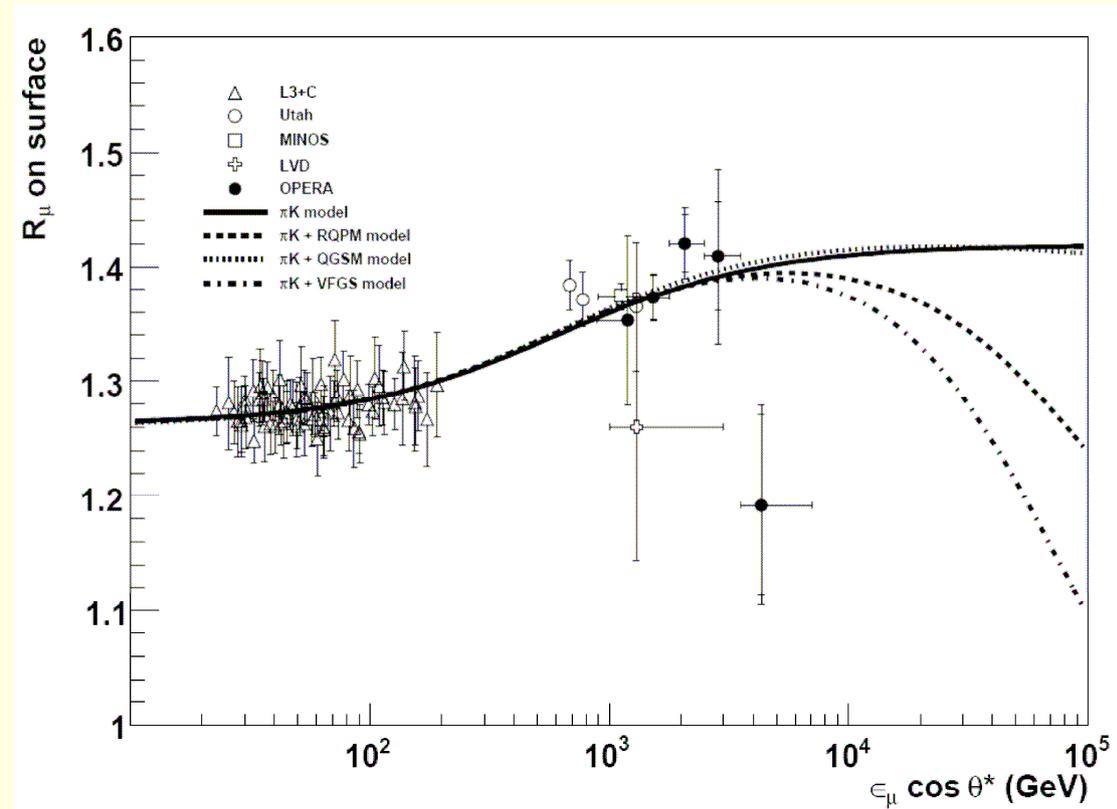
X	66710,10
Y	49899
Z	403,9



T _x	T _y	Flight Length (μm)	phi	minimum mass (GeV/c ²)
-0,0207	0,0198	313,1	173,2°	1,7



- μ^+/μ^- –Verhältnis
im TeV–Energiebereich
(LNGS: 3.800 m.w.e.)
- Datensatz: ca. 400.000
atmosphärische Myonen
(ein Teil der Daten von
2008)



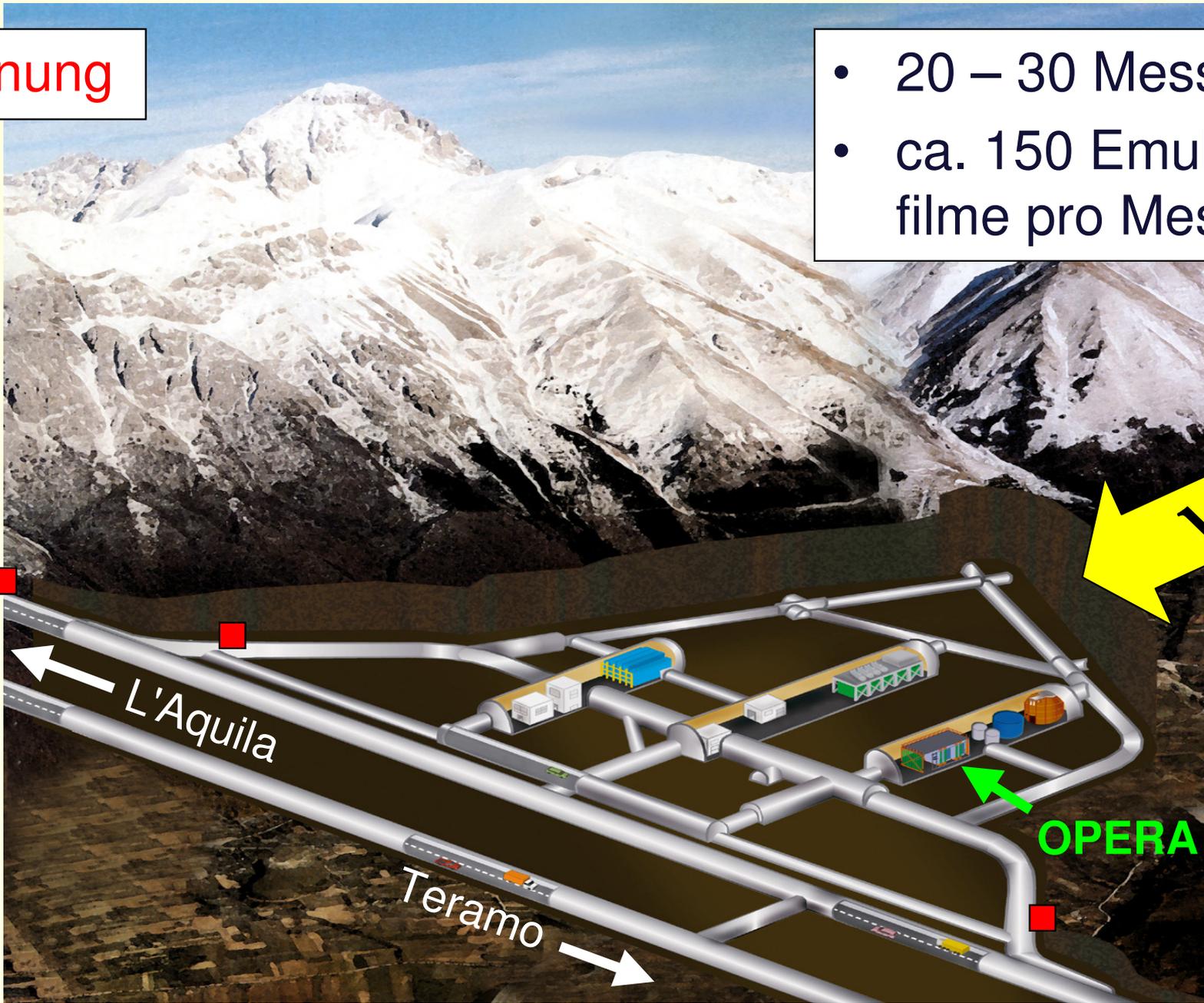
➔ "Measurement of the atmospheric muon charge ratio with the OPERA detector"

(<http://arxiv.org/abs/1003.1907>)

EPJ C: accepted for publication)

in Planung

- 20 – 30 Messpunkte
- ca. 150 Emulsionsfilme pro Messpunkt



- OPERA–Detektor und zugehörige Labore haben das Erdbeben vom 6.4.09 unbeschadet überstanden
- CNGS–Strahlbetrieb 2009: $\sim 3,5 \cdot 10^{19}$ pot
 - ~ 3.700 Neutrino–Wechselwirkungen im OPERA–Target
 - nach Auswertung: insgesamt $\sim 2,5$ τ –Ereignisse erwartet
- Analyse der Daten von 2008 ist fast abgeschlossen
- Scanning und Analyse der Daten von 2009 dauert an
- Ladungsverhältnis atmosph. TeV–Myonen wurde bestimmt
- Vermessung des CNGS–Strahlprofils ist in Planung
- Beginn des Strahlbetriebs 2010: Ende April