Laser-based Emittance Measurements for H- Beams

BI Day 2014

T. Hofmann, E. Bravin, U. Raich,
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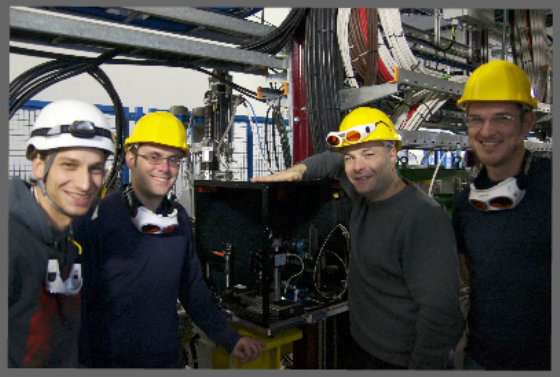

Thank you for your attention!

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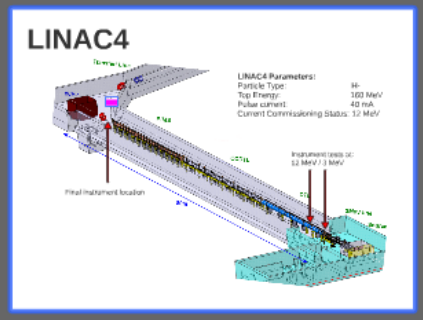

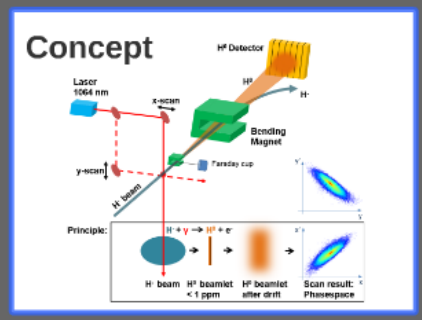

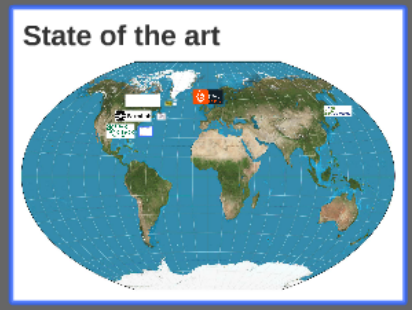

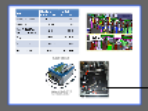

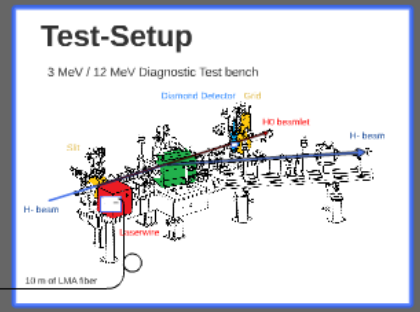

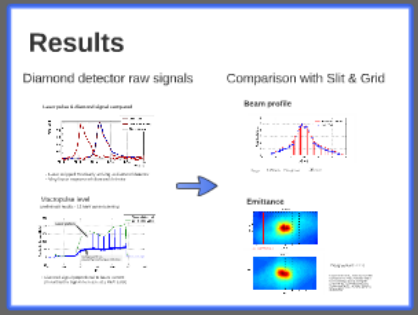

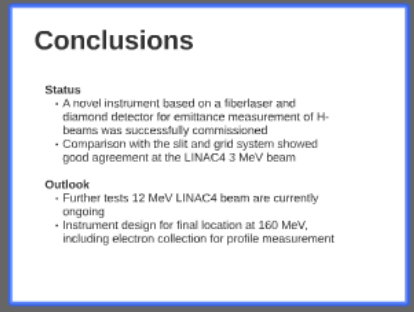

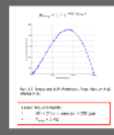

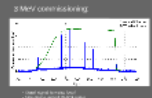

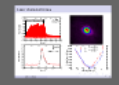

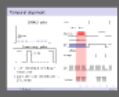

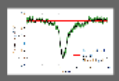

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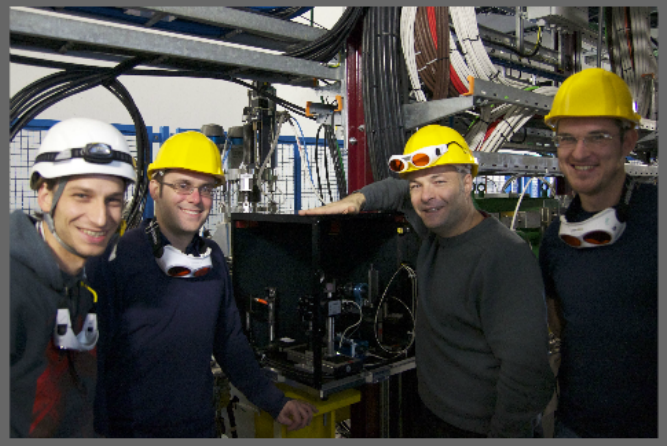

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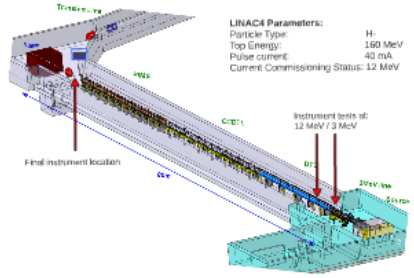
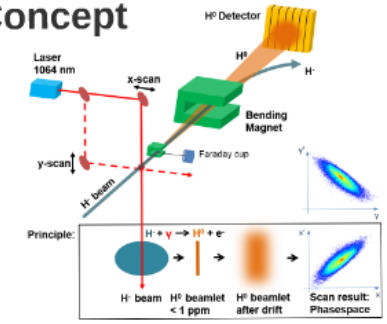
LINAC4

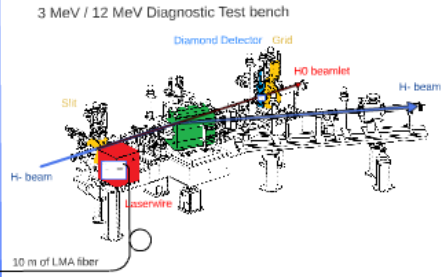


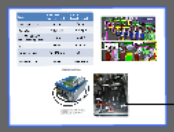
Concept



State of the art

Test-Setup

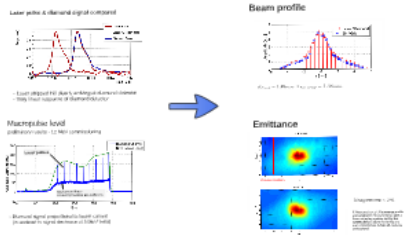




Results

Diamond detector raw signals

Comparison with Slit & Grid



Conclusions

Status

- A novel instrument based on a fiberlaser and diamond detector for emittance measurement of H- beams was successfully commissioned
- Comparison with the slit and grid system showed good agreement at the LINAC4 3 MeV beam

Outlook

- Further tests 12 MeV LINAC4 beam are currently ongoing
- Instrument design for final location at 160 MeV, including electron collection for profile measurement

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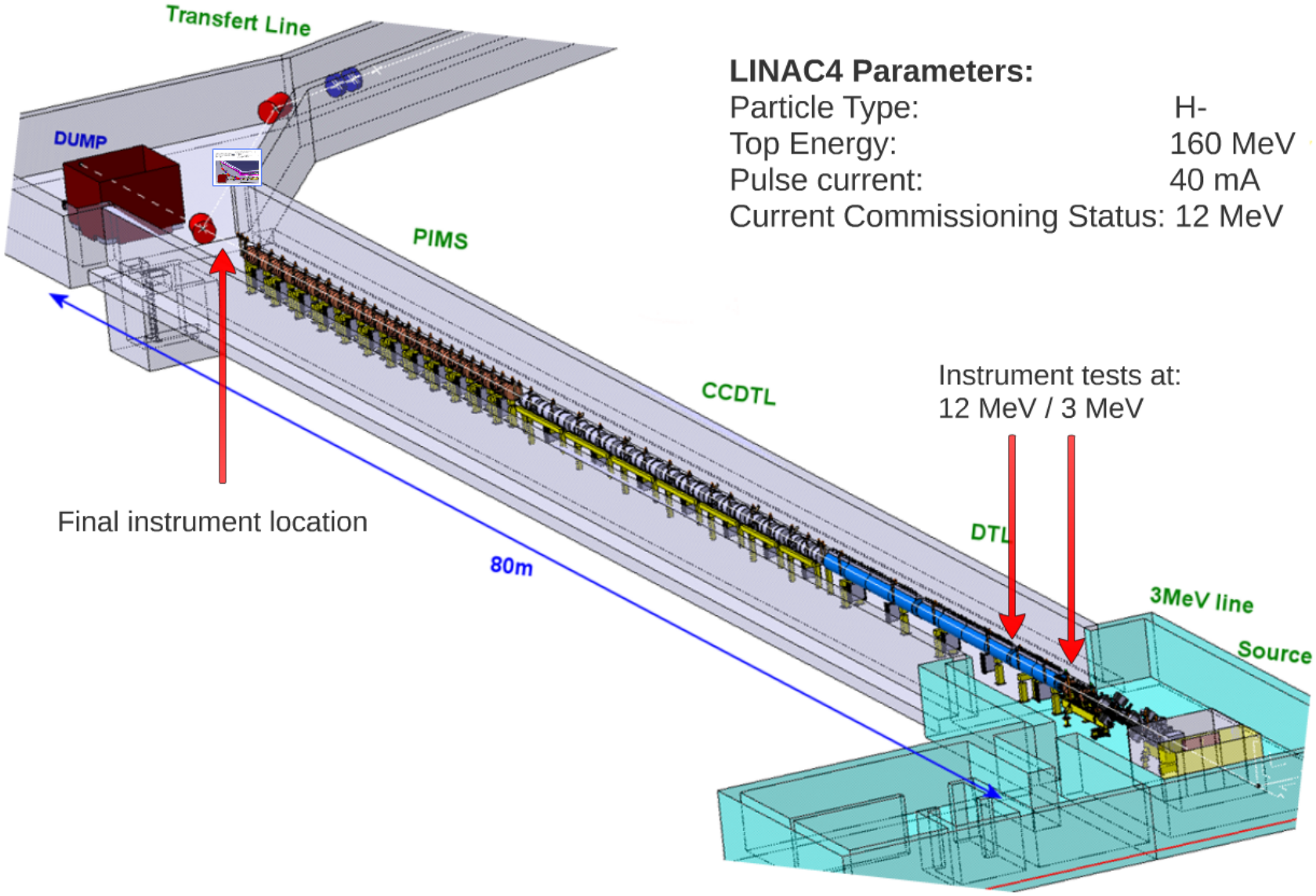


LINAC4 Parameters:

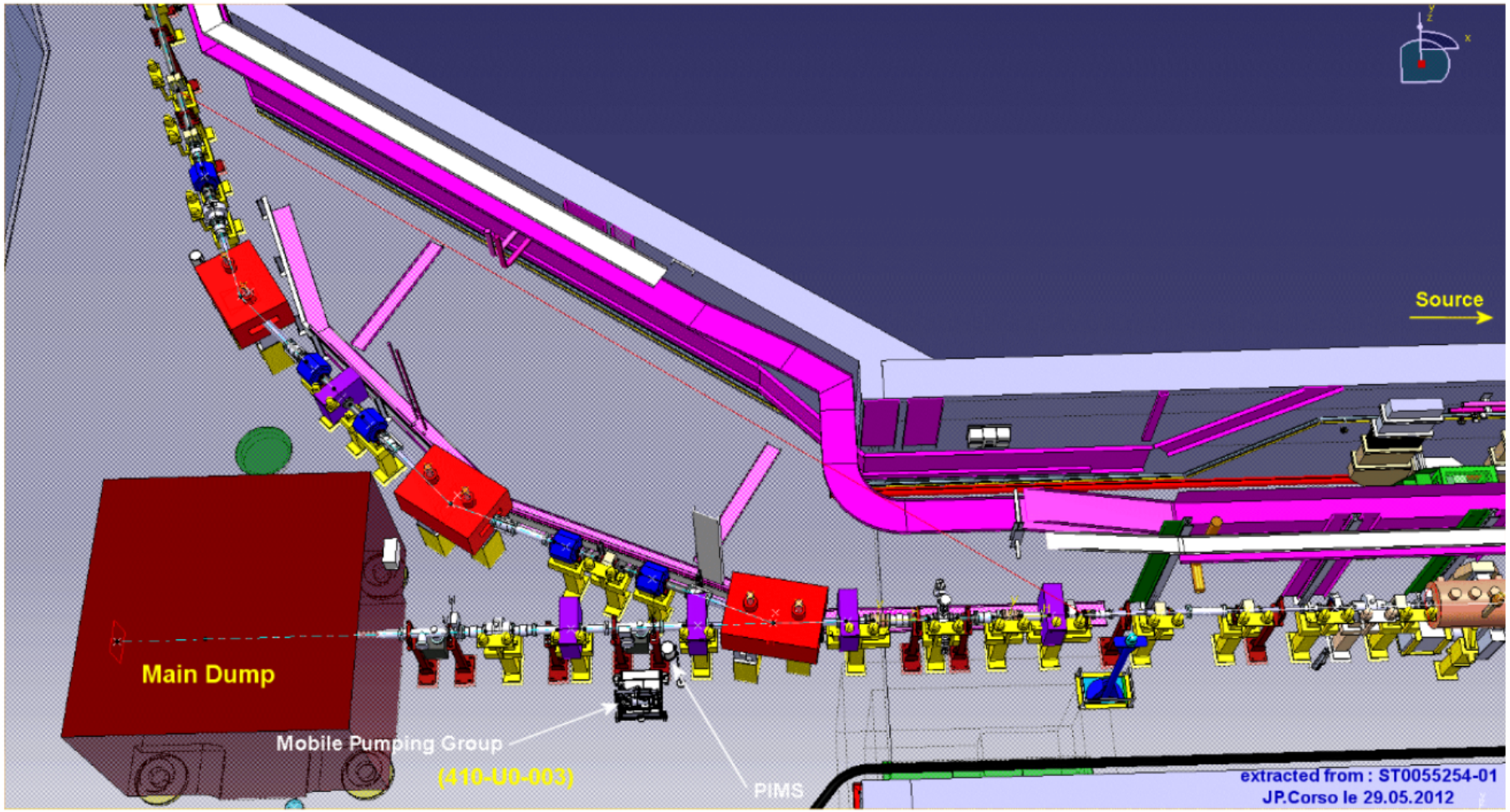
Particle Type:	H-
Top Energy:	160 MeV
Pulse current:	40 mA
Current Commissioning Status:	12 MeV

Conventional method for emittance measurement (**slit & grid**) is not working at this energy, due to the particle range.

Foreseen emittance measurement at 160 MeV:
"3 profile method"

Limitations:

- Maximum pulse length: 100 µs (400 µs nominal)
- Space charge disturbance
- Destructive



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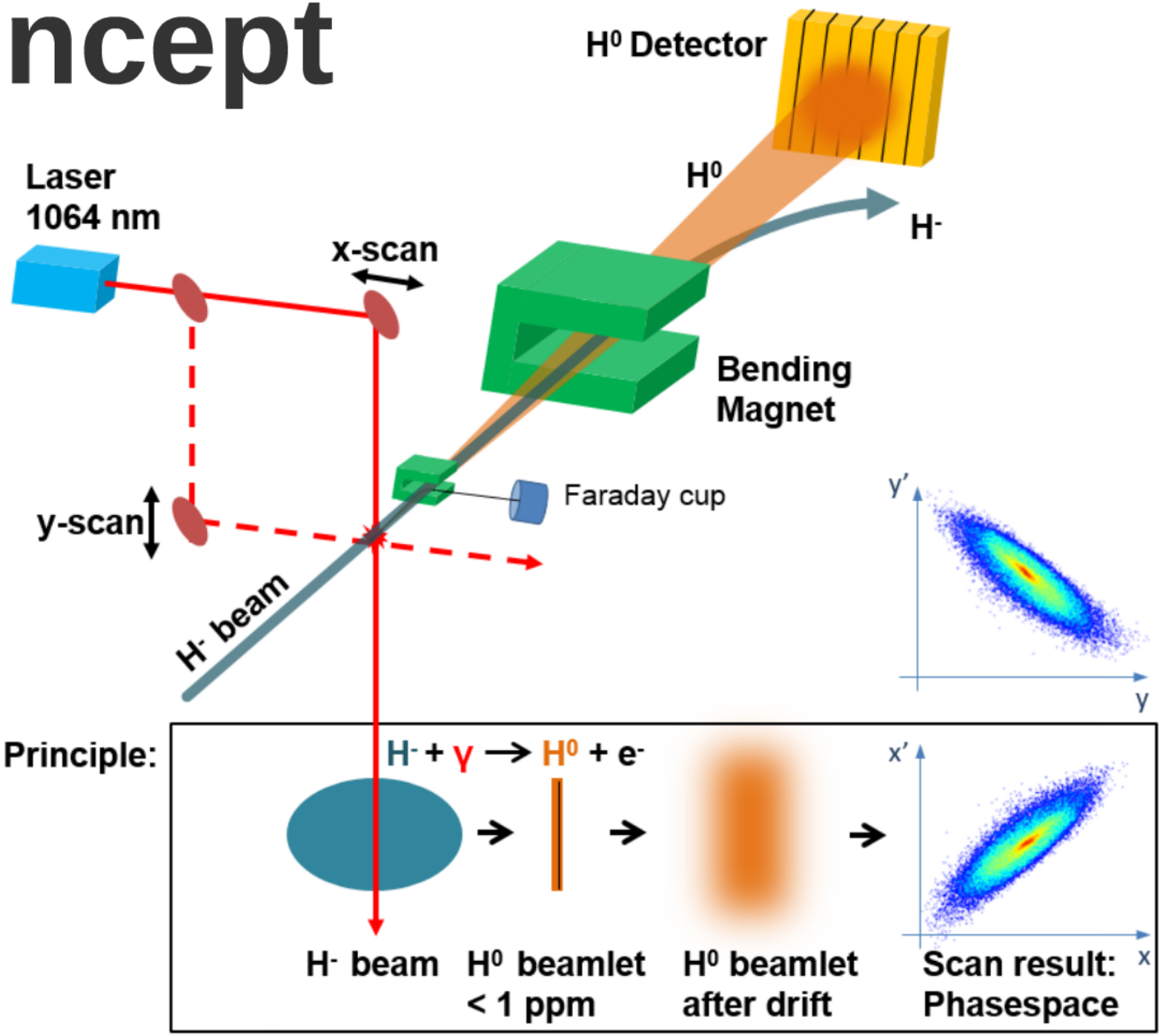

H⁰ Detector
Laser
1064 nm
x-scan
H⁰
H⁻
Bending
Magnet
Faraday cup
y-scan
H⁻ beam
y'
y
Principle:
H⁻ + γ → H⁰ + e⁻
x'
x
H⁻ beam
H⁰ beamlet
< 1 ppm
H⁰ beamlet
after drift
Scan result:
Phasespace

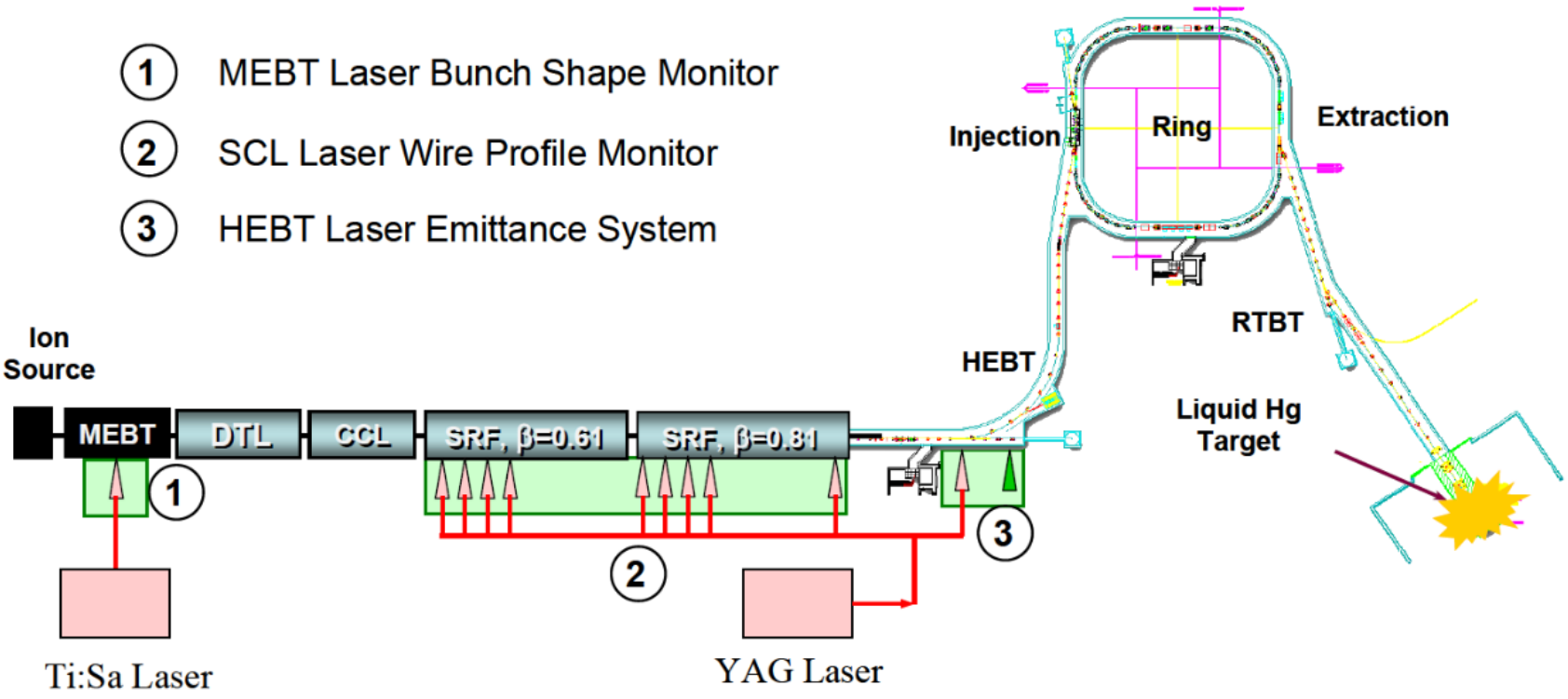
State of the art

Laser Diagnostics at SNS

Beam Energy: 2.5 MeV ... 1 GeV
Beam Current: 38 mA

Laser Pulse Energy: 50 mJ
Laser Pulse Width: 10 ns

1. MEBT Laser Bunch Shape Monitor
2. SCL Laser Wire Profile Monitor
3. HEBT Laser Emittance System

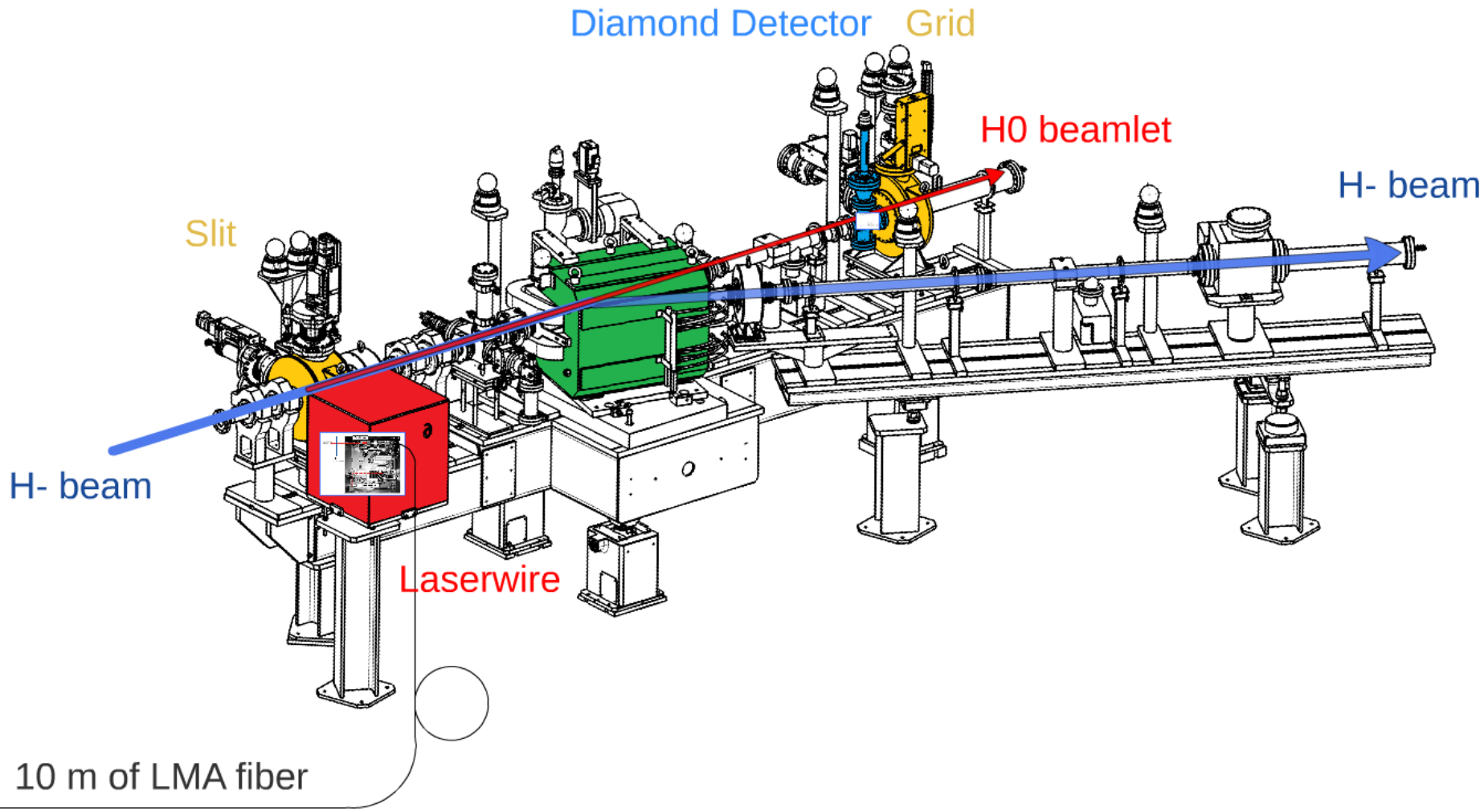


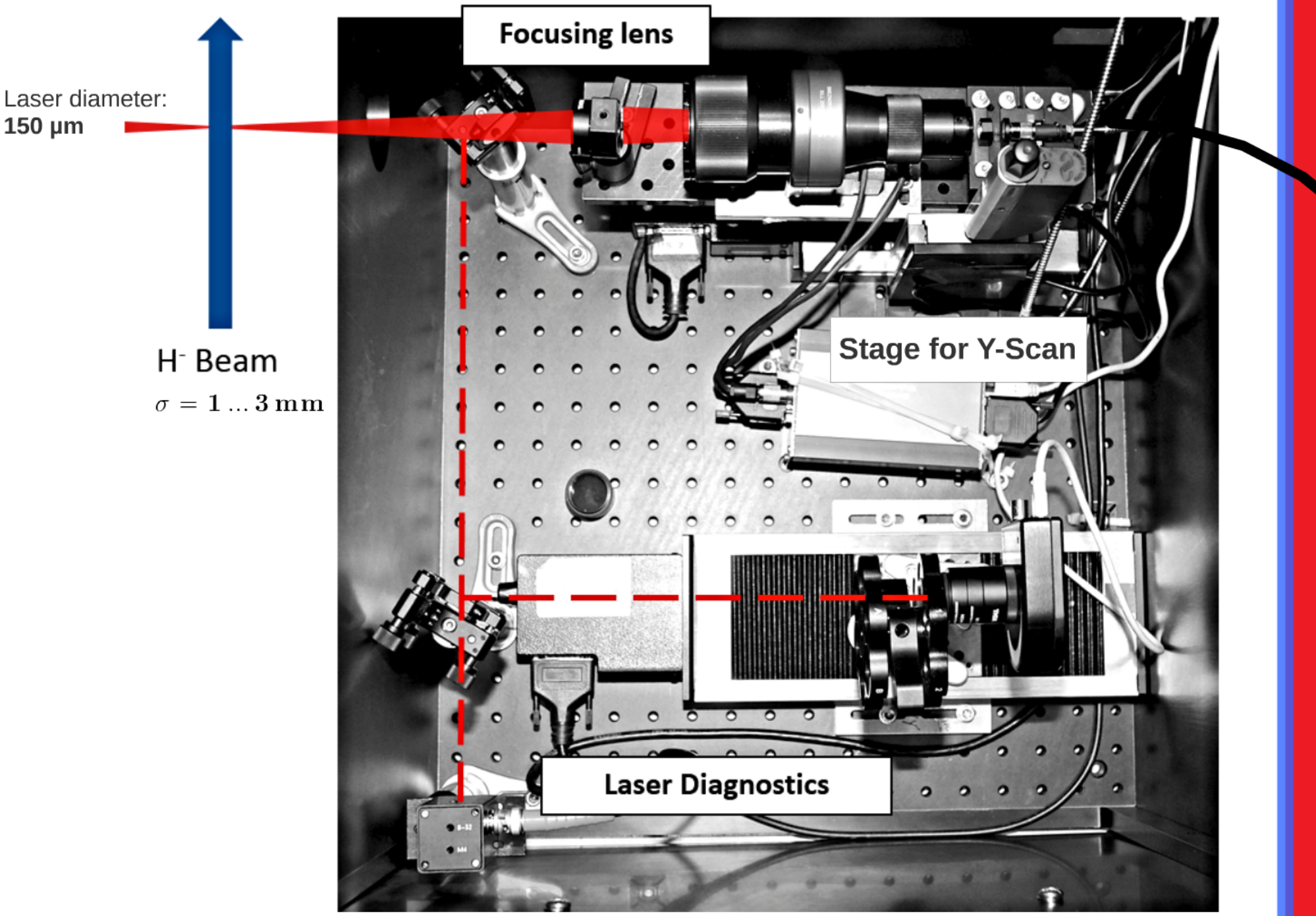
Y. Liu et al., Laser based diagnostics for measuring H- beam parameters, Proc. PAC 2011, New York, NY, USA

Challenge: 250m long free-space laser delivery

Test-Setup

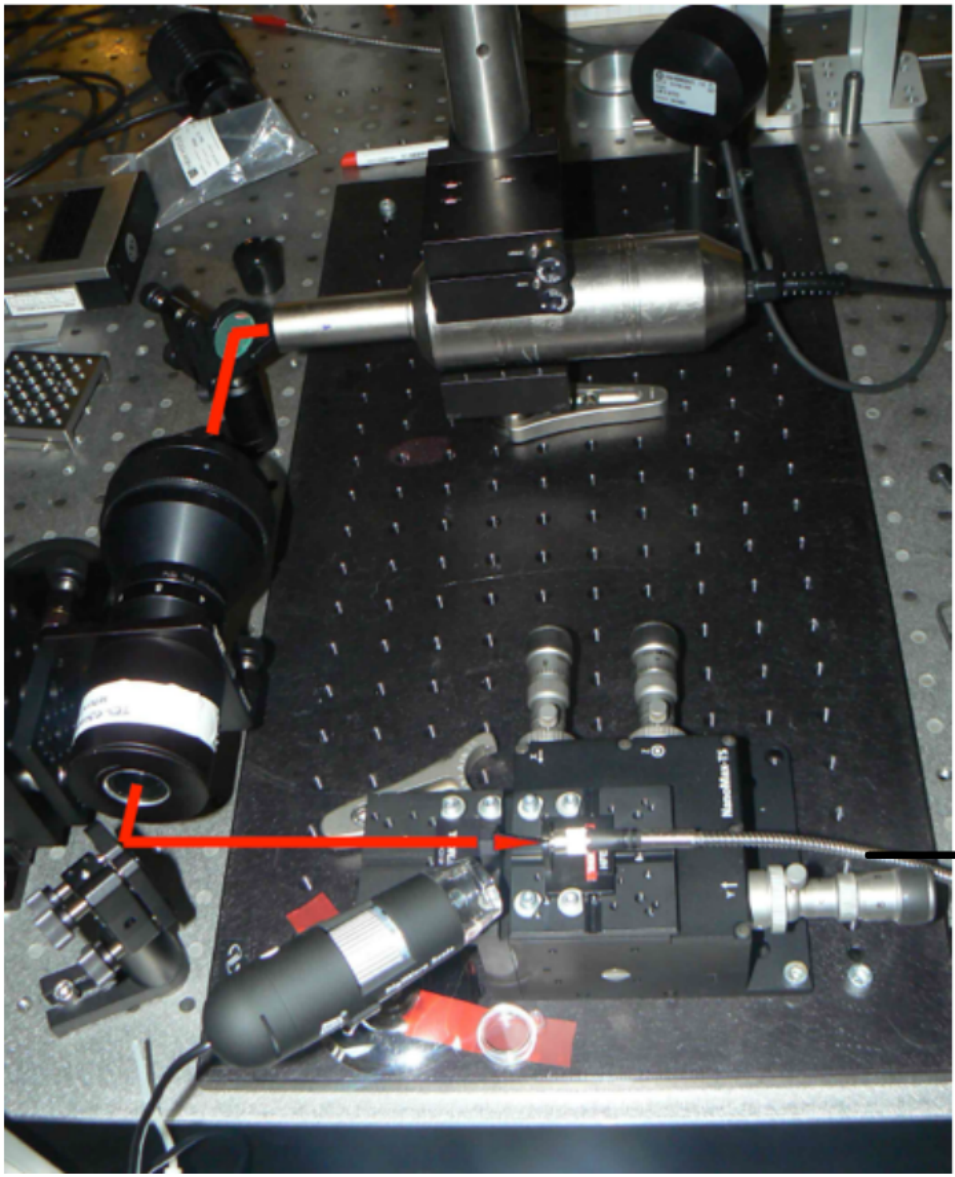
3 MeV / 12 MeV Diagnostic Test bench



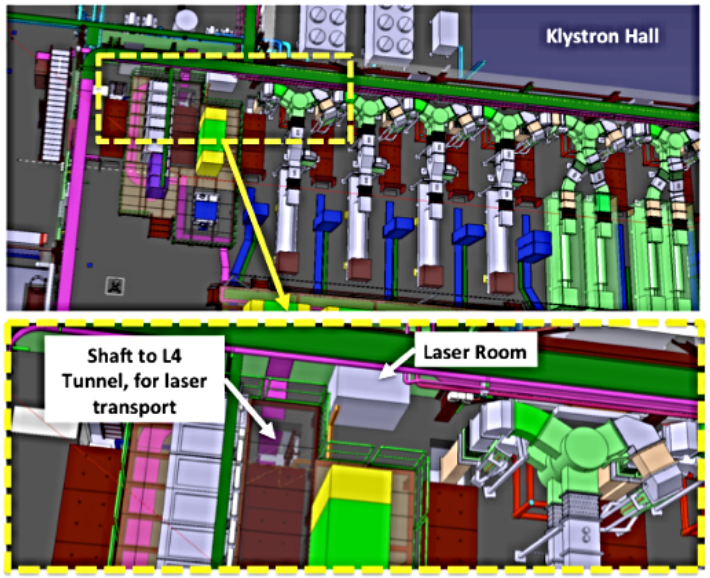

Laser diameter:
150 µm
H- Beam
$\sigma = 1 \ldots 3\,\mathrm{mm}$
Focusing lens
Stage for Y-Scan
Laser Diagnostics

Laser source

Manlight ML30-PL-R-TKS
(commercial available)



Laser	Fiberlaser (used in tests)	Nd-YAG (as reference)
Energy per pulse	**0.1 mJ**	**50 mJ**
Diameter	~ 150 µm	~ 200 µm
P_{strip} @ 160 MeV for H^- crossing Laser	**0.1 %**	**> 99 %**
t_{pulse}	80 ns	5…10 ns
Repetition rate	10…100 kHz	< 20 Hz
Beam transport	**Fiber**	**Free Space**



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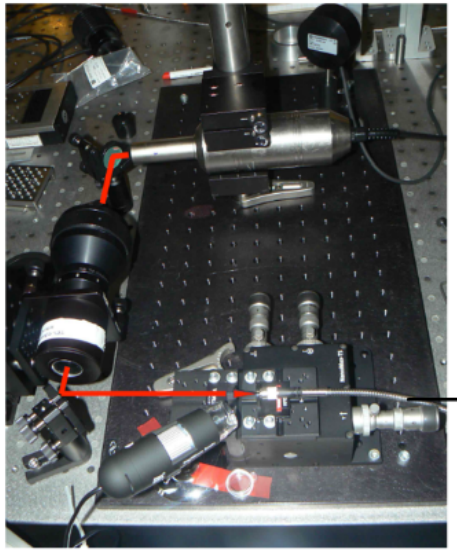
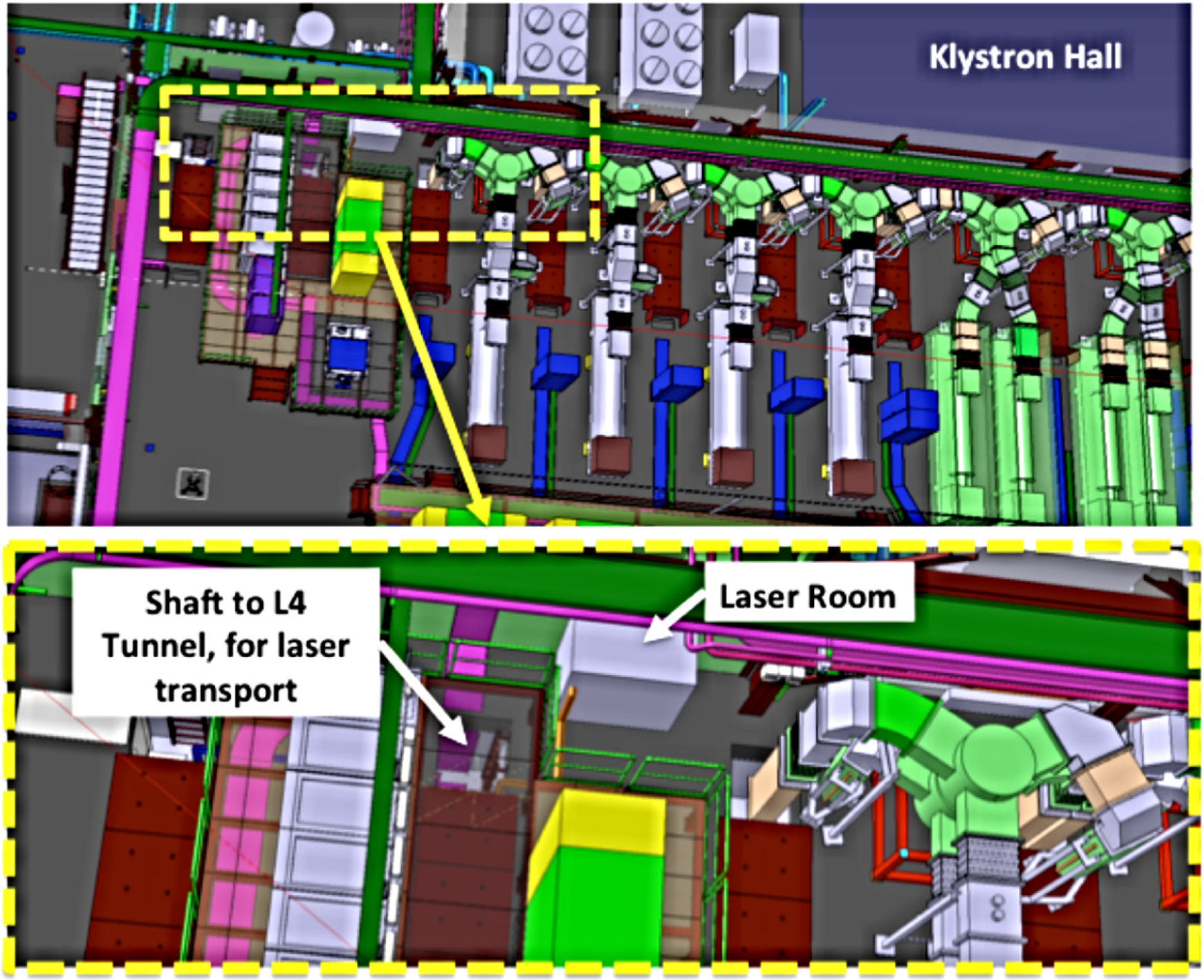
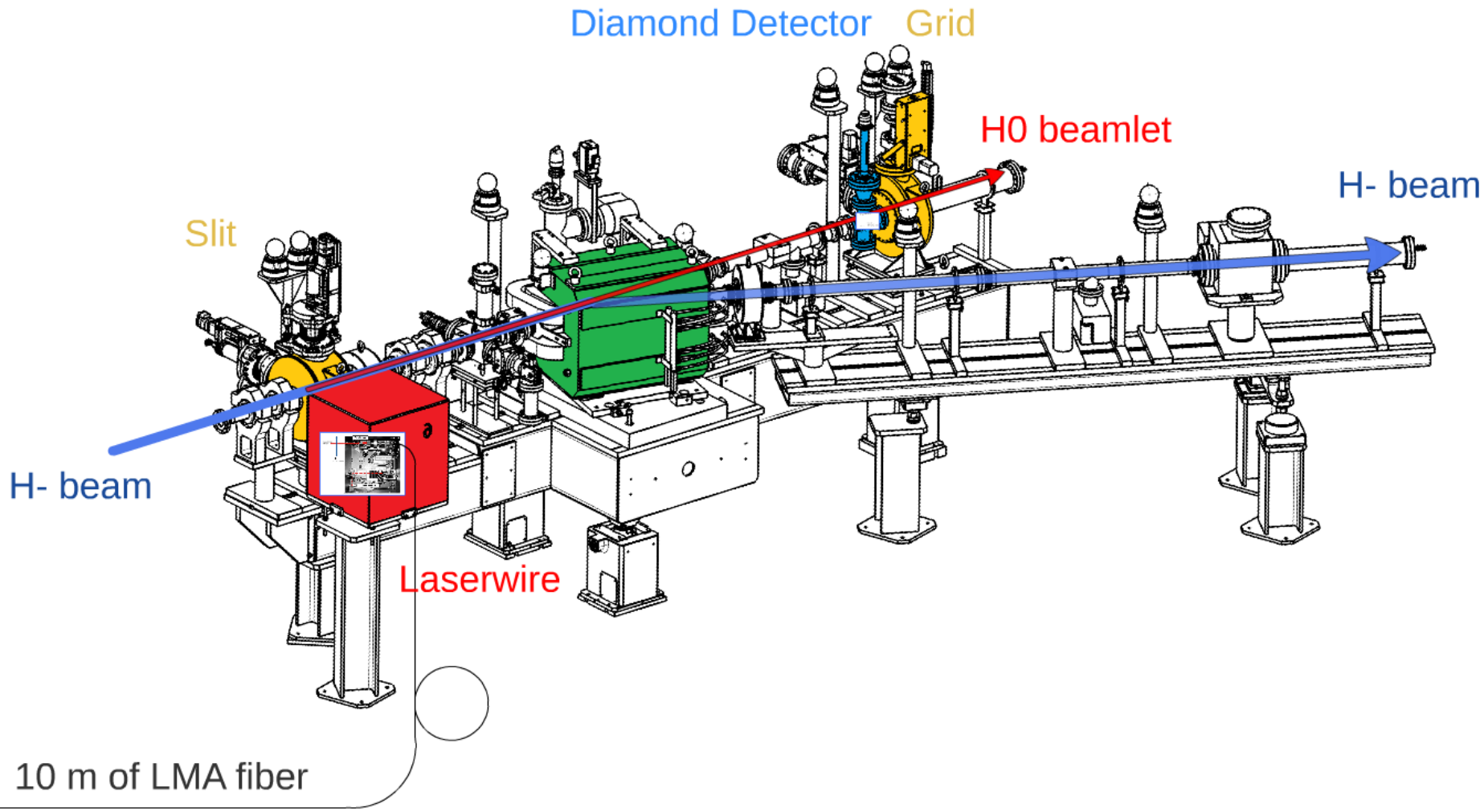



Klystron Hall
Shaft to L4 Tunnel, for laser transport
Laser Room

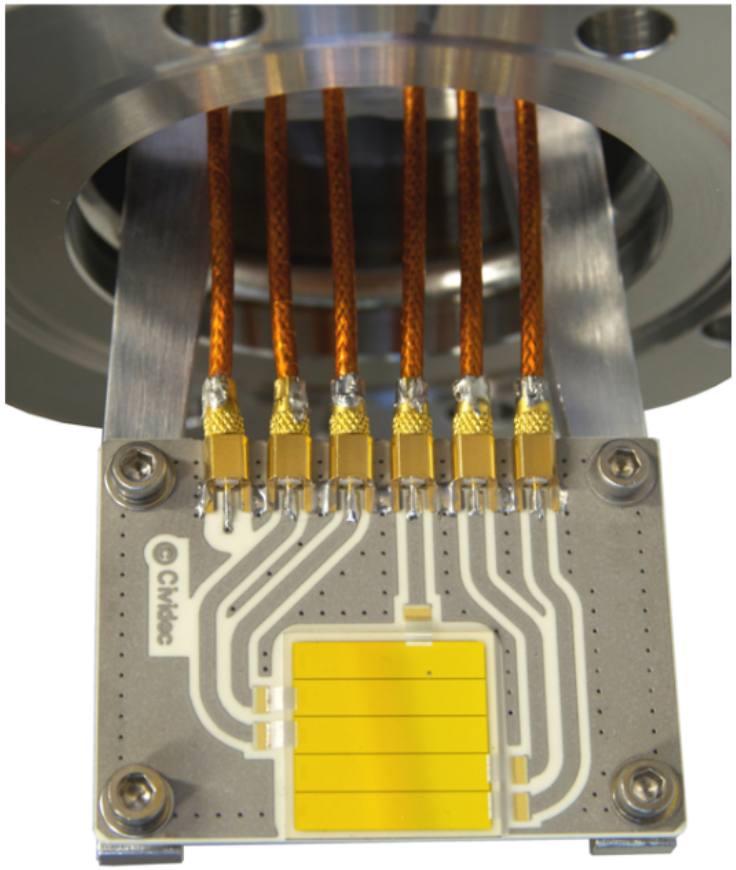
Test-Setup

3 MeV / 12 MeV Diagnostic Test bench

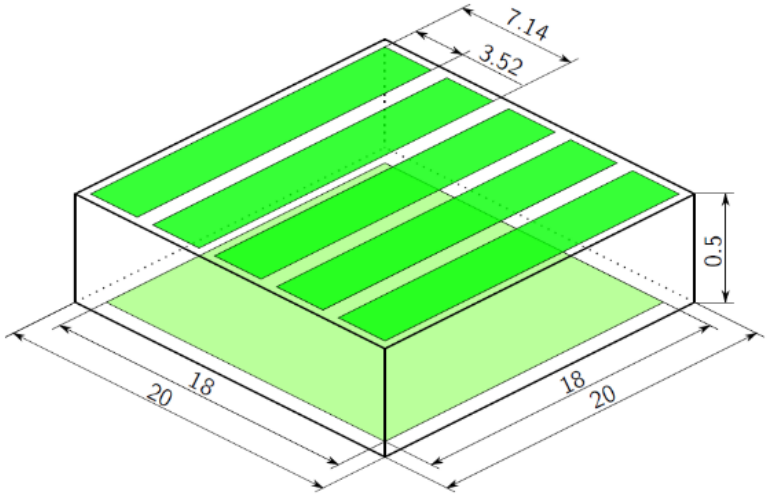


Diamond Strip Detector

- Prototype -



Ref: CIVIDEC Instrumentation, Austria

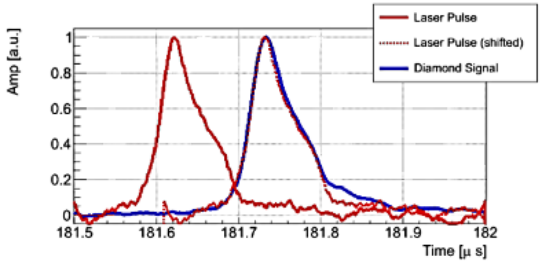


- High sensitivity (~$10^4\ e^- / H^0$)
- High bandwidth (< ns)
- Radiation tolerant ($10^{15}\ cm^{-2}$)
- Strip electrodes for spatial resolution

Results

Diamond detector raw signals

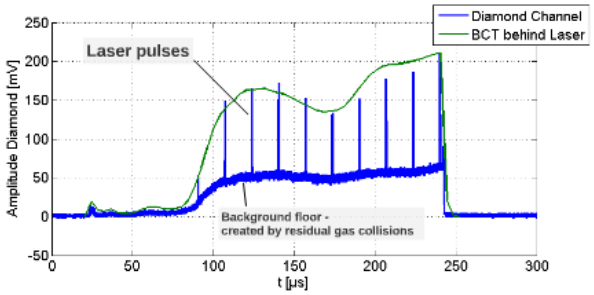
Laser pulse & diamond signal compared



- Laser stripped H0 clearly arriving at diamond detector
- Very linear response of diamond detector

Macropulse level

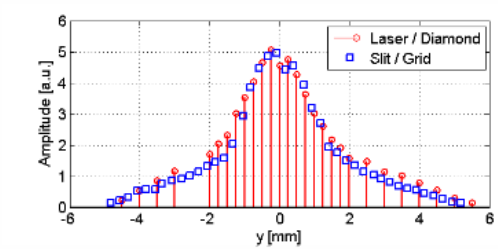
preliminary results - 12 MeV commissioning



- Diamond signal proportional to beam current (in contrast to signal decrease at 3 MeV tests)

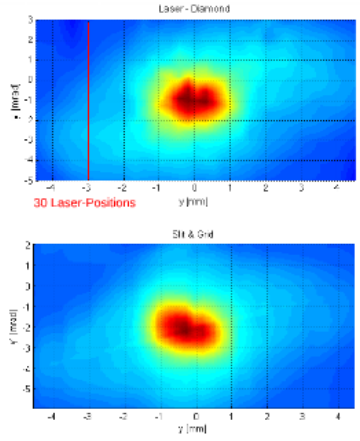
Comparison with Slit & Grid

Beam profile



$\sigma_{Laser} = 1.49mm \quad \sigma_{Slit/Grid} = 1.36mm$

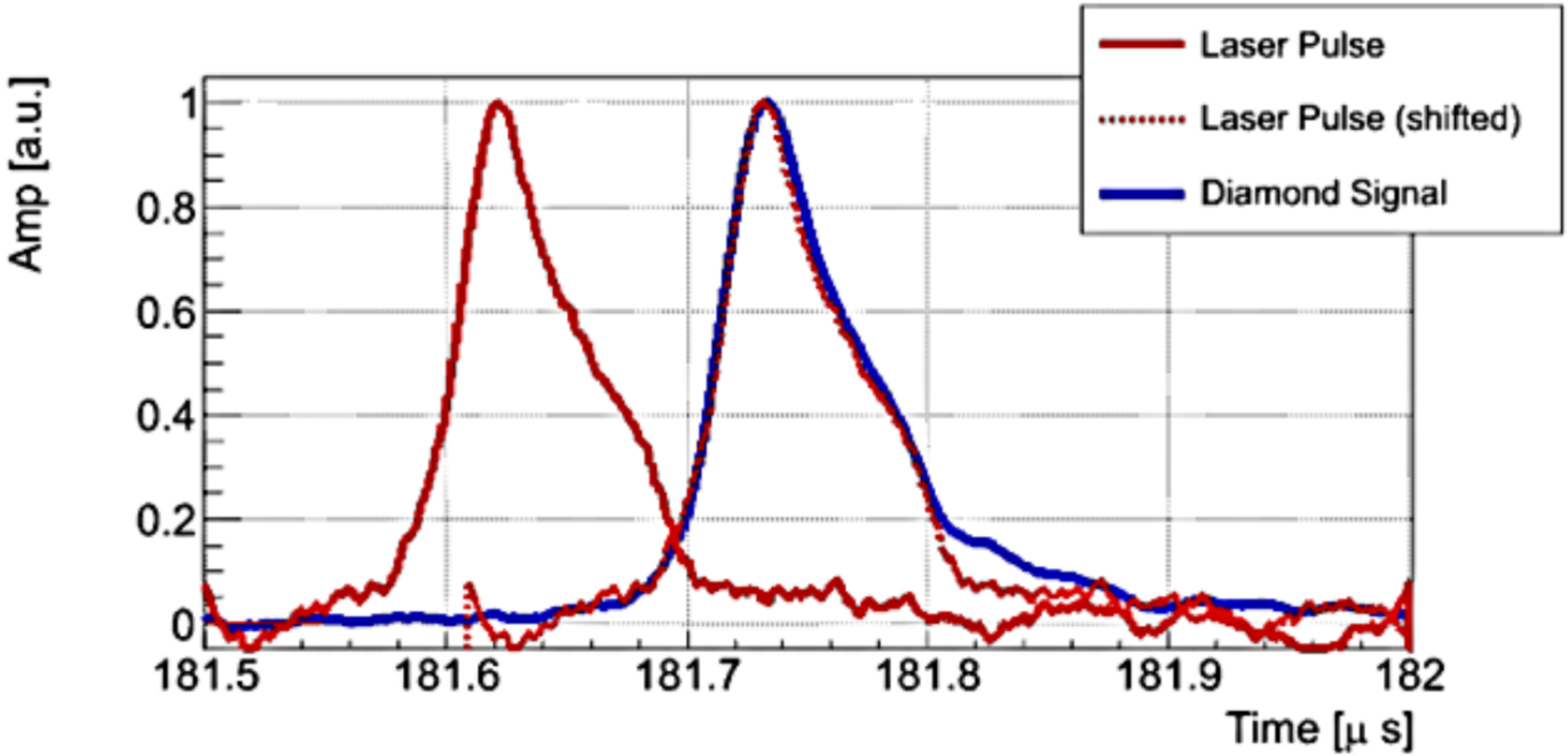
Emittance



Disagreement: < 2 %

F. Roncarolo et al., Transverse profile and emittance measurements with a laser stripping system during the CERN LINAC4 commissioning at 3 and 12 MeV, Proc. LINAC14, Geneva, Switzerland

Laser pulse & diamond signal compared



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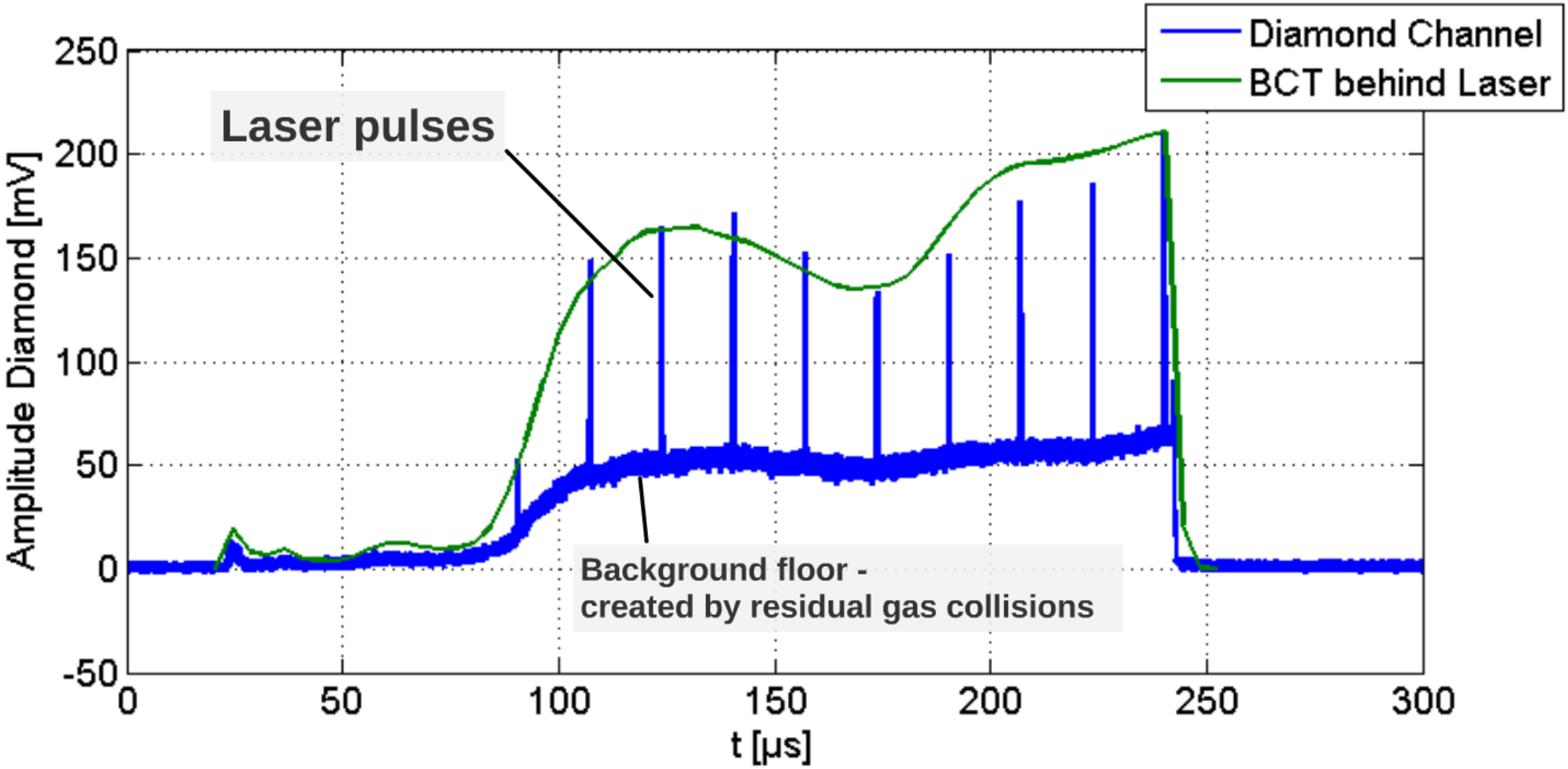

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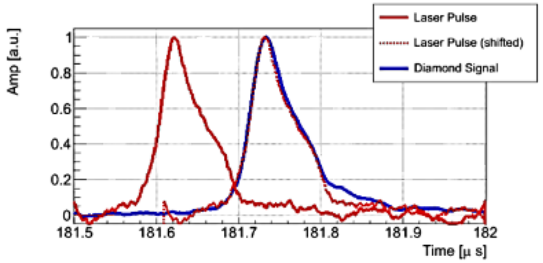

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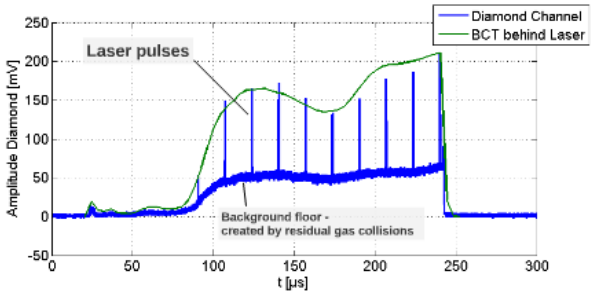

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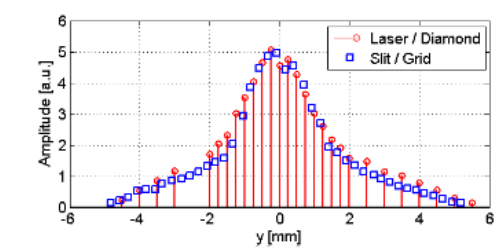

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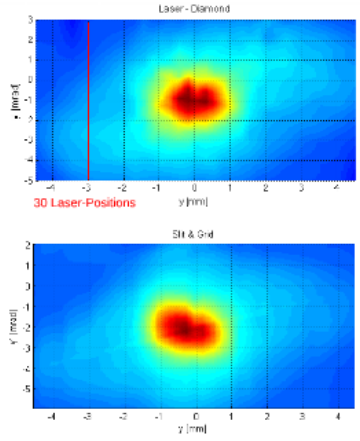

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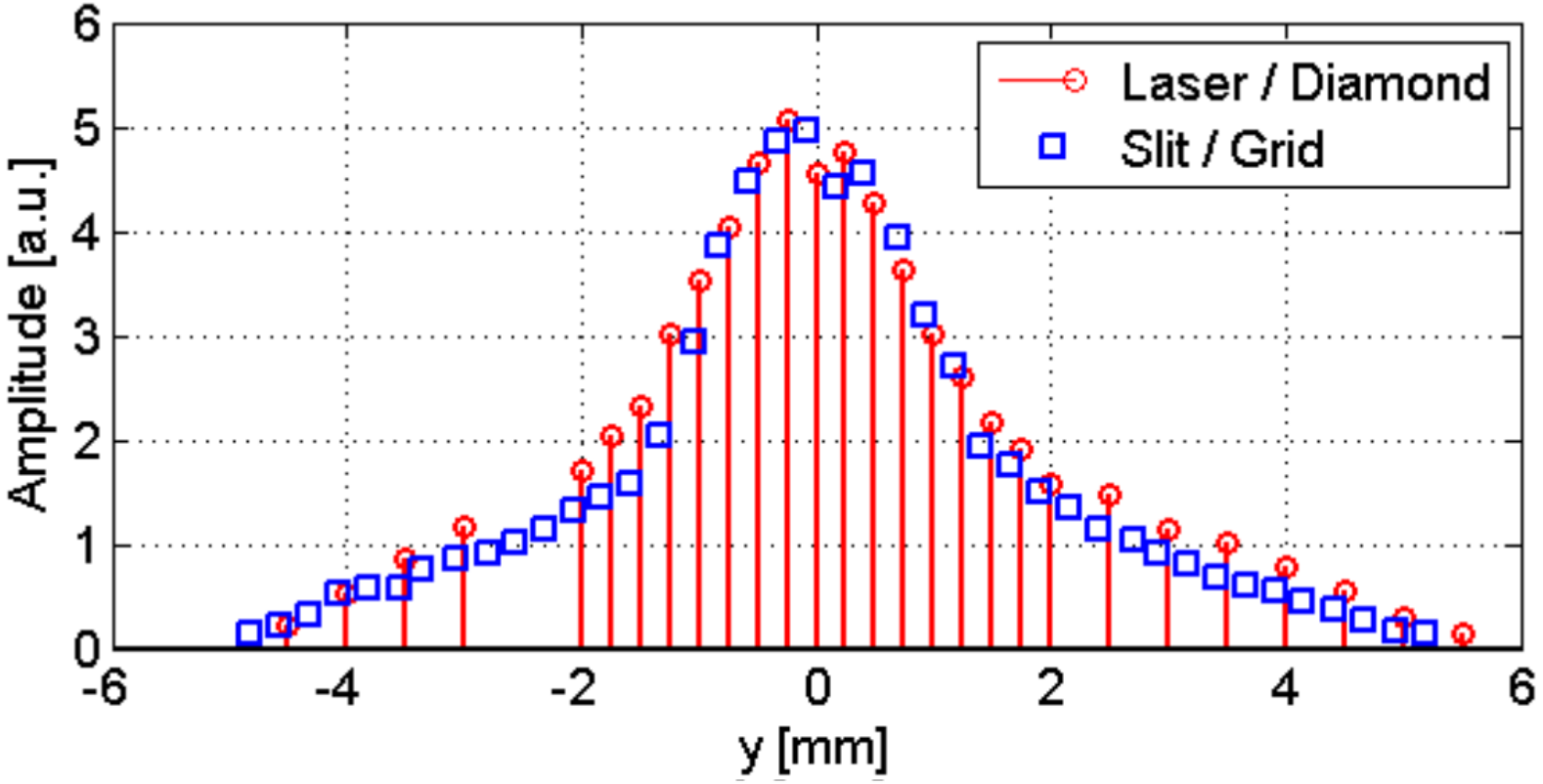

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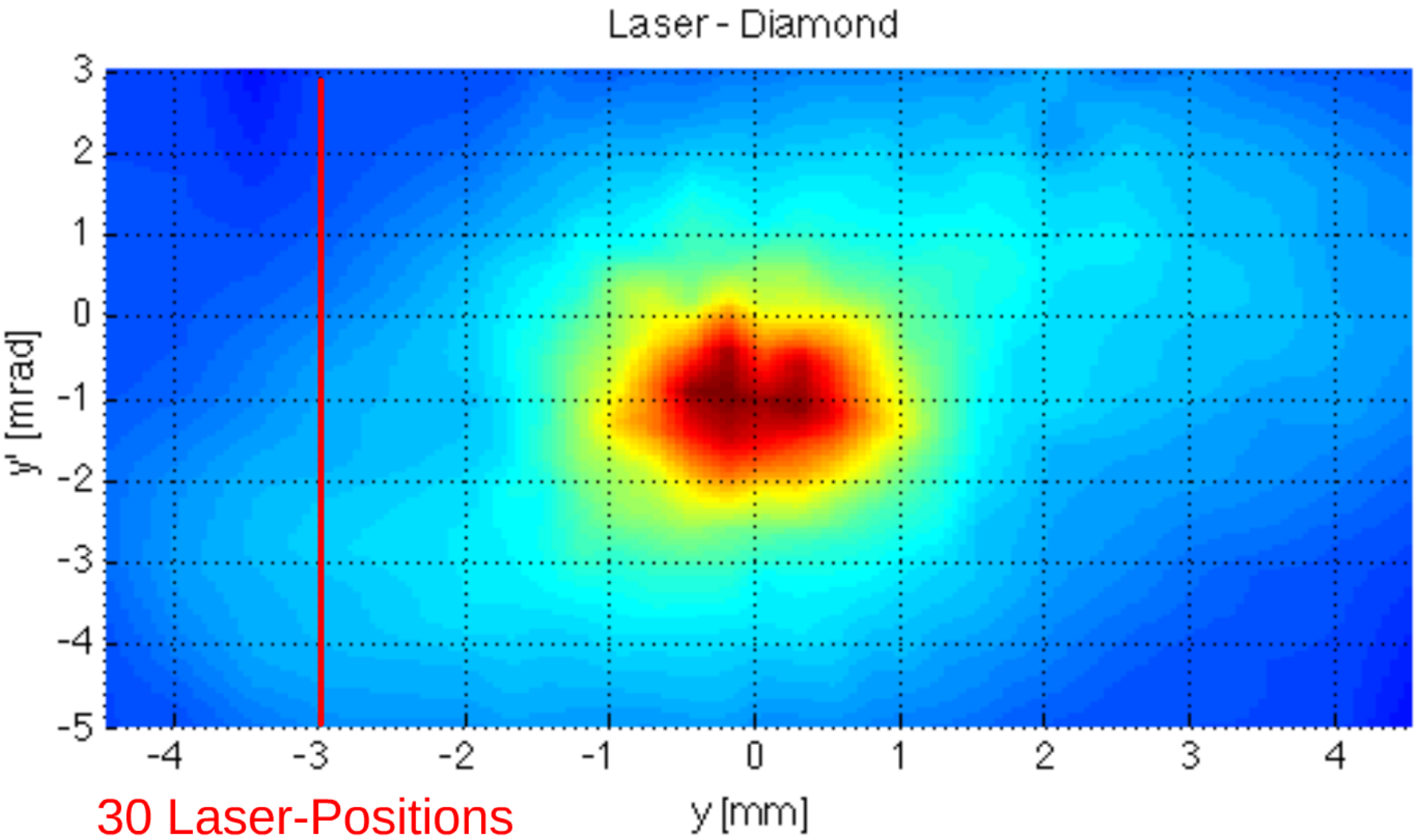
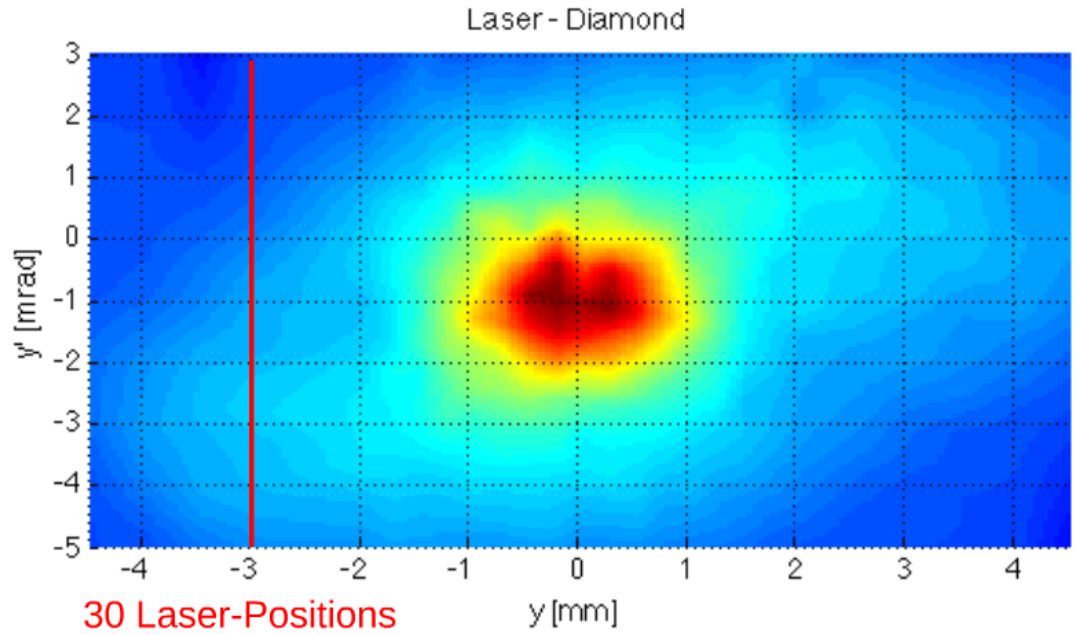
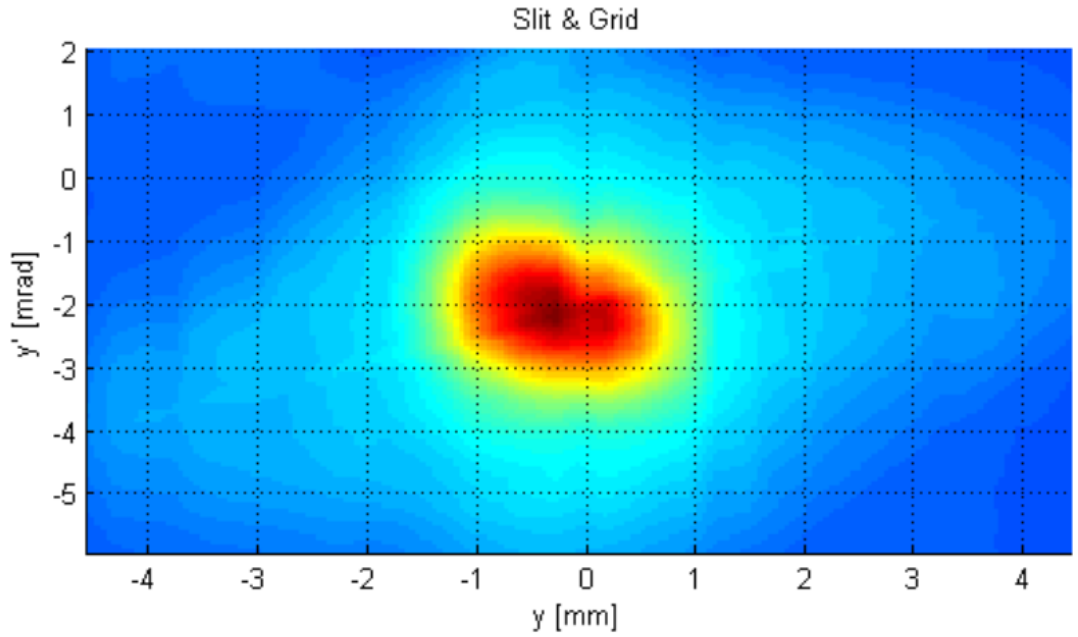


30 Laser-Positions

Emittance





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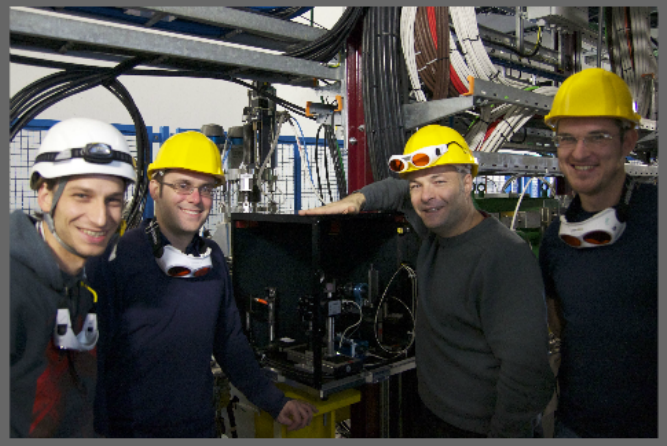

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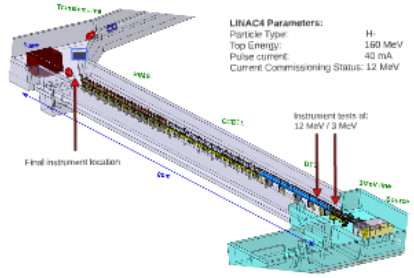
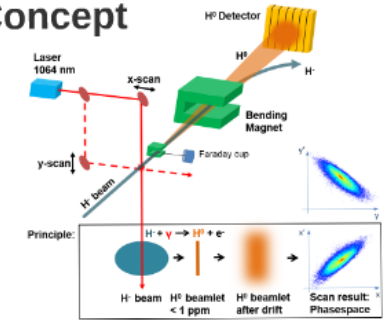
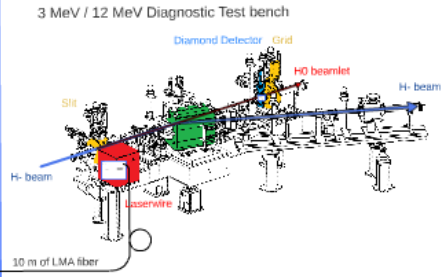


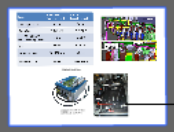
Concept



State of the art

Test-Setup

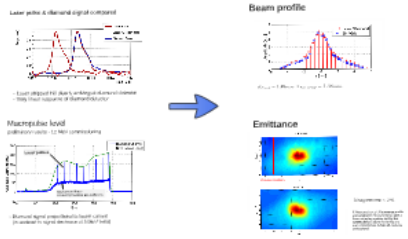




Results

Diamond detector raw signals

Comparison with Slit & Grid



Conclusions

Status

- A novel instrument based on a fiberlaser and diamond detector for emittance measurement of H- beams was successfully commissioned
- Comparison with the slit and grid system showed good agreement at the LINAC4 3 MeV beam

Outlook

- Further tests 12 MeV LINAC4 beam are currently ongoing
- Instrument design for final location at 160 MeV, including electron collection for profile measurement

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