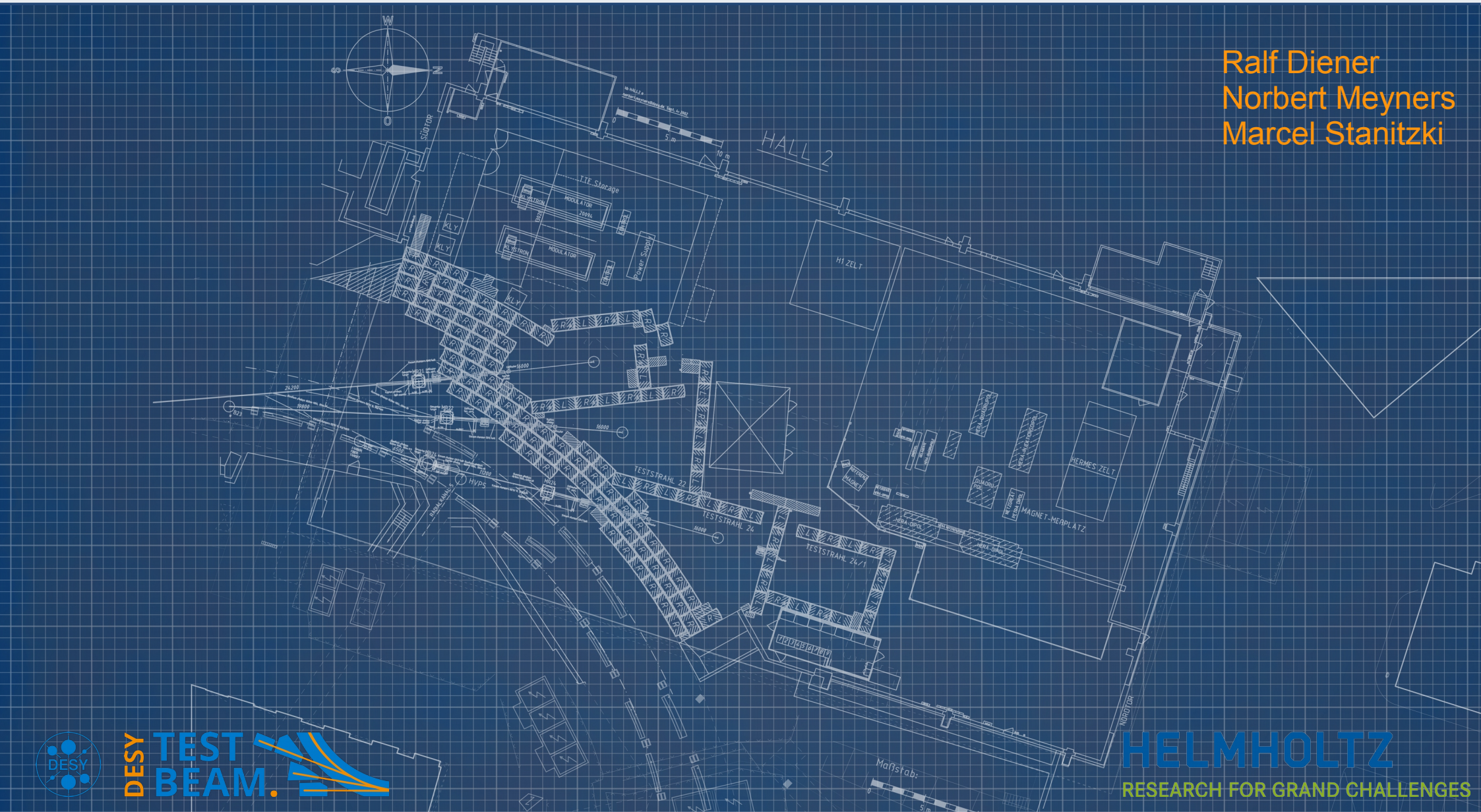
# The DESY II Test Beam Facility – Status and Future

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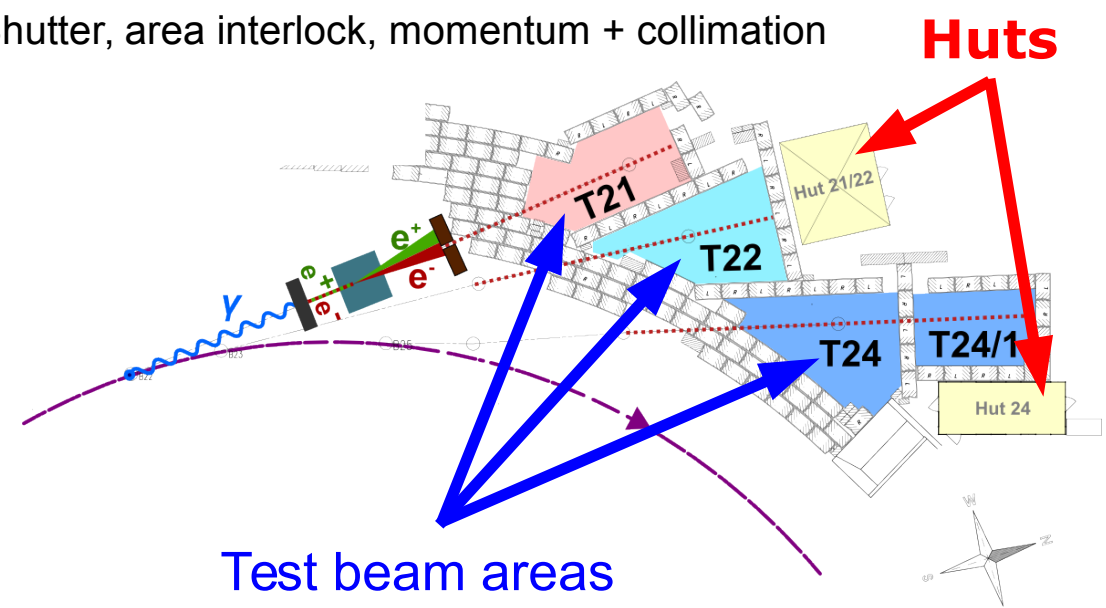
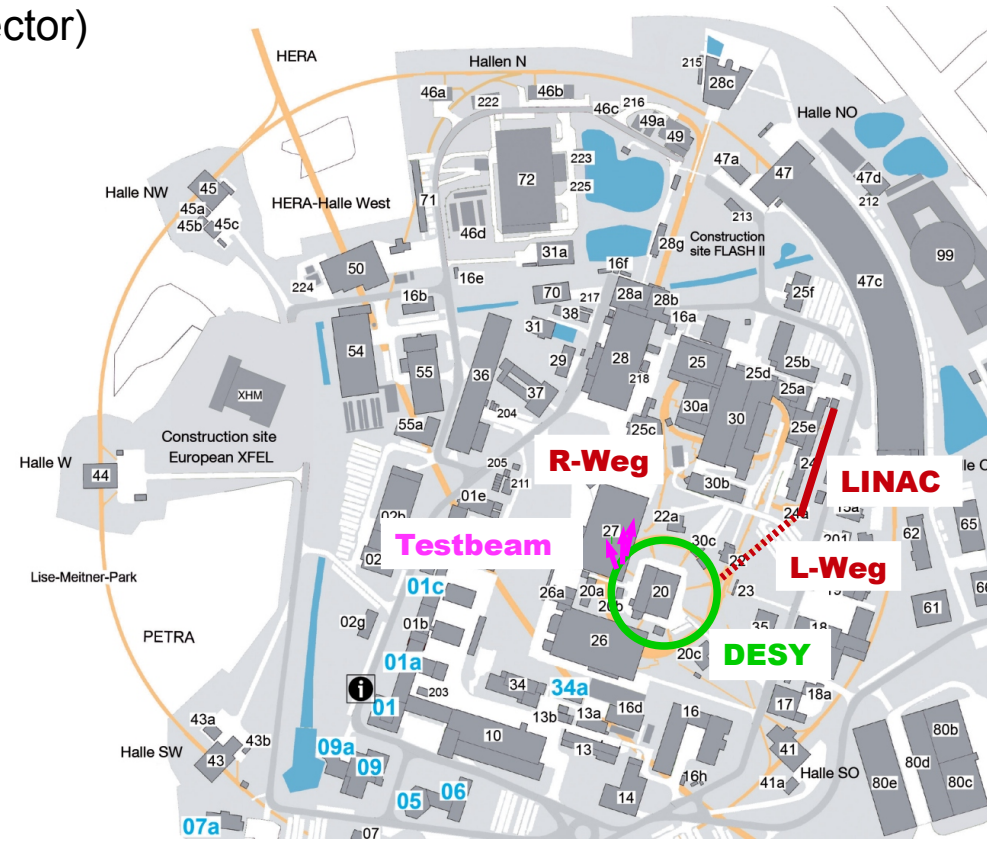
DESY TEST BEAM.

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

# DESY II Test Beam Facility

- Facility parasitic fed by DESY II synchrotron (PETRA III injector)
  - 1 bunch per fill, 30 ps, 1 MHz
- 3 carbon fiber targets generate bremsstrahlung photons
- Conversion at target to $e^+/e^-$ with energies up to 6 GeV
- Single electrons, rates depend on:
  beam line, energy, target, collimation
- Very high availability (~ 99 % uptime)
- Three individual beam lines, controlled by the user
  - Shutter, area interlock, momentum + collimation

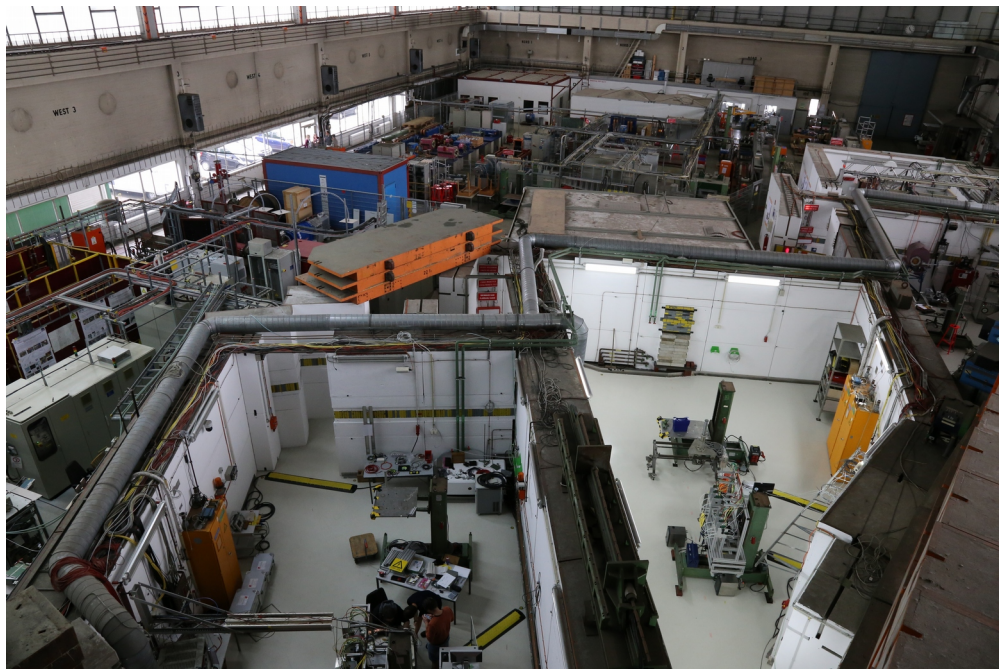


# DESY II Test Beam Facility - Infrastructure

- All the useful things:
  - 30 kg and 1 ton stages, 25 t crane
  - Patch panels: Ethernet, optical fiber, BNC, S-HV
  - IP cameras
  - Dry nitrogen, cooling water, gas setup (2 areas)
  - Beam monitor
  - Two EUDET-type beam telescopes
- Dipole magnet in TB 21 (~1.5 T)

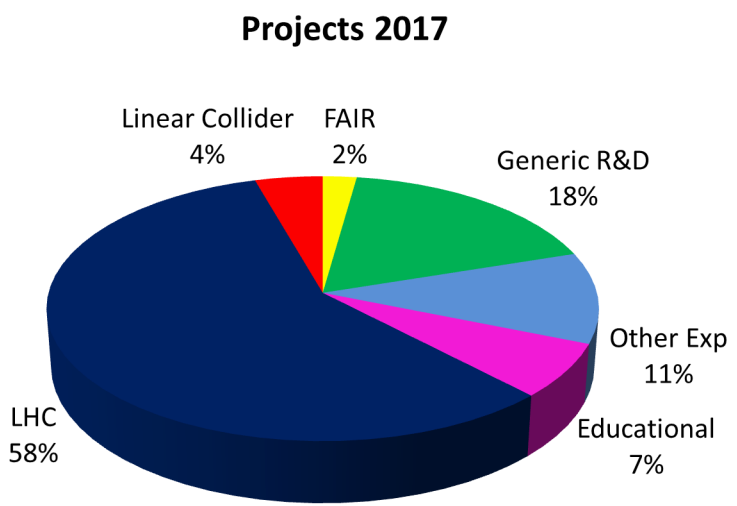
- Superconducting 1 T solenoid
  - Usable diameter ~ 75 cm
  - Mounted on movable stage

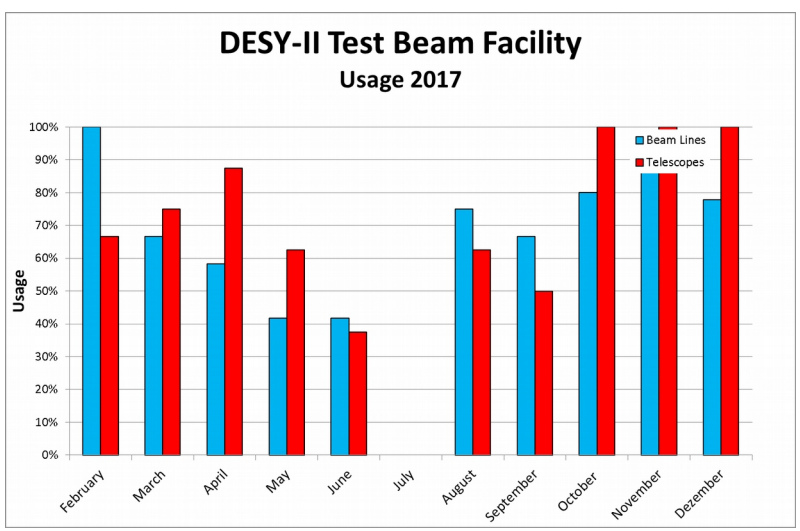


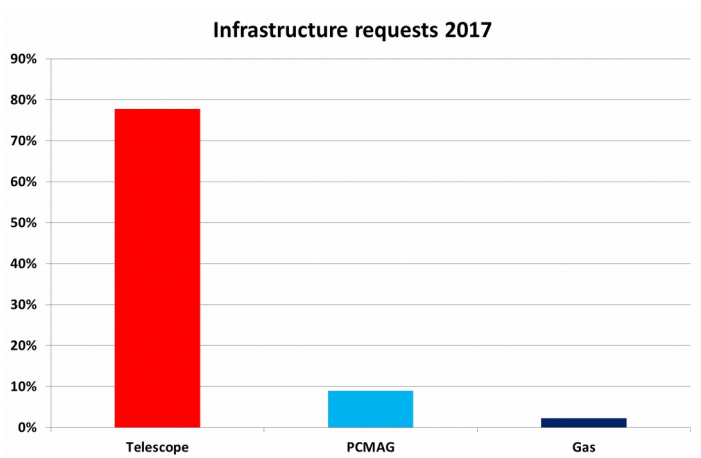
- Infrastructure projects
  - Common slow control system ✓
  - Large area strip telescope *in progress*
  - More Ethernet ports + all at 1 Gb *started*
  - New interlock system *started*
  - ...

# User Statistics 2017

- Running from February 23rd till December 22nd with 4 weeks summer shutdown
- 114 weeks available, 71 allocated (62 %)
  - Beam lines with telescope: 86 % allocated
- 58 % from LHC groups
- User statistics: 230 user, 106 first time at DESY
- Education
  “HEP for teachers”, summer students: 1 week each

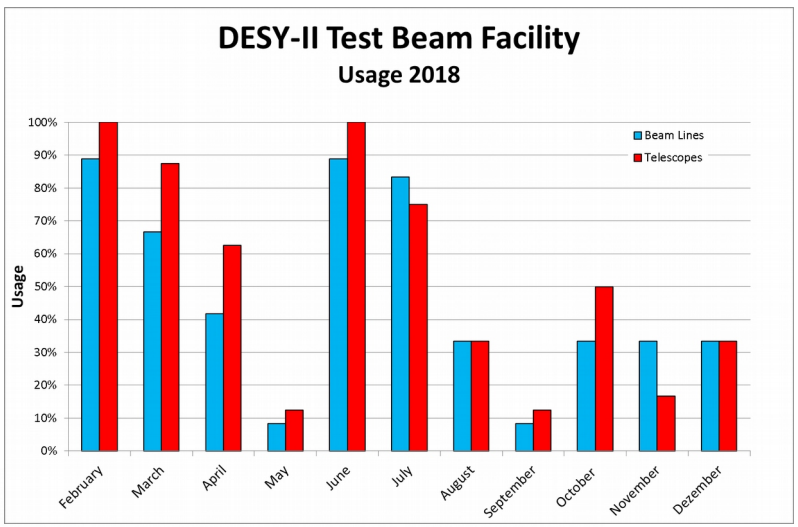


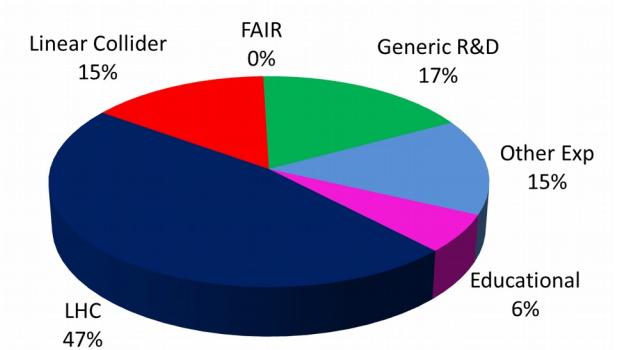



# Beam Time 2018

- Start February 12th, end December 21st
  4 weeks summer shutdown
  - 103 weeks available, 50 allocated
  - 12% all lines booked




| | Week | | TB21 | | TB22 | | TB24/1 | | TB24 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DATURA | | DURANTA | PCMAG | Telescope in PCMAG | none |
| 1-Jan-18 | 1 | | Shutdown | | | | | | |
| 8-Jan-18 | 2 | | | | | | | | |
| 15-Jan-18 | 3 | | | | | | | | |
| 22-Jan-18 | 4 | | | | | | | | |
| 29-Jan-18 | 5 | | | | | | | | |
| 5-Feb-18 | 6 | | Startup | | Startup | | Startup | | Startup |
| 12-Feb-18 | 7 | | CMS-Pixel-Phase-2 | X | XD-TBMST | X | | | CALICE-AHCAL |
| 19-Feb-18 | 8 | | CMS-Pixel-Phase-2 | X | ATLAS-OXF-HVCMOS | X | Strip Telescope Installation | | Mu3e-Tile |
| 26-Feb-18 | 9 | | ATLAS-Strip-Stress | X | ATLAS-OXF-HVCMOS | X | | | |
| 5-Mar-18 | 10 | | CMS-Pixel-Phase-2 | X | Mu3e | X | | | |
| 12-Mar-18 | 11 | | CMS-Pixel-Phase-2 | X | ATLAS-ITk-Pixel | X | | | CALICE-AHCAL |
| 19-Mar-18 | 12 | | | | ATLAS-ITk-Pixel | X | | | |
| 26-Mar-18 | 13 | | CMS-HGCAL | X | ATLAS-ITk-Pixel | X | | | |
| 2-Apr-18 | 14 | | | | | | | | |
| 9-Apr-18 | 15 | | CMS-OT-MaPSA | X | ELAD | X | | | |
| 16-Apr-18 | 16 | | CMS-OT-MaPSA | X | | | | | |
| 23-Apr-18 | | | | | | | | | |
| 30-Apr-18 | 18 | | CMS-Pixel-Phase-2 | X | ATLAS-Strip-Embed | X | | | |
| 7-May-18 | 19 | | | | | | | | |
| 14-May-18 | 20 | | | | | | | | |
| 21-May-18 | 21 | | | | | | | | |
| 28-May-18 | 22 | | ELAD | X | | | | | |
| 4-Jun-18 | | | | | Setup | | | | |
| 11-Jun-18 | 24 | | CMS-Pixel-Phase-2 | X | ATLAS-ITk-Strips | X | | | |
| 18-Jun-18 | 25 | | CMS-Pixel-Phase-2 | X | ATLAS-ITk-Strips | X | | | NICA-MPD |
| 25-Jun-18 | 26 | | CMS-Pixel-Phase-2 | X | Mu3e | X | | | NICA-MPD |
| 2-Jul-18 | 27 | | CALICE-SiW-ECAL | X | ATLAS-Strip-Stress | X | | | |
| 9-Jul-18 | 28 | | X-Ray-Crystal-Rad | | ATLAS-Strip-Embed | X | CALICE-SiW-ECAL | | |
| 16-Jul-18 | | | Summer Shutdown | | | | | | |
| 23-Jul-18 | | | | | | | | | |
| 30-Jul-18 | | | | | | | | | |
| 6-Aug-18 | | | | | | | | | |
| 13-Aug-18 | 33 | | SummerStudents | X | | | | | |
| 20-Aug-18 | 34 | | SummerStudents | X | | | | | |
| 27-Aug-18 | 35 | | CMS-OT-MaPSA | X | | | | | |
| 3-Sep-18 | 36 | | CMS-OT-MaPSA | X | | | | | |
| 10-Sep-18 | 37 | | | | | | | | |
| 17-Sep-18 | 38 | | | | | | | | |
| 24-Sep-18 | 39 | | | | | | | | |
| 1-Oct-18 | 40 | | X-Ray-Crystal-Rad | X | | | | | |
| 8-Oct-18 | | | | | Setup | | | | HEP for Teachers |
| 15-Oct-18 | 42 | | | | ATLAS-ITk-Strips | X | | | |
| 22-Oct-18 | 43 | | | | ATLAS-ITk-Strips | X | | | |
| 29-Oct-18 | 44 | | | | Mu3e | X | | | |
| 5-Nov-18 | 45 | | | | | | | | |
| 12-Nov-18 | 46 | | | | | | | | |
| 19-Nov-18 | 47 | | | | | | LCTPC-Micromegas | | |
| 26-Nov-18 | 48 | | | | ATLAS-ITk-Pixel | X | LCTPC-Micromegas | | |
| 3-Dec-18 | 49 | | | | ATLAS-ITk-Pixel | X | | | |
| 10-Dec-18 | 50 | | OSCaR | | ATLAS-ITk-Pixel | X | Interlock Installation | | |
| 17-Dec-18 | 51 | Beam till 21/12 0800 | Interlock Installation | | | | | | |
| 24-Dec-18 | 52 | | Shutdown | | | | | | |

# Workshop - Future of Test Beams at DESY

- 2-day DESY test beam workshop, October 2017

- Main motivation and objectives
  - PETRA IV plans
  - Ideas for possible upgrades of the facility and the infrastructure
  - Long shutdown 2 in 2019/20 at CERN

  → Need to prepare science case for the DESY II Test Beam Facility

- Outline
  - Presentation of the status and possible future developments
  - All user communities invited to present their requirements and wishes + discussion
  - Written report handed in January to the directorate to feed into DESY planning

# Workshop - Attending Communities

- LHC
  - Atlas (ITk strips+pixel), CMS (tracking+HGCAL), Alice (ITS), LHCb (SciFi)
- Linear Collider(s)
  - Calice, LCTPC, CLIC (vertex/tracker)
- Belle II (VXD: SVD+PXD)
- Mu3e (recurl pixel layers)
- Dune (LAr TPC, ECAL, 3D scintillator target)
- GSI/FAIR (heavy ion)
  - CBM (Compressed Baryonic Matter) / HADES
  - Panda (EDD: endcap disc DIRC)

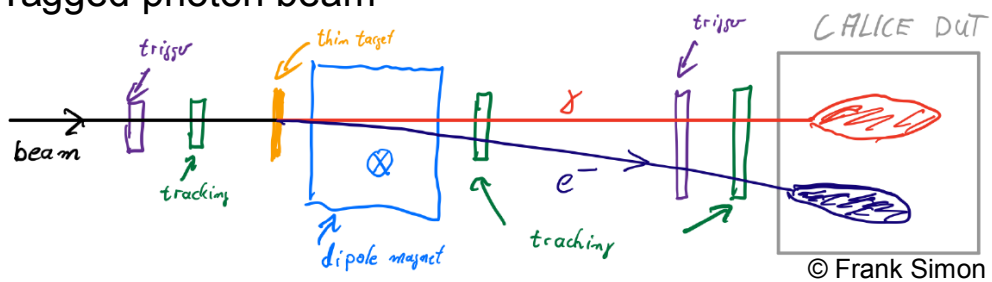
# Workshop - User Feedback

- Quote: “Don't fix it, it's working”
- Beam reliability and availability important and highly appreciated
- Support (incl. telescopes) rated very good
- Run time from Feb-Dec okay
- Availability of DESY test beams extremely important during LS2 at CERN
  - Summer shutdowns should be limited during LS2
  - Install a third beam telescope from CERN
- Needs after 2025 hard to predict, but consensus was that it will be needed

# Workshop - User Wishes

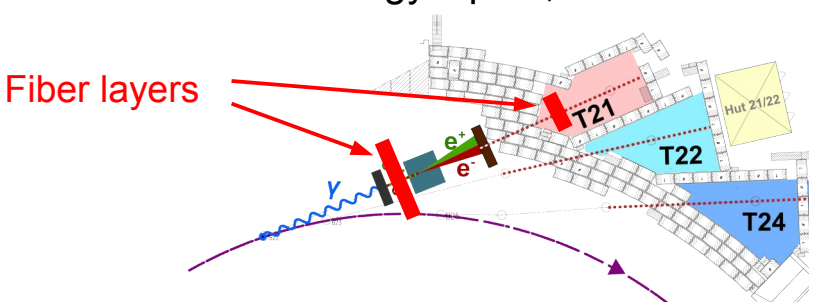
- Beam wish-list
  - Lower energies < 1GeV
    (e.g. DUNE detector down to a few 10 MeV)
  - Higher energies (tracking → less scattering)
  - Higher rate
    - Repetition rate of single electrons (25 ns / 40 MHz)
    - Multiplicity per event (pixel sensors)
  - Bunch train mode (e.g. ILC like)
  - Secondaries (pions, muons)
- Service wish-list
  - $X_0$ scanning using beam telescopes
- Telescope future → See other talks at this WS

- Infrastructure wish-list
  - Tagged photon beam




© Frank Simon

  - Precise timing system (< 20 ps)
  - Energy calibration per event
    - Precise calorimeter (BGO)
    - Fiber "tracker" - two layers:
      one before beam energy dipole, one in the area

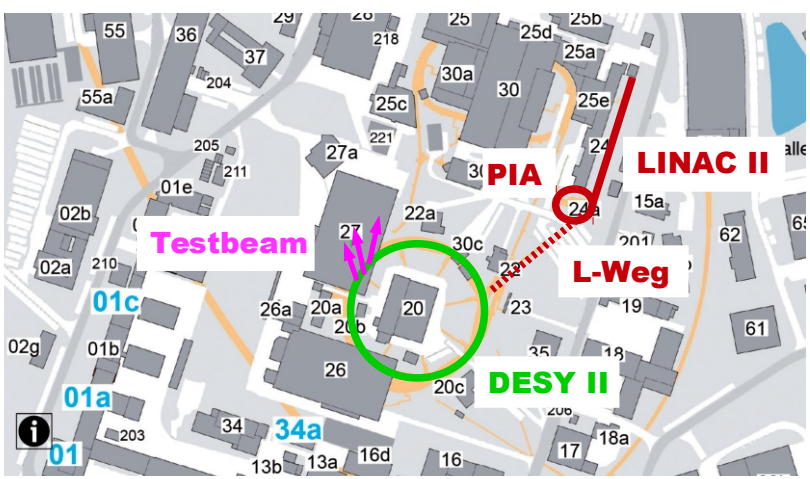


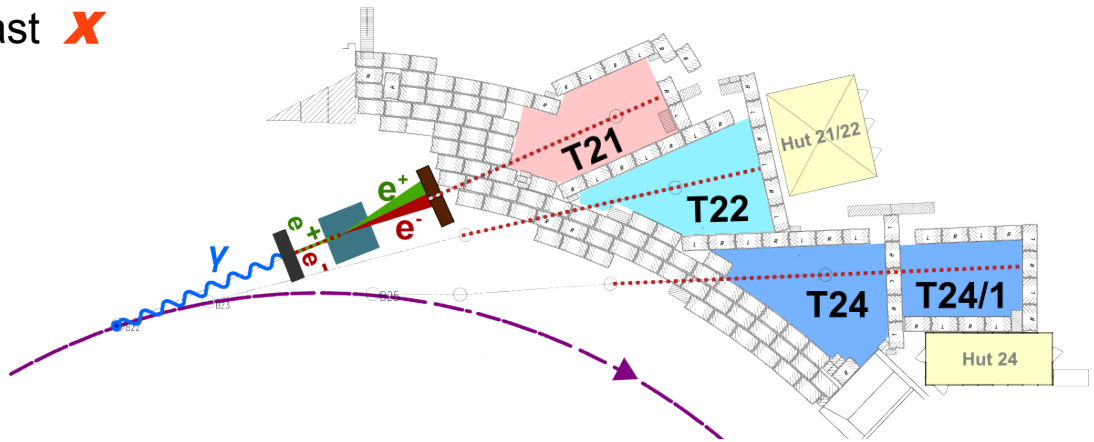

  - Common, low mass cold box for irradiated sensors inside the telescope

**Disclaimer:**
**Projects on the following slides are neither finished planning, nor funded or decided**

# Workshop - Upgrade Ideas: Higher Rates I

- Thicker Bremsstrahlung target → destroys beam too fast ✗
- Higher current → not much more possible ✗
- Higher energy → not possible in normal operations ✗
- Multiple bunches (√)?
  - Currently only one bunch possible, though
    - Linac II could deliver more
    - PIA could be used as a simple roundabout
    - DESY II could in principle handle more buckets
  - But: Kicker from Linac II / PIA → DESY II too slow




- Fast kicker
  - R&D would be a great project to keep up with current developments outside DESY
    … planning started, not finally decided
  - Kicker speed: one has to see what's achievable
  - Maybe 10-40 bunches in DESY?
  - Could possibly be installed in parallel to current $e^-$ kicker
  - How long do the target fibers survive higher rate?
    → New system (anyway under discussion) with more fiber spares?

# Workshop - Upgrade Ideas: 4th Beam Line

- Current beam lines well used, seldom overbooked
  → current three beam lines enough
- Under study:
  4th beam line using DESY beam directly
  - Use the R-Weg (former transfer line to DORIS)
  - Extraction line already installed
  - Only dumped beam would be used

    → Repetition rate up to 12.5Hz
  - Intensity: >1x10$^{8}$ to 3x10$^{10}$ particles/bunch
  - Extraction energy 456 MeV - 6.3 GeV (7 GeV)

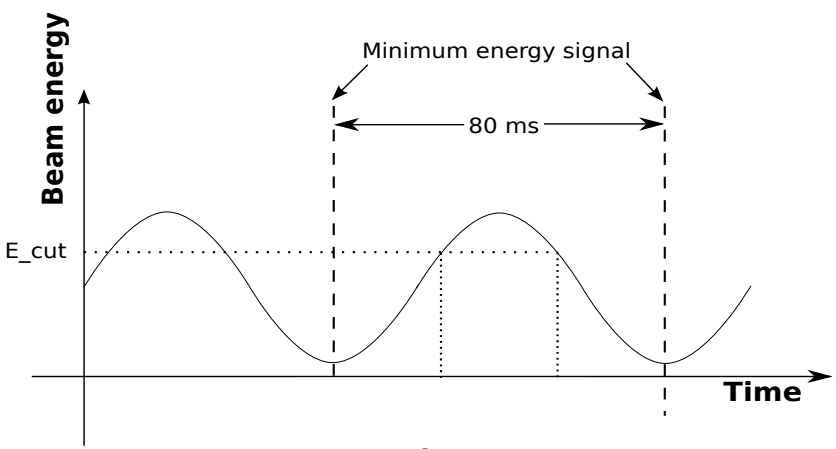
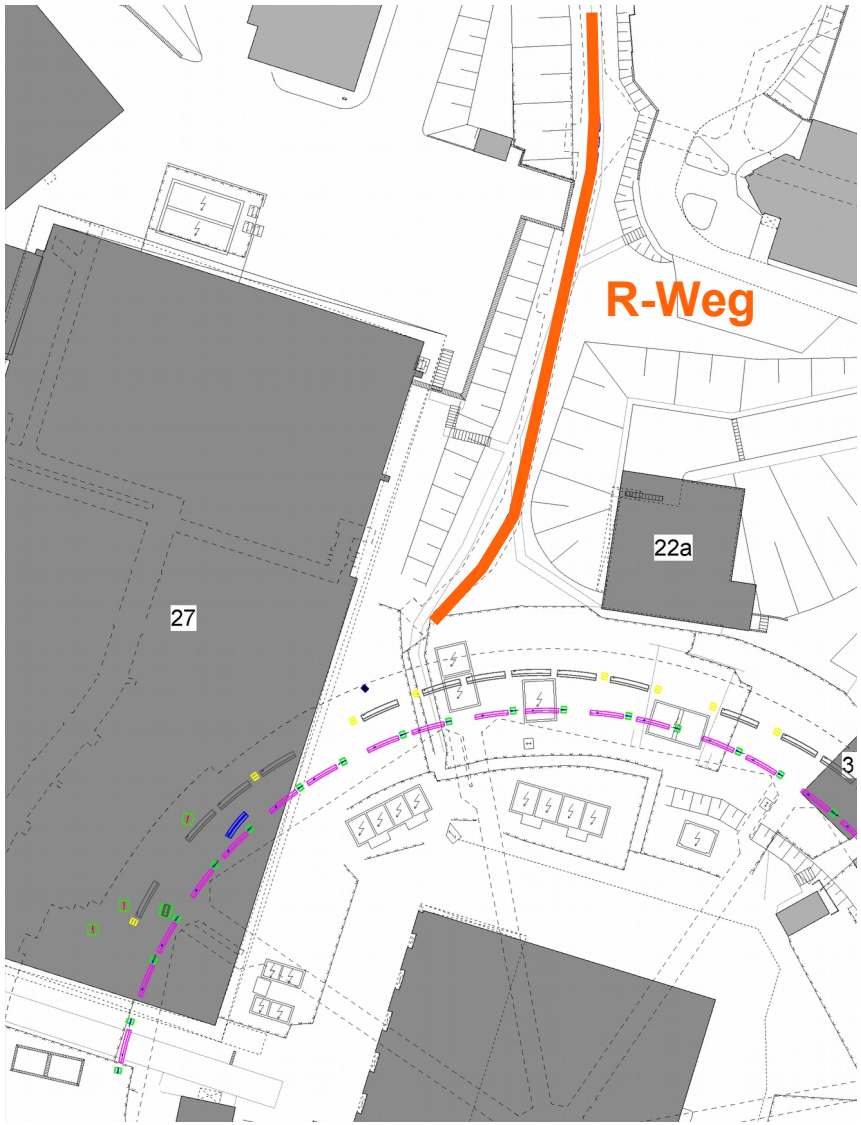



Fig.: DESY II energy cycle



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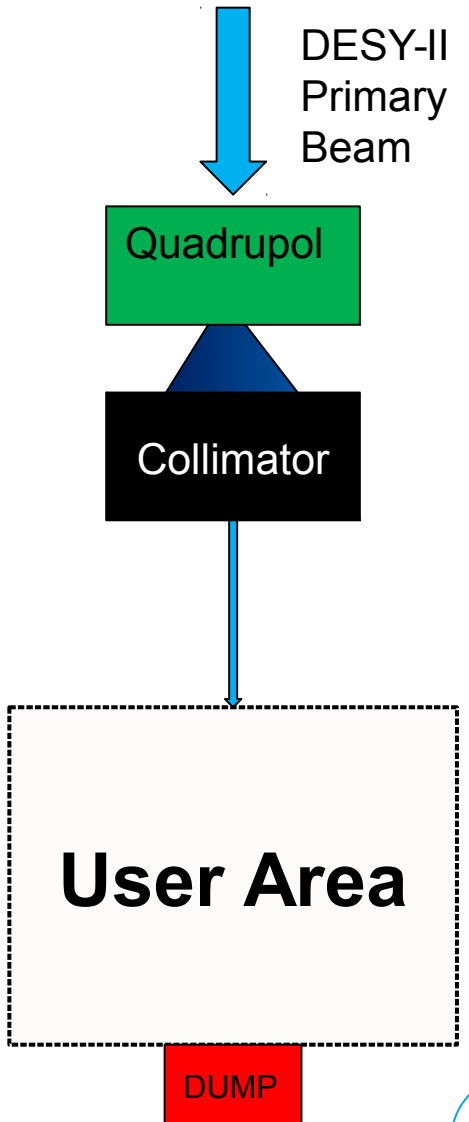
  - Only dumped beam would be used

    → Repetition rate up to 12.5Hz
  - Intensity: >1x$10^{8}$ to 3x$10^{10}$ particles/bunch
  - Extraction energy 456 MeV - 6.3 GeV (7 GeV)
- To be done
  - Small hall (~10x15 m)
  - Interlock system and shielding
  - Targets, collimators, instrumentation
  - Upgrade of DESY II instrumentation
  - In a first step: no hall just using the existing tunnel?

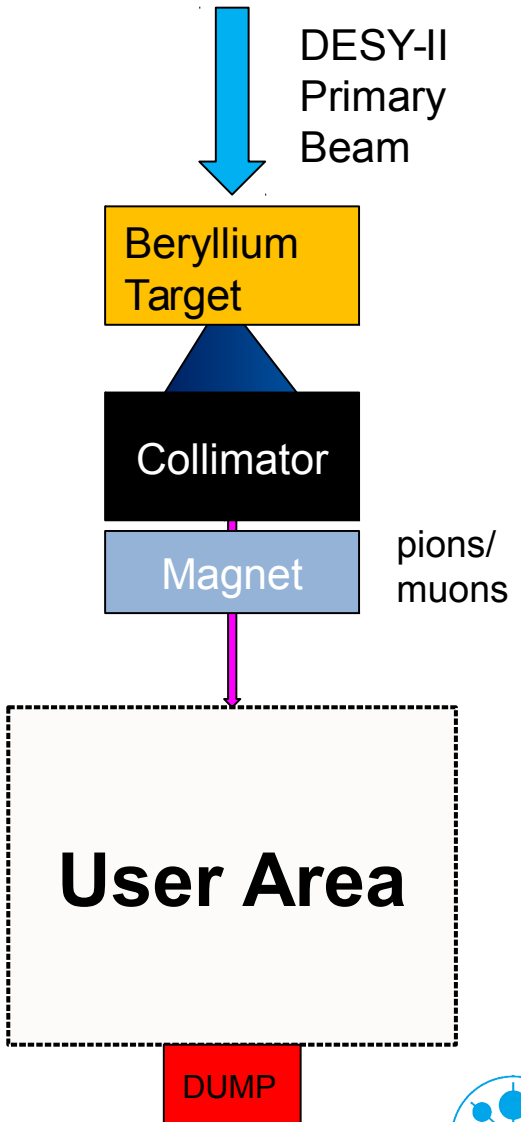
# Workshop - Upgrade Ideas: 4th Beam Line / High Rates II

- Extraction of DESYII bunches
- "Full" bunches
  - Rate 12.5 Hz, energy 6.3 GeV
  - Fanning and collimating of the bunch: $10^{10}$ down to 100 electrons / $cm^2$



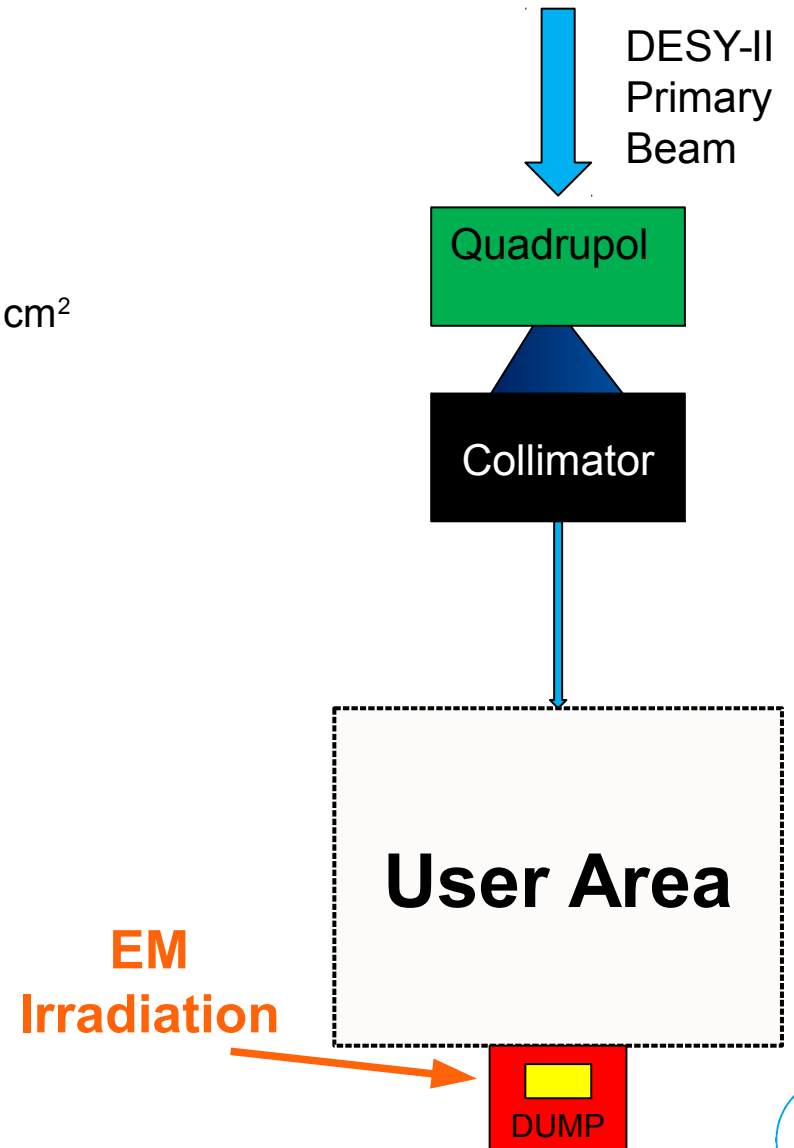
# Workshop - Upgrade Ideas: 4th Beam Line – Secondaries

- Extraction of DESYII bunches
- "Full" bunches
  - Rate 12.5 Hz, energy 6.3 GeV
  - Fanning and collimating of the bunch: $10^{10}$ down to 100 electrons / $cm^2$
- Secondary particles:
  - Dump on Be target → pions and muons (and neutrons, protons)
  - Energies up to 4 GeV / O(10) pions per bunch
  - In Europe currently only at CERN



# Workshop - Upgrade Ideas: 4th Beam Line – EM Irradiation

- Extraction of DESYII bunches
- "Full" bunches
  - Rate 12.5 Hz, energy 6.3 GeV
  - Fanning and collimating of the bunch: $10^{10}$ down to 100 electrons / $cm^2$
- Secondary particles:
  - Dump on Be target → pions and muons (and neutrons, protons)
  - Energies up to 4 GeV / O(10) pions per bunch
  - In Europe currently only at CERN
- Irradiation
  - Tungsten Target (~10 $X_0$) → intense electromagnetic shower
  - Irradiation chamber at the End
  - Operated parasitically, radiation damage studies



# Workshop - Upgrade Ideas: PETRA IV - Injector

- PETRA IV: “Ultimate” light source
  - Driven by photon science community
  - Timescale ~ mid-twenties
  - Project evolving → Conceptual Design Report 2018
- Initial approach:
  Use DESY II as-is as PETRA IV injector
  - DESY II well over 30 years old:
    Refurbishment of nearly all components
    → Effort probably nearly as high as
    for a new injector
- Options
  - 6 GeV Linac
  - Booster ring in PETRA IV tunnel
  - DESY IV in existing tunnel + new LINAC IV:
    - Low emittance 6 GeV booster, ramped at 3 Hz
    - ~ 320 m circumference
    - Injection energy ~ 300 MeV

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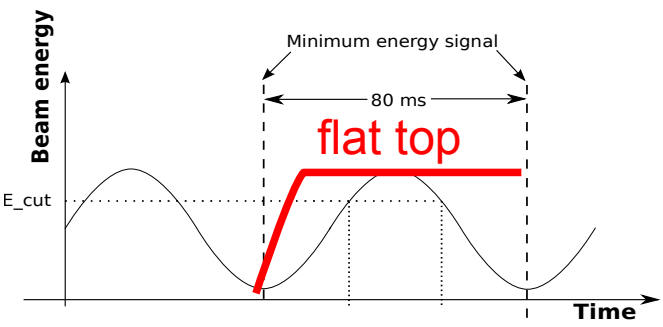
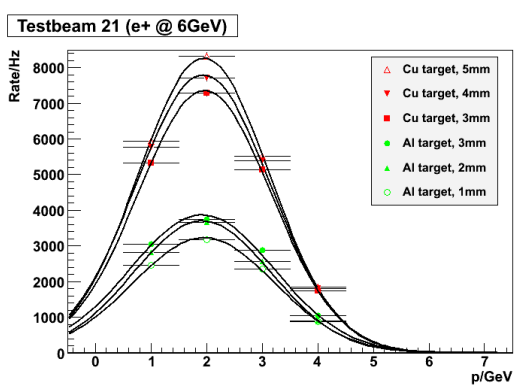
    - Low emittance 6 GeV booster, ramped at 3 Hz
    - ~ 320 m circumference
    - Injection energy ~ 300 MeV

- DESY IV impact
  - Dismantling of DESY II and current test beam setup
  - Current beam generation would still work
  - Interesting opportunities for the test beam facility
  - Flat-top mode, multi-bunch mode → higher rates




  - Resonant extraction of primary beam → “High Rates III” (energy independent) + structured beam



# Conclusion

- Status and near future
  - Currently maintenance and clean-up ongoing before start on February 12th
  - 2018: ~50% booked until now
  - DESY test beam essential during LS2@CERN in 2019/2020 → maximize available beam time
  - Beam line for schools in 2019/2020 @ DESY?

- DESY Testbeam Facility Workshop
  - Input from community and science case for test beam facility essential

    Outcome:
  - Confirmed necessity till at least 2025
  - A lot of interesting input on infrastructure needs and upgrade possibilities
    - Manpower limited
  - Future possibilities for beam improvements
    - Multi-bunch mode
      → possible in ~1-2 yrs?
    - 4$^{th}$ beam line (high rate, secondaries, irradiation)
      → possible in ~2-4 yrs?
    - DESY IV (flat-top, resonant extraction)
      → mid 2020s?