Physics Beyond Colliders

Status

Mike Lamont, Clause Vallee, Joerg Jaeckel
November 2016

- PBC strategy, studies, status
- Organization
- Detail the studies and resources for BDF/SHiP.
SNAPSHOTS ON:

- Future of existing programs
- New Fixed Target facilities
- New other facilities
- Non accelerator programs
Wish to further study QCD deconfinement with charm after LS2
(add vertex detector)

Also a unique facility to be maintained for control of future neutrino beams
COMPASS: a spectrometer for proton spin physics and spectroscopy

Wish RF separated antiproton and kaon beams ($I \times 50$) after LS2 for further DY and spectroscopy studies
New idea: direct measurement of the dominant contribution to the theoretical error on $(g-2)_\mu$ from $\mu$-$e$ elastic scattering

High statistics space-like measurement could reduce by factor 2 the current error derived from time-like processes

*Might be feasible with reasonable resources within the (modified) COMPASS setup*
NA62: \((K \to \pi \nu \nu)\) rare decay

Wish to run \(~1\) year in beam dump mode after LS2 to look for Heavy Neutral Leptons

Compact beam dump: \(~11 \lambda_i\) Cu-based beam-defining collimator (TAX)
radio protection-compliant even if target removed

Decay volume \(~60\) m long (in vacuum):
reasonable acceptance to long-lived states
New idea: NA62-KLEVER for \((K^0 \rightarrow \pi^0\nu\bar{\nu})\) rare decay

~50 events could be collected with a similar but basically new detector
Method complementary to lower energy experiment KOTO at JPARC

*Would require a new high intensity \(K^0\) beam*
SNAPSHOTS ON:

Future of existing programs

New Fixed Target facilities

New other facilities

Non accelerator programs
Beam Dump Facility already under study at CERN
Dark sector search complementary to SHiP: invisible decays from missing energy

First implementation in 2016 by NA64 on an electron test beam

Wish to extend the method to $\mu / \pi / K / p$ beams (+ possibly higher intensity e’s with AWAKE techno)

Source of A’s:

Invisible decay of invisible state!

level $<10^{-12} - 10^{-9}/e^-$

S. Andreas et al., arXiv: 1312.3309
S.G., PRD(2014)
In brief

<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA62</td>
<td>Beam dump mode optimization: respective study will be conducted</td>
</tr>
<tr>
<td>NA64+</td>
<td>Study to start in Q4 2017. Can be combined with NA61</td>
</tr>
<tr>
<td>KLEVER COMPASS</td>
<td>Complex studies – aim for first physics based evaluation and accelerator side analysis before starting</td>
</tr>
<tr>
<td>DIRAC@SPS NA60</td>
<td>Known difficulties with existing infrastructure and/or beam-lines. Collaboration resources and timeline also to be studied.</td>
</tr>
<tr>
<td>SHiP</td>
<td><strong>Complete technical feasibility studies of a beam dump facility</strong></td>
</tr>
</tbody>
</table>
SNAPSHOTS ON:

Future of existing programs

New Fixed Target facilities

New other facilities

Non accelerator programs
New ideas: Fixed Target physics with LHC beams

Proposed for comprehensive PDF/Spin/HI measurements in a new kinematical domain

Internal gas target or Crystal extraction

Upstream of LHCb and/or ALICE

Proposed for measurement of magnetic moments of short lived baryons
Electrostatic Storage Ring for proton EDM

$10^{-29}$ e-cm sensitivity would correspond to 100 TeV for new physics energy scale.

Pure electrostatic ring applicable to proton only

Design sensitivity: $4 \times 10^{-29}$ e-cm

Requires:
- electrostatic deflector 8MV/m
- magnetic shielding
- high precision SQUID BPMs to monitor the total radial magnetic field by vertical beam position separation between CW/CCW


Lot of interest worldwide – kickoff workshop next March
New idea: Gamma Factory

Use LHC beam to convert laser photons into 0.1 - 400 MeV $\gamma$ rays

Expected factor $10^7$ intensity increase compared to present e-driven $\gamma$ ray beams, would open a completely new field of physics measurements and applications.

Initial tests - take partially stripped ions in SPS and LHC
NuSTORM

Well controlled $\nu$ beam from a $\mu$ storage ring.

Would allow precise $\sigma(\nu)$ measurements.

Also a path towards a $\nu$ factory or a $\mu$ collider.

Will look at physics case and sketch possible implementation at CERN
SNAPSHOTS ON:

Future of existing programs
New Fixed Target facilities
New other facilities
Non accelerator programs
IAXO: Next generation Axion Helioscope beyond CAST

Wish to profit from CERN magnet expertise (ATLAS-like large bore toroid)

NB: similar wish to benefit from CERN high field magnet developments by Light Shining through the Wall experiments (ALPS III)
DARKSIDE (LNGS):
“Ultimate” WIMP search with depleted LAr double phase TPC

Wish to exploit synergies with CERN on LAr, cryogeny, low noise SiPMs, etc...
NEXT STEPS

• Working Groups being set up to address:
  • the physics case of the proposed projects in the worldwide landscape
  • their feasibility and possible implementation at CERN (or elsewhere)
    ... with involvement tuned to the level of maturity of the projects

• Follow-up PBC workshop foreseen in 2017.

• Final deliverable due end 2018: summary document as input to the European Strategy Update process (2019-20).
  *Will gather facts on the projects (no ranking!)*
  *to facilitate future orientations from the ESU group.*
Organization

- BDF working group
- EDM working group
- Conventional beam working group
- LHC FT study group
- PBC-AF Committee
- Technology working group
- Proton production plan
- NuSTORM study
- AWAKE++ study
- Gamma Factory study
- BSM physics working group
- QCD physics working group
Physics sub working groups:

BSM subgroup:

- Projects: SHIP/NA64+/NA62+/IAXO/OSQAR-ALPS-III/EDM
- Members:
  2 theorists: Maxim Pospelov (Victoria Univ., Canada), Clare Burrage (Nottingham Univ., UK)
  4 experimentalists: Sasha Rozanov (CPPM Marseille), Giuseppe Ruoso (INFN-Legnaro, Italy),
  Klaus Jungmann (KVI-Groningen, Netherlands), Klaus Kirch (PSI, Switzerland)
  1 representative/project

QCD subgroup:

- Projects: COMPASS+/\mu-e/LHC FT (gas target+crystal extraction)/DIRAC+/ NA60+
- Members:
  2 theorists: Markus Diehl (DESY, Germany), Jan Pawlowski (Heidelberg, Germany)
  1 experimentalist: Gunar Schnell (Basque University, Spain)
  1 representative/project
## Deliverables

<table>
<thead>
<tr>
<th>COMPLEX</th>
<th>Fully developed proton performance plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDF</td>
<td>Complete technical feasibility studies – input to SHIP CDS</td>
</tr>
<tr>
<td>EDM</td>
<td>Fully developed proposal including preliminary costing</td>
</tr>
<tr>
<td>SPS NA</td>
<td>Establish requirements, initiate feasibility studies</td>
</tr>
<tr>
<td>LHC FT</td>
<td>Preliminary conceptual design report</td>
</tr>
<tr>
<td>GAMMA</td>
<td>Exploratory study, initiate initial tests</td>
</tr>
<tr>
<td>AWAKE+</td>
<td>Exploratory study</td>
</tr>
</tbody>
</table>

### Technology

- Explore possible technological contributions by CERN to externally hosted facilities
- Document actual use of CERN infrastructure
- Facilitate potential use of CERN infrastructure
- Study physics case and technical requirements as input to ESU

### nuSTORM

- Exploratory study of implementation at CERN
- Review potential scientific impact
The main challenges for a BDF

- Target design for longevity and reliability
- Extraction from SPS
- High cumulated radiation doses
  - Injectors, injection, extraction, target, etc…
- Radiation damage on materials
  - Extraction septa, target and target station
- Personnel and environmental protection
  - Close distance to the CERN site boundary
  - Detailed environmental study needed
- Good compatibility with North Area operation

Complete technical feasibility studies of a beam dump facility in the CERN North Area (extraction, target, radiation protection)
Technical feasibility studies

• Extraction, beam-line and splitter
  – Brennan Goddard (TE-ABT)
• Target and target complex
  – Marco Calviani (EN-STI)
• Radiation protection
  – Heinz Vincze (HSE-RP)
• Safety engineering
  – Fernando Pedrosa (HSE-SEE)
Beam transfer challenges for BDF

- Fairly extensive work has been done to date for SHiP + CENF
  - Need catalogue of other BDF requests (spill, energy, intensity, PoT, ...)
  - Direct impact on SPS HW and beam physics (e.g. non-local FE)
- Slow extraction beamlosses limits the intensity from SPS
  - CNGS reached 4e19 PoT/y with FE
  - SE to NA in present years aiming at 1.2e19 PoT/y, LSS2 activation
  - Major thread of studies: SLAWG, Crystal Assisted Extraction WG, ...
- Beamline design the other important thread
  - Upgrade of existing TT20 (powering, PPM, BI, ...)
  - New section of beamline to BDF target
  - Dilution system (magnets, powering, ...)
  - Subsystems (magnets, powering, interlocks, BI, vacuum, SU, ...)
  - Infrastructure (CE, cabling, cooling, ventilation, HE, ...)
  - Splitter/switch magnets
- Work is ongoing, with extraction beamloss most active
WGAs and resources

- SPS Losses and Activation WG: SLAWG INDICO 7887 (mandated by IEFC)
- Slow Extraction from SPS Assisted by Bent Crystals: SESABC INDICO 8556 (mandated by ATS director)
- TT20 for BDF: splitters and TL design: INDICO 8700 (not mandated by anyone)

Resources
- ABT PhD student already working on slow extraction (FCC and its HEB, and SPS for SHiP)
- ABT/OP FELL: from mid 2017 for beamline and operational aspects
- MSC FELL: starts early 2017 for Splitter design and prototype
- ABT TECH working on SPS activation analysis
- Fractions of staff + FELL (probably totalling 0.5 – 0.7 FTE)
BDF Target & Target complex: status and perspectives

10th November 2016

M. Calviani (EN/STI) and colleagues
### Proposed activities

<table>
<thead>
<tr>
<th>SHiP target complex R&amp;D for TDR (2017-2019)</th>
<th>Total (kCHF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Analysis of the assembly, configuration and fabricability of the cladded refractory metal blocks</td>
<td>650</td>
</tr>
<tr>
<td>2) Material irradiation R&amp;D</td>
<td>200</td>
</tr>
<tr>
<td>3) Feasibility of water-cooled cast iron blocks with embedded SS pipes</td>
<td>180</td>
</tr>
<tr>
<td>4) Feasibility of the target water cooling system and pre-design validation + ventilation system</td>
<td>420</td>
</tr>
<tr>
<td>5) Study of a He-cooled target</td>
<td>220</td>
</tr>
<tr>
<td>6) Integration studies for target complex + transport/handling study</td>
<td>100</td>
</tr>
<tr>
<td>7) R&amp;D for fully metal, high flow rate and pressure-compatible water plugin</td>
<td>50</td>
</tr>
<tr>
<td>8) R&amp;D for He-vessel circulation and prototyping activities</td>
<td>650</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2470</strong></td>
</tr>
</tbody>
</table>

- **2.47 MCHF includes fellow budget**
Status of fellows for BDF T&TC

- News from AFC-2016-2:
  - 1 FELL in EN/STI: design and optimization of the target/dump for the BDF and respective target complex + follow-up of the construction and tests of the prototype target(s)
  - 1 FELL in EN/MME: material studies associated to the target/dump, refractory metals, HIPping, erosion/corrosion issues
  - 1 FELL in EN/CV: CFD studies for the target, He-vessel and follow-up on the study for the He circulation and external contract. Optimization of the ventilation system

- Contributing:
  - 1 FELL in HSE/RP + HSE/SEE
Main milestones and activities

2017
- Optimization of the target complex design with external company
- Start pre-design critical services (i.e. CV)
- Proceed towards a robust target/dump

2018
- Proposed beam tests upstream T6 to validate dump design
- He-vessel contract assignment and building
- Further reflection on target complex design

2019
- Post-mortem of target design
- Write-up of the Comprehensive Design Report
Preliminary integration studies

- Global preliminary “experimental” (not machine) integration would be of much help for the global design and optimization for the facility
- Support would be required for the realization of the He-vessel prototype (in EHN1-ext?)
Civil engineering studies

- Some preliminary civil engineering studies would be helpful for the validation of feasibility and better cost estimation in view of the strategy
  - Studies could start as early as S2 2017 with the existing information available (w/ draughtsman)
- Then in 2018 a dedicated contract could be establish for the most critical aspects (i.e. JC and TC (or for the whole facility (?)))
  - 1 FELL for 1 year to be organized
Radiation Protection

• RP manpower needed from 2016 to 2019 in order to complete all required RP studies for the CDS of SHiP.
  – 2.4 staff FTEs (in the next 4 years)
  – concentrated the workload concentrated into the years 2017 and 2018 which we consider as the most time consuming years for the preparation of the CDR.
  – Have funds for one fellow for a minimum of 2 years (material cost: ~200 to 300 kCHF)

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>TOTAL (4 yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicist</td>
<td>0.1</td>
<td>1</td>
<td>0.9</td>
<td>0.1</td>
<td>2.1</td>
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<tr>
<td>Technician</td>
<td>0</td>
<td>0.2</td>
<td>0.1</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>0.1</td>
<td>1.2</td>
<td>1</td>
<td>0.1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Heinz Vincke
Conclusions

• PBC structure taking shape. Lot of interesting stuff but two main concrete proposals to be pushed in the medium term:
  – Beam Dump Facility
  – EDM

• 4 MCHF committed to BDF
  – Problem is not getting the planned work done but finding more money to meet the enthusiastic scope widening (integration, civil engineering)
  – Those involved are taking it seriously