CONVENTIONAL BEAMS WG

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On behalf of the Conventional Beams WG
Physics Beyond Colliders Workshop, 1 March 2017
Outline

• Introduction: Mandate, members, organisation
• Conventional beam working group kick-off
• Requests from different experiments
• Outlook & Requirements
PBC Structure

- BSM physics working group
- QCD physics working group
- BDF working group
- EDM working group
- PBC-AF committee
- Technology working group
- LHC FT working group
- Proton production study
- NuSTORM study
- AWAKE++ study
- Gamma Factory study

Conventional beam working group
Mandate

Conventional beams subgroup:

Evaluation of NA62 beam dump, COMPASS RF separated beam, NA61++ beam, KLEVER beam. Possible siting at CERN of NA64++, $\mu$-e experiment, NA60++, and DIRAC++ beams.

The level of details of the pre-studies will have to match the maturity of the projects.

A first meeting took place on the 22nd of February
General Remarks

- The experiments and modifications presented require in many cases new beam lines, locations and/or infrastructure.
- In many cases the **feasibility** remains to be demonstrated or the beam lines must be built, modified or optimised.
- Therefore **studies will be required** which involve heavily the EN-EA physicists as well as a number of equipment groups.
- **Prioritisation** must be done in agreement with the Physics working groups and overall PBC chairs.
- Some **resources** are essential for these studies (PBC, projects, etc.) and in many cases active support from the community would be helpful.
- Some studies can start already or have even started recently.
Conventional Beams WG strategy

During the kickoff workshop a large number of fixed target proposals were presented. It is important to perform pre-proposal studies in order to allow the PBC committee and concerned working groups to progress with their evaluation.

Given the relatively long list of studies, we were asked to first focus on those leading to a possible short and medium time-scale implementation and requiring only limited resources for their implementation. Additional studies will be performed based on the information provided by the collaborations and the following criteria:

- according to the analysis of the physics WG
- where sufficient details are known required for an implementation study
- where a study can be performed within the timescale of the European Strategy update.
CBWG Kick-Off Agenda

09:00 → 09:15  Introduction  
Speaker: Ljubomir Gatignon (CERN)

09:15 → 09:30  NA62 Beam dump  
Speaker: Evgeni Goudzovski (University of Birmingham), Tommaso Spadaro (Istituto Nazionale Fisica Nucleare Frascati (IT))

09:30 → 09:45  NA64++  
Speaker: Paolo Crivelli (Eidgenoessische Technische Hochschule Zuerich (CH))

09:45 → 10:00  KLEVER  
Speaker: Matthew Moulson (Istituto Nazionale Fisica Nucleare Frascati (IT))

10:00 → 10:15  Mu-e  
Speaker: Clara Matteuzzi (Università & INFN, Milano-Bicocca (IT))

10:15 → 10:30  DIRAC++  
Speaker: Daniel Drijard (CERN)

10:30 → 10:45  NA60++  
Speaker: Enrico Scomparin (Università e INFN (IT))

10:45 → 11:00  NA61++  
Speaker: Antoni Aduszkiewicz (University of Warsaw (PL))

11:00 → 11:15  COMPASS++  
Speaker: Oleg Denisov (INFN, sezione di Torino)

11:15 → 12:00  Discussion and Outlook  
Speakers: Ljubomir Gatignon (CERN), Markus Brugger (CERN)
• Short-term: continue program with heavy ion and hadron beams at various energies
• For open charm studies need $\sim 10x$ higher Pb beam intensities ($10^6$ Pb/spill)
• Improve spot and angular spread of secondary beams at low energies
• Improve spill for Pb beams

Pb beam intensities are mainly limited by shielding and available space
Muons also become limiting
Spill structure: for proton production study group
COMPASS++

- **Short-term**: existing muon and hadron beams allow COMPASS to extend current program (SiDIS, DY)

- **RF separated K⁻ and pbar beams**
  would provide unique opportunity: normal composition 2.5% K⁻ and 0.5% pbar (today at 190GeV)

  - Would aim for $3 \times 10^7$ pbar/s or $8 \times 10^6$ K⁻/s at about 100 GeV/c.
  Not a priori excluded, based on preliminary estimates from other proposals, but *no real study has been done so far*.

  - Such a study requires resources in several groups (RF, CRG, EPC, EA, etc.) and remains to be launched. CEDAR development also crucial.

  - For hadron spectroscopy and Drell Yan requires a RF separated beam at >120 (even 190) GeV. Limited by the available technology and distance.

  - For charm mesons propose a **pbar beam at low momenta** (<20 GeV).

  - Consolidation and infrastructure upgrades are required and to be studied.
NA64++: Dark photon search

• **Short-term:** Continue measurements with pure $e^-$ beam (H4), as well as hadron beams in H4 for background qualification and other invisible decays

Request permanent location

So far standard beam

• Clear **three stage physics program:**
  • Phase-1: current operation with pure $e^-$ beam (2017-2018)
  • Phase-2: 10x increased integrated intensity (visible + invisible channel)
  • Phase-3: use AWAKE-like $e^-$ beam (intrinsically pure): AWAKE WG

• Also a possible request between Phase-2 and 3: a **high-intensity muon beam** for $L_\mu$-$L_\tau$ gauge boson. This request is yet to be discussed.
  • Could possibly be combined with M2 / COMPASS / Mu-e (see later)
NA60++, DIRAC++

NA60++: Drell-YAN, J/Ψ, critical endpoint search

- **Size of the experiment** is $O(8 \times 8 \times 10 \text{ m}^3)$
  - could fit in existing North Area Halls

- To get the necessary integrated luminosity, beam intensities of $\sim 10^7 \text{ ions/s}$ are mandatory (assuming $\sim 5 \text{ s}$ bursts)
  - Does this restrict the choice to ECN3?
  - Is it possible to share it with other experiments?

- The physics program of NA60+ includes, in terms of beam:
  - **few week periods with ion beams** from $\sim 20 \text{ GeV}$ to top SPS, performing a detailed energy scan
    (example: $20,30,40,80,120,160 \text{ GeV/nucleon}$)
  - **corresponding periods of proton beams** (reference), scan could be coarser, beam intensities $\sim 5 \times 10^8 \text{ p/s}$

- 20x10 m², 3 $10^{11} \text{ p/s}$, 5 months

- Both experiments require beam intensities not realistic for surface halls.
  - Required area width is substantial, especially if shielding included.

- To be clarified:
  - Where can it be installed?
  - Can it somehow be made compatible with K12+NA62
    (space for detectors, front-end shielding, proton sharing, RP issues, etcetera?)

- **Or do we need a new facility, e.g. upstream of SHiP in BDF?**
Mu-e (for $g_\mu$-2 systematics)

- Need 150 GeV/c muon beam
  - Intensity $> 1.3 \times 10^7 \mu/s$
- Standard M2 condition
- However, occupies $>20$ m length
- Running time: one or several full years (can possibly be optimized).

- Experiment incompatible with present COMPASS implementation.
- If COMPASS has to stay in place, need to study the best layout (muon beam and target area modification) to allow for 20 metres or more. This is likely feasible with a combination of target area, CEDAR and beamline modification. But beam change must be reversible within a shutdown.
Phase 1:
Use existing K12 and NA62 layout, but close the TAX beam dump to stop the charged beam.
Move T10 target out, optimise muon sweeping.
No hardware changes.
First test run done in 2016!
Only beam settings changed

Phase 2:
- Run first a full year in Phase 1 configuration.
- Can then make hardware changes during YETS and consider dumping protons further downstream (better acceptance, but probably reduced muon sweeping efficiency).
- Can move or replace SCRAPER (by MIB) to allow fast change to neutral beam (see KLEVER).
- New dump: ideally mobile (to allow for neutral beam) or fixed? Cost?
FOR 1-YEAR RUN

HORIZONTAL PLANE:

K12 BEAM OPTICS FOR NA62-DUMP

VERTICAL PLANE:

LARGE ANGLE VETOES
Is this still possible in TCC8+ECN3. Or: **what has to be done to make it possible in ECN3?** Major study required.

BDF implementation/configuration to be also investigated.

Crystal converter needs **neutral test beam** – Modification of K12, e.g. During NA62 beam dump run?
Beam intensity

• A general issue is the \textbf{maximum beam intensity}.

• In some cases the intensity is limited by \textbf{RP considerations}. In that case \textbf{shielding studies} or a new location may be considered. The latter may have major impact (CE, beam modifications, etc).

• In other cases the \textbf{beam line and/or infrastructure} (targets, dumps, ventilation, interlocks) must be substantially upgraded or rebuilt (or built from scratch), such as for KLEVER: Such projects will involve many groups.

• Some experiments also require an increased available intensity in the machines (either alone or if combined with others). \textbf{Losses} must be optimised $\rightarrow$ \textbf{SLAWG working group} (very active). \textbf{Machine performance} may need to be improved (e.g. for BDF) $\rightarrow$ several accelerator study groups.

\textbf{Such studies are coordinated in the overall PBCacc working group.}
Identified Test Beam Studies

• KLEVER has a conceptual design of a $K_L$ beam involving a crystal based photon converter. Its effect on the $K_L$ beam can be significantly reduced by using a crystalline converter, aligned with the beam.
  
  • To test and validate the concept, a test with a tagged photon beam is considered, as well as at a later stage a possible test with a neutral kaon beam in the K12 line.

• Other experiments may require test beams as well:
  • a prominent example in the BDF working group is SHiP.
  • or target test requirement for $\mu$-e

• Test beams may also require discussions in this WG, in particular if the test beam implies non-standard requirements.
Resources and Time line

- The PBC deadline is **end of 2018 / beginning 2019**, in time to provide input for the European strategy decision.
- The first priority of the studies is to clarify the **technical feasibility and complexity** of the various considered proposals.
- Another important part of the study is to **evaluate the expected time line and resource requirements** for the proposed experiments.
- Ideally, feedback can also be provided **how various proposals could be effectively combined or scheduled** in order to allow for an optimized use of the experimental areas in line with beam availabilities.

- It’s important to note that the timeline of the requested studies is also correlated with the required respective resources and their time profile.
  - for this **additional resources are needed** (and must in most cases be trained).
Running/planed Drell-Yan experiments, COMPASS (π⁻ beam on $p^\uparrow$) – unique experiment

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Particles</th>
<th>Energy (GeV)</th>
<th>$x_b$ or $x_t$</th>
<th>Luminosity (cm² s⁻¹)</th>
<th>$P_b$ or $P_t$ (f)</th>
<th>rFOM#</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPASS (CERN)</td>
<td>π⁺ + $p^\uparrow$</td>
<td>190 GeV</td>
<td>$x_t = 0.1 - 0.3$</td>
<td>$2 \times 10^{33}$</td>
<td>0.14</td>
<td>$P_t = 80%$ f = 0.22</td>
<td>$1.0 \times 10^{-3}$</td>
</tr>
<tr>
<td>PANDA (GSI)</td>
<td>pbar + $p^\uparrow$</td>
<td>15 GeV</td>
<td>$x_t = 0.2 - 0.4$</td>
<td>$2 \times 10^{32}$</td>
<td>0.07</td>
<td>$P_t = 90%$ f = 0.22</td>
<td>$1.1 \times 10^{-4}$</td>
</tr>
<tr>
<td>AFTER</td>
<td>$p^\uparrow + p$</td>
<td>7 TeV</td>
<td>$x_b = 0.1 - 0.9$</td>
<td>$2 \times 10^{32}$</td>
<td>0.06</td>
<td>$P_b = 100%?$</td>
<td>$2.3 \times 10^{-5}$</td>
</tr>
<tr>
<td>NICA (JINR)</td>
<td>$p^\uparrow + p$</td>
<td>collider</td>
<td>$x_b = 0.1 - 0.8$</td>
<td>$1 \times 10^{32}$</td>
<td>0.04</td>
<td>$P_b = 70%$</td>
<td>$6.8 \times 10^{-5}$</td>
</tr>
<tr>
<td>PHENIX/STAR (RHIC)</td>
<td>$p^\uparrow + p^\uparrow$</td>
<td>collider</td>
<td>$x_b = 0.05 - 0.1$</td>
<td>$2 \times 10^{32}$</td>
<td>0.08</td>
<td>$P_b = 60%$</td>
<td>$1.0 \times 10^{-3}$</td>
</tr>
<tr>
<td>fsPHENIX (RHIC)</td>
<td>$p^\uparrow + p^\uparrow$</td>
<td>$\sqrt{s} = 200$</td>
<td>$x_b = 0.1 - 0.5$ x_b = 0.05 - 0.6</td>
<td>$8 \times 10^{31}$ $6 \times 10^{32}$</td>
<td>0.08</td>
<td>$P_b = 60%$ $P_b = 50%$</td>
<td>$4.0 \times 10^{-4}$ $2.1 \times 10^{-3}$</td>
</tr>
<tr>
<td>SeaQuest (FNAL: E-906)</td>
<td>p + p</td>
<td>120 GeV</td>
<td>$x_b = 0.35 - 0.9$ x_b = 0.1 - 0.45</td>
<td>$3.4 \times 10^{35}$</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pol tgt DY* (FNAL: E-1039)</td>
<td>p + p</td>
<td>120 GeV</td>
<td>$x_t = 0.1 - 0.45$</td>
<td>$4.4 \times 10^{35}$</td>
<td>0 - 0.2*</td>
<td>$P_t = 85%$ f = 0.176</td>
<td>0.15</td>
</tr>
<tr>
<td>Pol beam DY§ (FNAL: E-1027)</td>
<td>p + p</td>
<td>120 GeV</td>
<td>$x_b = 0.35 - 0.9$</td>
<td>$2 \times 10^{35}$</td>
<td>0.04</td>
<td>$P_b = 60%$</td>
<td>1</td>
</tr>
</tbody>
</table>
RF separated beam: specification from Drell-Yan program

• particle type / beam composition RF separated negatively charged hadron beam, 50% antiprotons, 50% of Kaons

• beam intensity $10^8$ particles/second of total flux

• beam momentum: preferably $> 120$ GeV

• beam momentum spread (no energy scan is required). Beam momentum spread of 1-2% for a beam of 100GeV/c momentum seems reasonable and enough.

• beam super-cycle structure. The shortest super-cycle possible (33 s). Long flat top is favourable from the point of view of data usage, but depends on beam experts (production target), PT experts (PT heating).

• beam spot size. Beam spot in the target should be not smaller than 2cm (meaning $\sigma_{x,y} = 1$ cm), as we had in 2015.

• beam particle identification: Essential.
Dark photon is produced through kinetic mixing of a Bremsstrahlung photon in the ECAL. The dark photon would escape then the setup undetected through the invisible decay $A'$.

**Dark Photon signature:**
- Missing energy in the ECAL (ECAL threshold $<50$ GeV)
- No activity in VETO and HCAL
- Reconstructed momentum compatible with a 100 GeV particle
- Emitted synchrotron radiation compatible with an electron
Electron beam: NA64++ plans after LS2

2020-2024: Full exploitation of NA64++ setup
Primary goal: acquire $10^{12}$ eot invisible and possibly visible modes (this will depend on the results of the 2017-2018 runs)

Secondary goal: detailed study of backgrounds processes to assess the ultimate sensitivity of the experiment and test of detector upgrades (see next slide).

Requested beam:
- max possible intensity for 100 GeV electrons, lowest possible hadron/muon contamination, smallest possible low energy tails.

Infrastructure
- “Permanent” location would be essential due to the increasing complexity in the apparatus the installation time would grow significantly.
NA61++

Required beams

- **Beams:**
  - Protons at 20-120 GeV/c
  - Pb ions at 13A-158A GeV/c

- **Improve beam quality** mostly at low energies secondary beams
  - Beam transverse size $\Phi < 8$ mm
  - Beam slope $< 200$ $\mu$rad

- **Beam intensity** $\approx 10^6$ Pb ions/spill (10 s)
  - Upgrade of the H2/NA61 radiation protection

- **Reduced beam intensity oscillation** on NA61 target during the spill
  - $\Delta I/I < 10\%$
NA60++ Experimental set-up

- The NA60 experiment was housed in the **ECN3 underground zone**.
- It was **dismantled in 2010** to make space for NA62 installation.

- **NA60+ layout** close to NA60 → possibility of adapting the set-up to cover the same kinematic region for various beam energies.
The possible scheme of the setup and detectors
Tentative timeline

Studies with GEANT 4 under way to study:
- geometrical configuration
- target modularity and thickness
- number of tracking Si planes
- need to have particle identification

\sim 1 \text{ year}

Plan to have exploratory beam tests:
- \textbf{first in 2017} using an existing setup in area 128 (H8 beam)

\sim 2 \text{ years}

Once the optimization is made:
- detector elements: Hamamatsu sensors, existing r/o electronics,
- explore if existing calorimeters\&muon system can be re-used,…

\sim \text{ ??? years}

\rightarrow \text{ In the meanwhile try to build a collaboration!}

Clara Matteuzzi
Primary beam requirements

$10^{19}$ pot/yr $\times$ 5 years $\rightarrow 2 \times 10^{13}$ ppp/16.8s

Maximum instantaneous rate: $7 \times 10^{12}$ pot/eff. second

- Need uniform spill structure

Advantages of siting in K12/ECN3:

- Long beam cavern and experimental hall needed
- 100-m neutral beamline to reduce background from $\Lambda$ and regenerated $K_S$
- 140-m experiment length to contain FV and provide effective background rejection
- Experimental infrastructure & NA48 LKr calorimeter already in place

Can intensity requirement be met in P42/K12?

Need to evaluate feasibility and estimate cost of upgrades to target area and transfer lines

- Transport
- Splitting
- Targeting
- Collimation
- Dumping
- Experimental area
Summary and outlook

Project timeline:

2017-2018  Project consolidation and proposal
            • Beam test of crystal pair enhancement

2019-2021  Detector R&D

2021-2025  Detector construction
            • Possible K12 beam test in cooperation with NA62++

2024-2026  Installation during LS3

2026-      Data taking beginning Run 4

Major goals in context of Conventional Beam WG:

• Tagged-photon test beam for measurements of pair production enhancement in crystals for validation of SAC concept and beam photon absorber

• Feasibility and cost studies for high-intensity upgrades to P42/K12 target area and transfer lines