A Superconducting Proton/Electron Linac at KEK

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KEK, 9 July 2014

Main characteristics of the proposed facility

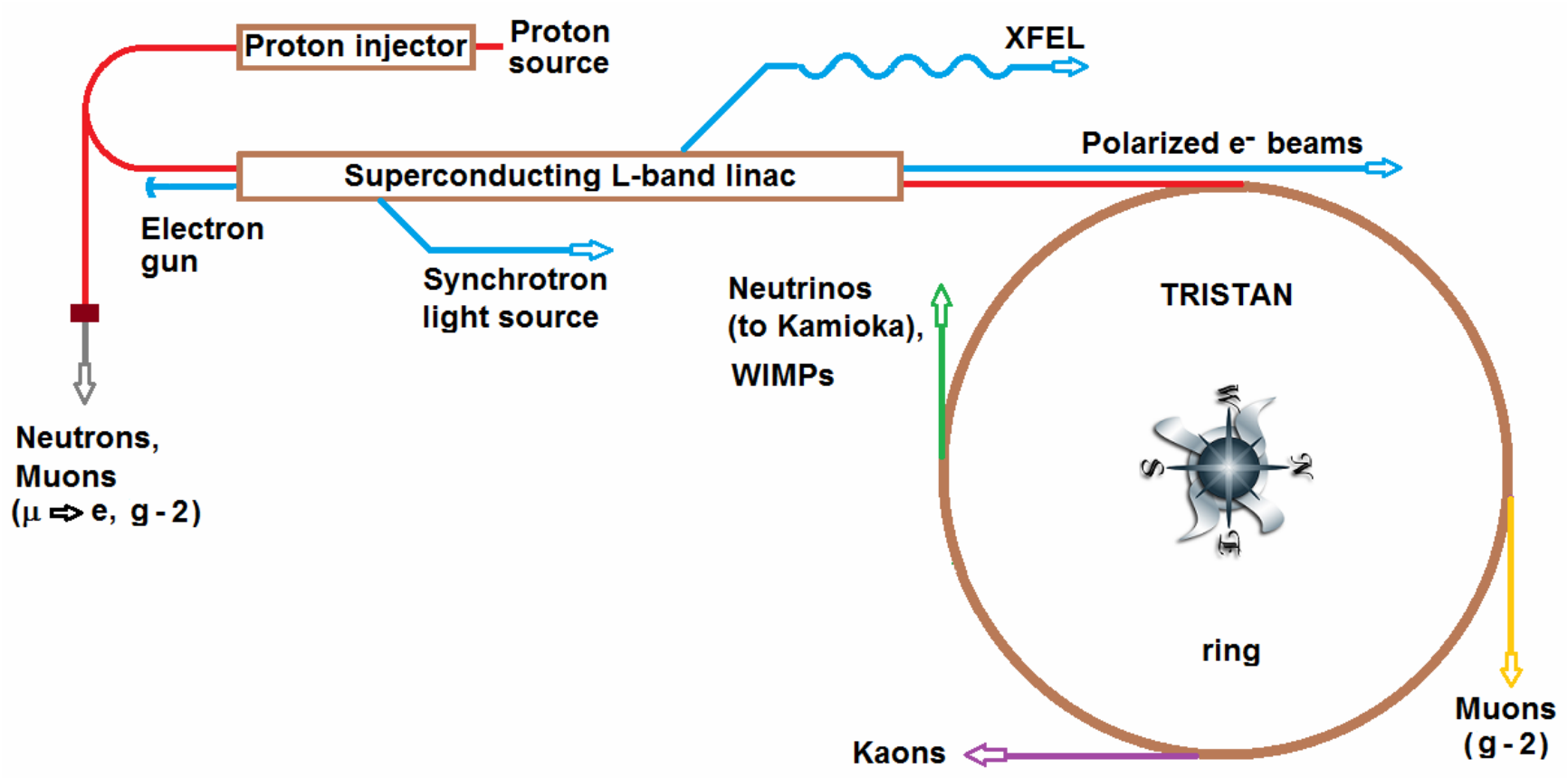
Pulsed SC linac based on ILC-type cavities and rf sources, constructed using the existing KEK accelerator infrastructure.

Both protons and (polarized) electrons can be accelerated, which considerably increases its physics potential.

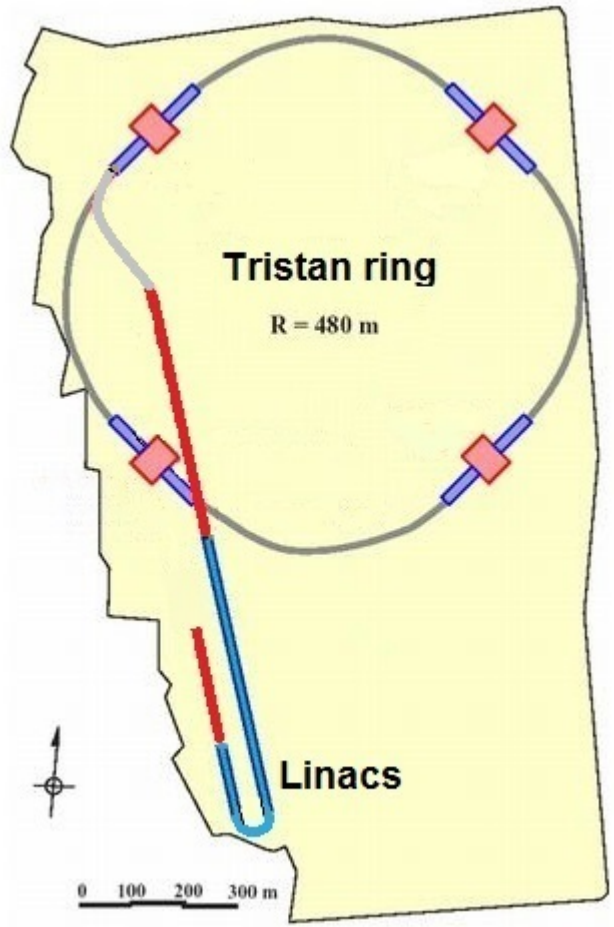
By avoiding the use of circular machines, the beam power could reach 15 MW at a linac beam energy of 20 GeV.

At a later stage, a 60-GeV proton synchrotron could be installed inside the Tristan ring.

Schematic layout of the facility



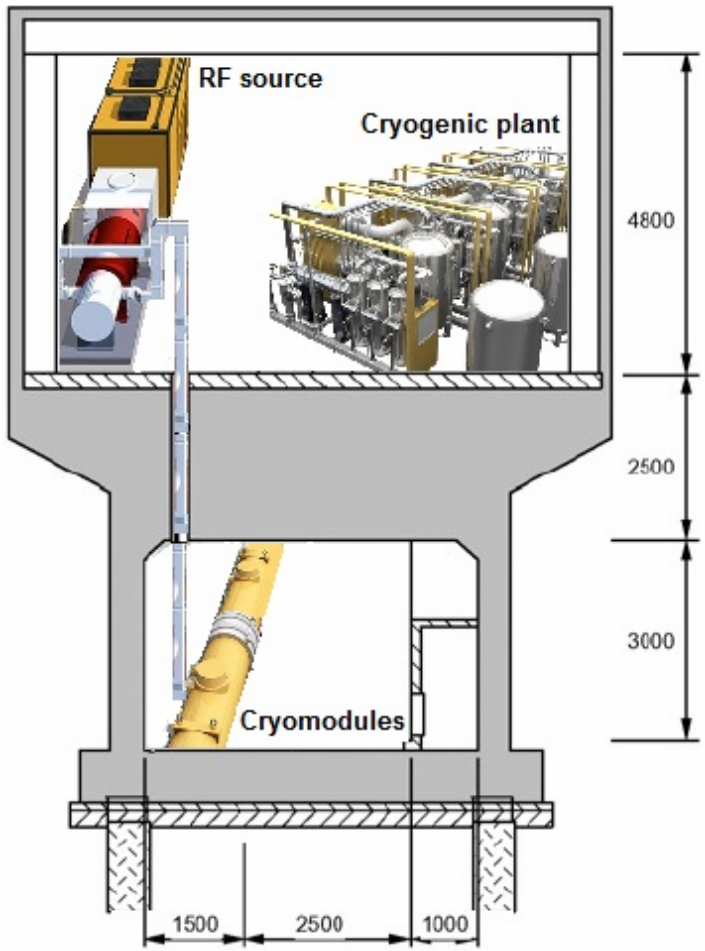
KEK site with Tristan ring and electron linacs



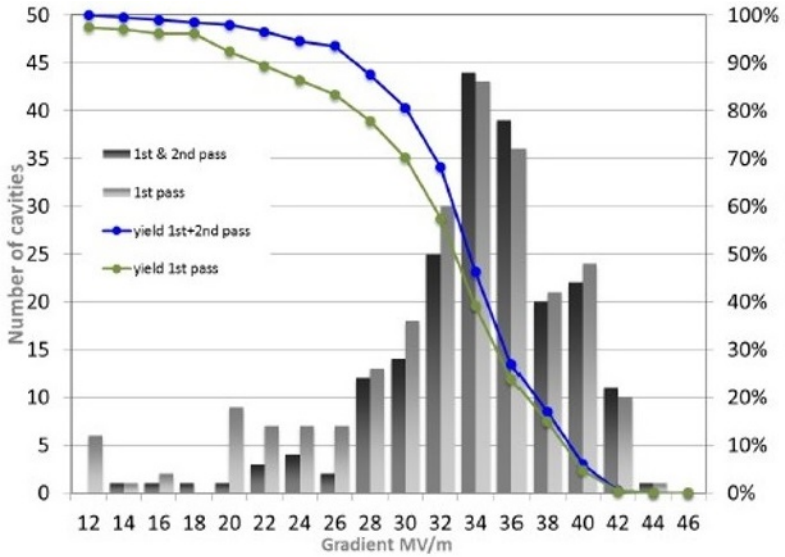
Existing linac: blue

Extended tunnels: red

Front view of linac tunnel & klystron gallery

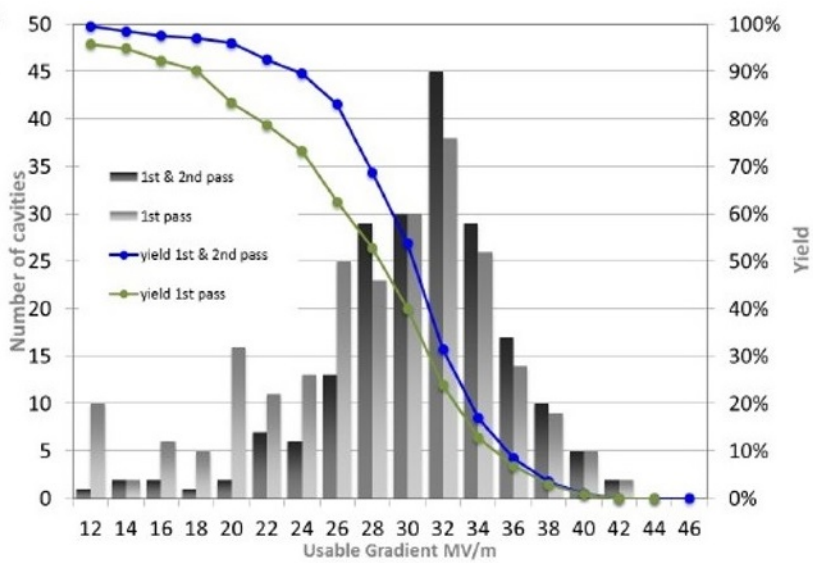


Measured accelerating gradients of ~200 ILC-type cavities (2. pass)



Average **maximum** gradient:

(32.8 ± 4.9) MV/m



Average **usable** gradient:

(29.3 ± 5.1) MV/m

Because of large ohmic losses, accelerating gradients in a CW linac are limited to about 15 MV/m. A pulsed ILC-type linac would therefore be a factor of two shorter – and cheaper – than a CW linac with the same beam energy!

Main parameters of the SC linac

Beam energy	20 GeV
Beam power	15 MW
Repetition rate	20 Hz
Protons per pulse	2.3×10^{14}
Beam pulse length	1.2 ms
Average current per pulse	31 mA
Duty cycle	2.4 %
RF frequency	1.3 GHz
Klystron average power	150 kW
Klystron peak power	5 MW
Klystron pulse length	1.5 ms
Effective accelerating gradient	20 MV/m
Peak power per coupler	460 kW

Proton beam power

$$\mathcal{P}ower\ [\text{MW}] = \mathcal{E}\ [\text{MV}] \times I\ [\text{A}] \times \tau\ [\text{s}] \times \mathcal{R}\ [\text{Hz}]$$

Based on the parameters of the SC linac (see the previous page),

$$\mathcal{P}ower = 20{,}000\ \text{MV} \times 31\ \text{mA} \times 1.2\ \text{ms} \times 20\ \text{Hz} = 15\ \text{MW}$$

$\mathcal{N} = \mathcal{P}/\mathcal{E}$ - number of protons per second.

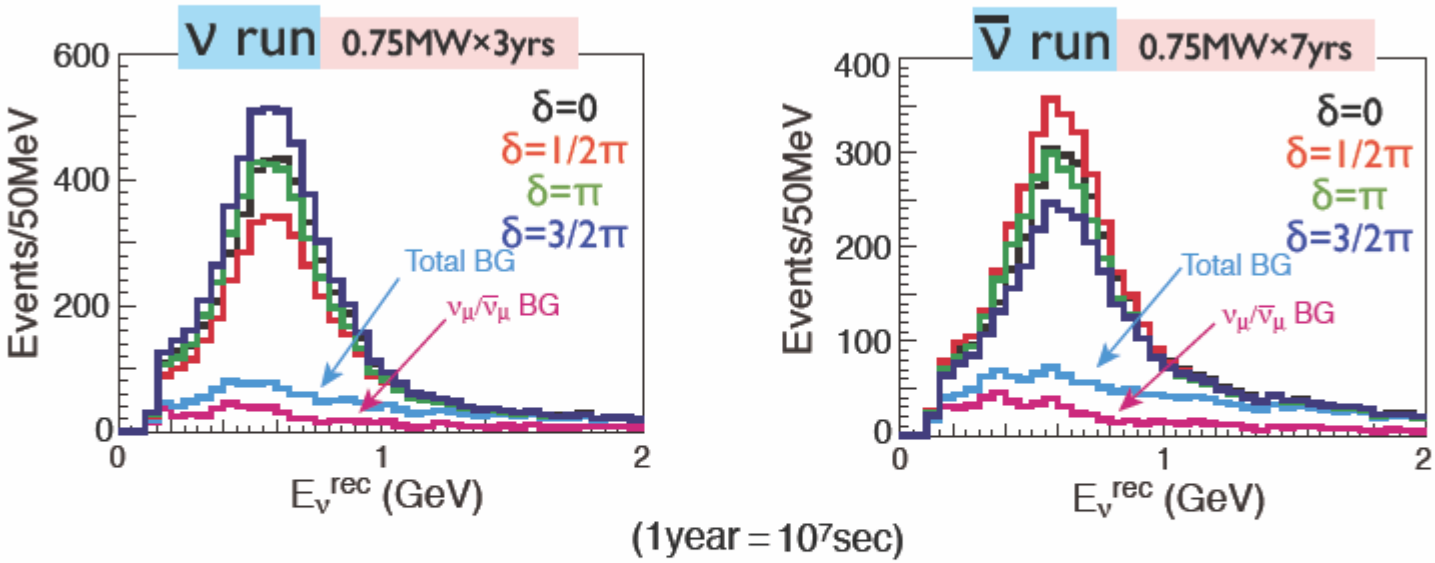
$\mathcal{N}_p = \mathcal{N}/\mathcal{R}$ - number of protons per pulse.

$I = (\mathcal{N}_p \times 1.6 \times 10^{-19}\ \text{C})/\tau$ - current per pulse;

τ is beam pulse length (1.2 ms).

T2HK neutrino oscillation experiment

$\sin^2 2\theta_{13}=0.1$



(1year = 10^7sec)

	Signal ($\nu_\mu \rightarrow \nu_e$ CC)	Wrong sign appearance	$\nu_\mu/\bar{\nu}_\mu$ CC	$\nu_e/\bar{\nu}_e$ contamination	NC
ν (2.25MW · 10^7s)	3,560	46	35	880	649
$\bar{\nu}$ (5.25MW · 10^7s)	1,959	380	23	878	678

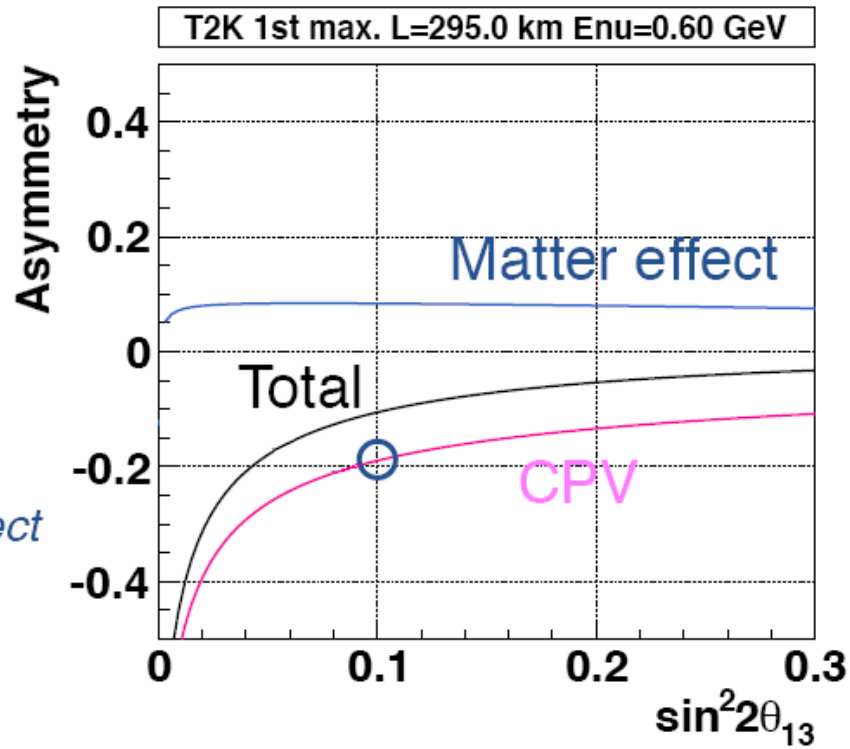
K. Sakashita (KEK), Feb. 2013

CP violation in neutrino oscillations

20% CPV effect at $\sin^2 2\theta_{13} = 0.1$
w/ maximum CPV ($\sin\delta=1$)
at 1st peak

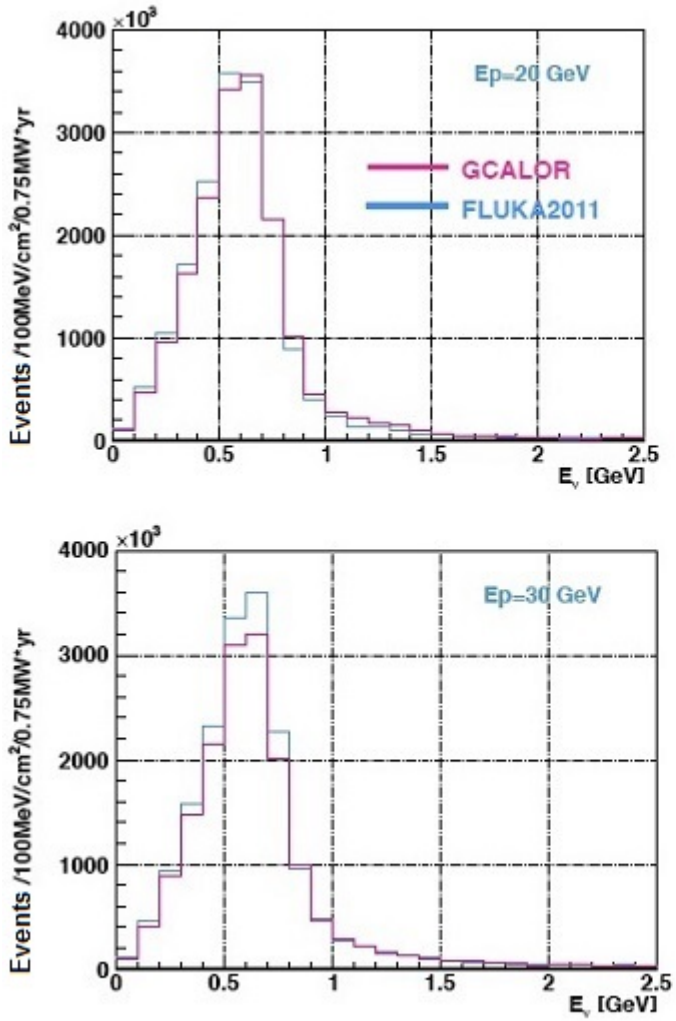
→ need ~10k events in order to detect CPV @ more than 3σ for $\sin\delta > 0.2$ (asym. = 4%)

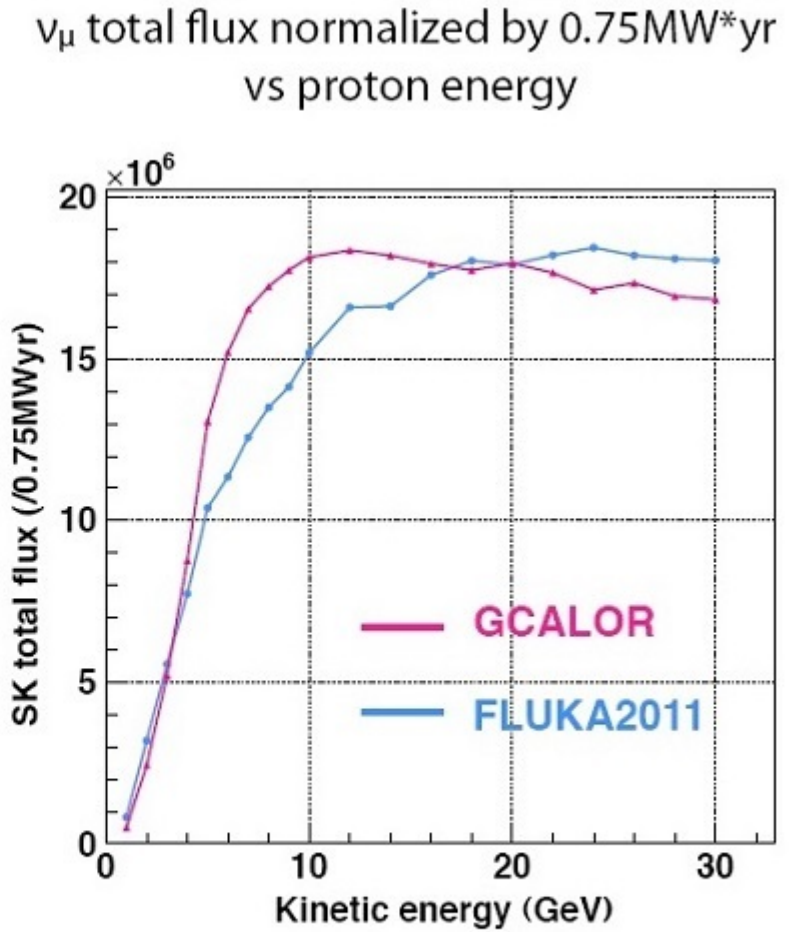
need to distinguish CPV from matter effect
(w/ energy spectrum at long distance)
or need knowledge of mass hierarchy



K. Sakashita (KEK), Nov. 2011

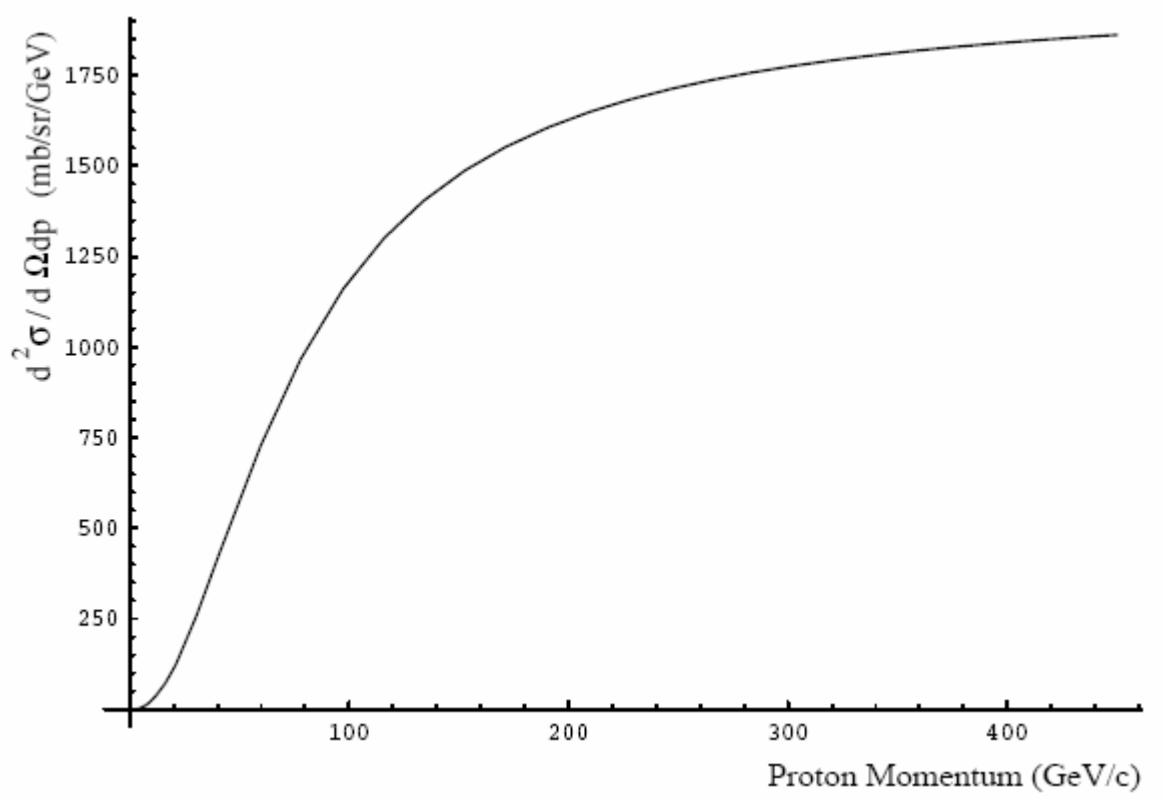
Neutrino flux dependence on proton energy



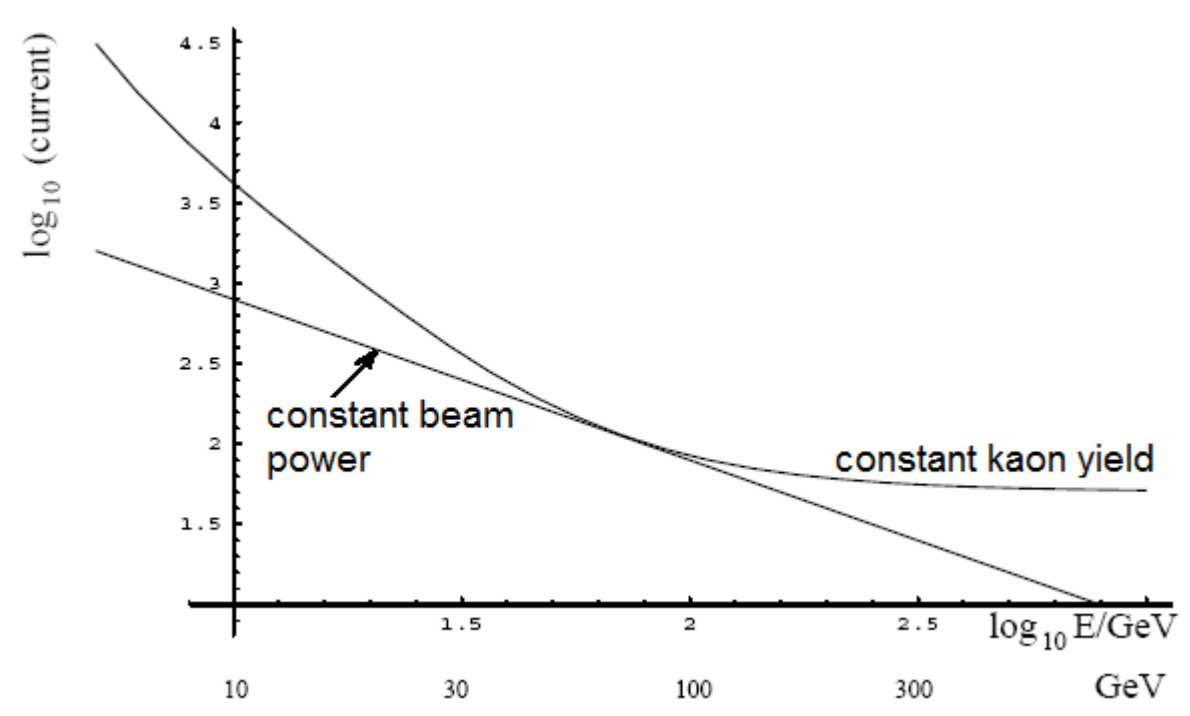


K. Sakashita (KEK), March 2014

Kaon yield as a function of proton energy



Optimum beam power for a given kaon yield



The beam power required for a given kaon yield would be lowest at energies between 40 and 100 GeV.

Concluding remarks

The proposed facility would be a versatile source of high-intensity proton and electron beams with energies of up to 20 GeV;
the maximum beam power of the SC linac could reach 15 MW.

The facility would be built using the existing KEK accelerator infrastructure and J-PARC beam lines.

Neutrino and antineutrino beams produced at the proposed 15MW "proton driver" would yield, within 2 years of data taking, more than 10,000 electron neutrino "appearance events" in the 0.5Mt fiducial volume of the Hyper-Kamiokande detector.

At a later stage, a 60-GeV proton synchrotron could be installed inside the Tristan ring in order to produce high-energy neutrino and kaon beams.