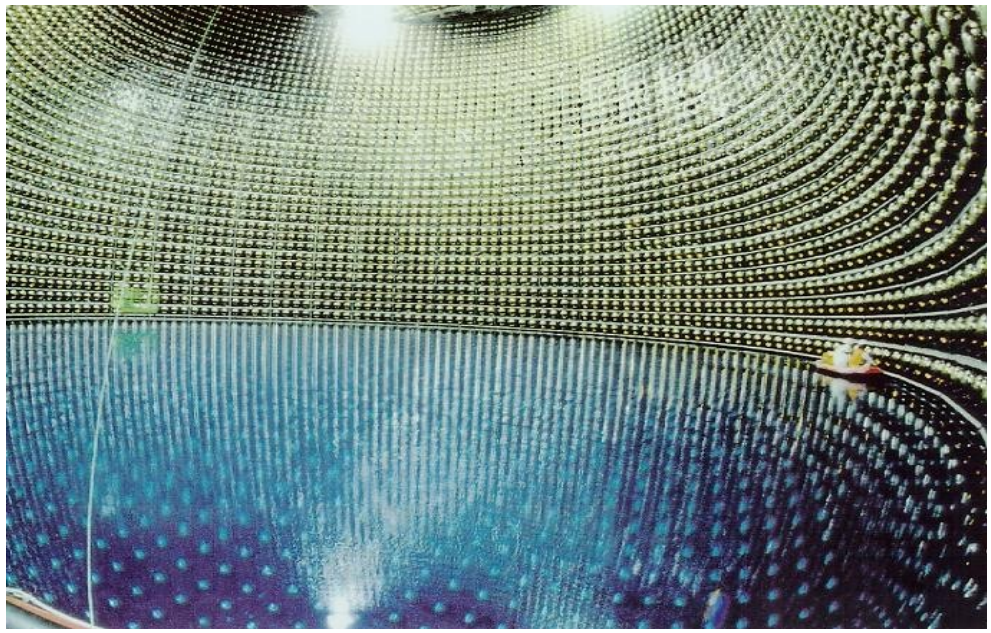
Physics 115
General Physics II



Session 36

Practice Q's
Brief Review
If time permits:
A little bit about neutrinos...

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Lecture Schedule

12-May	Mon	23	DC Circuits & Meters	21.5-21.8
13-May	Tues	24	DC Circuits	21.5-21.8
15-May	Thurs	25	RC circuits	21.6-21.7
16-May	Fri	26	Circuits - Neurons	
19-May	Mon	27	Magnetism	22.1
20-May	Tues	28	Magnetic Force	22.2-22.5
22-May	Thurs	29	Magnetic Fields	22.6-22.7
22-May	Fri	30	Induced EMF, Applications	23.1-23.3
26-May	***holiday***		NO CLASS	
27-May	Tues	31	Energy, RL circuits	23.4-23.8
29-May	Thurs	32	Transformer	23.9-23.10
30-May	**Fri**		**EXAM 3 - Chapters 21,22,23**	
2-Jun	Mon	33	AC circuits	24.1-24.3
3-Jun	Tues	34	AC circuits	24.4-24.5
5-Jun	Thurs	35	Resonance, Applications	24.6
6-Jun	Fri	36	Last class - review	
June 9	**FINAL EXAM**		**2:30-4:20 p.m.**	**Comprehensive**
	Mon		**Monday, June 9, 2014**	

Today

Announcements

Formula sheet(s) for final exam are posted in slides directory

- Final exam is **2:30 pm, Monday 6/9, here**
  - 2 hrs allowed, (really, 1.5 hr needed),
  - Comprehensive, but with extra items on material covered after exam 3 (Phasors and Power Factor will NOT be in the exam)
  - Usual arrangements
  - I will be away all next week, Dr. Scott Davis will be your host

- Homework set 9 is due tonight, **Friday** 6/6, 11:59pm

1) A coil with a self-inductance of 6.0 H is connected to a dc source through a switch. As soon as the switch is closed at $t = 0$ s, the rate of change of current is 2.0 A/s. What is the emf induced in this coil at $t = 0$ s?

A) 6.0 V

B) 3.0 V

C) 12 V

D) 1/3 V

E) 0 V

Answer: C

$$\left|\mathcal{E}_{\text{coil}}\right| = L\left|\frac{\Delta I}{\Delta t}\right| = \left(6.0H\right)\left(2A/s\right) = 12V$$

2) Figure above shows a simple ac circuit composed of a capacitor connected across the terminals of an ac generator. If the frequency (in Hz) of the generator is doubled, what happens to the capacitive reactance of the capacitor?

A) It increases by a factor of 4.

B) It increases by a factor of 2.

C) It increases by a factor of $\sqrt{2}$.

D) It decreases by a factor of 2.

E) It decreases by a factor of 4.

Answer: D

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$X_C' = \frac{1}{2\pi(2f)C} \rightarrow X_C' = \frac{X_C}{2}$$

3) In a series *RLC* circuit, the values of the inductance and capacitance are both doubled. In comparison with the resonance frequency of the original circuit, the new resonant frequency will be

A) the same as before.
B) reduced to one-half the original value.
C) reduced to one-quarter the original value.
D) increased by a factor of two.
E) increased by a factor of four.

Answer: B

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$\omega_0' = \frac{1}{\sqrt{2L2C}} = \frac{1}{2\sqrt{LC}} \rightarrow \omega_0' = \frac{\omega_0}{2}$$

4) A generator produces EMF = 100 volts RMS and is connected to an inductor with L= 200 mH. The current I = 2 amperes RMS. What is the frequency of the EMF, in Hz?

A) 40 Hz
B) 250 Hz
C) 160Hz
D) 60 Hz
E) none of the above

reactance: $X_L = \omega L = 2\pi f L$

current: $I = V / X_L \rightarrow 2A = 100V / \left[2\pi f \left(0.20H\right)\right]$

$$f = \frac{100V}{2\pi\left(0.20H\right)\left(2A\right)} = 39.7Hz$$

Note: exam will not cover “phasor diagrams” or “power factor”

ALL THE STUFF YOU LEARNED this term! Congratulate yourself...

FLUIDS (Ch. 15 in text)

$\rho = M / V$, $P = F / A$, $P_{gauge} = P - P_{ATM}$

At depth h, $P = P_0 + \rho g h$ Bouyant force = weight of fluid displaced

Continuity: $\rho_0 A_0 v_0 = \rho_1 A_1 v_1$ (compressible flow); $A_0 v_0 = A_1 v_1$ (incompressible)

Bernoulli: $P + \frac{1}{2} \rho v^2 + \rho g y = \text{constant}$

Toricelli's Law: $v = \sqrt{[2gh]}$ for water jet from depth h

TEMPERATURE AND HEAT (Ch. 16 in text)

Temperature: Celsius has 0= freezing, 100 = boiling point for water at 1 atm

Kelvin scale has 0 = absolute zero (no molecular motion) = -273C

Expansion of solids: $\Delta L = \alpha L_0 \Delta T$, $\Delta V = \beta V_0 \Delta T$ (for many solids $\beta = 3\alpha$)

Heat <-> work: 1 cal = 4.186J, 1 Cal = 1000 cal,

specific heats $c = Q / (m\Delta T)$; conduction: $Q = kAt \Delta T/L$, k=thermal conductivity

Radiation: Power radiated = $e\sigma AT^4$

GAS LAW, PHASE CHANGES (Ch. 17)

Ideal Gas $PV = nRT = NkT$ $U = 3/2nRT = 3/2NkT$

Boltzmann's constant: $k_B = 1.38 \times 10^{-23}$ J/K gas const R = 8.31 J/mol K

mole = 6×10^{23} molecules (Avogadro's #)

1 mol = A grams of substance (A=molecular or atomic mass number)

Boyle's Law: for const T and N, PV=constant

Charles' Law: for constant P and N, V/T = constant

Kinetic theory of gases: $(\frac{1}{2} mv2)av = (3/2)\, kT$ (monatomic gas)

RMS speed $v=\sqrt{[3kT/m]}$

Latent Heat L = J/kg to change phase, $Q = mL$

THERMODYNAMICS (Ch. 18)

0^{th} Law of Thermodynamics: 2 objects in thermal equilibrium with a 3^{rd} are in equilibrium with each other (no net heat transfer)

1^{st} Law $\Delta U = Q - W$

2^{nd} Law For a closed system $\Delta S > 0$ or $= 0$

Constant P process Work = $P \Delta V$

Isothermal process Work = $nRT \ln (V_f / V_i)$

Adiabatic process $Q=0$

Specific heats for ideal gases: $Q=nC\Delta T$, $C_V=(3/2) R$, $C_P = (5/2) R$

For reversible heat engines (Carnot) efficiency $e = W/Q_h = 1 - Q_c/ Q_h = 1 - T_c/ T_h$

$Q_h = Q_c + W$

COP for Heat Pump $= Q_h / W$, COP for Refrigerator $= Q_c / W$

Entropy $\Delta S = \Delta Q/T$ at constant T

ELECTRIC CHARGE, FORCE, FIELD (Ch. 19)

Permittivity of Vacuum $\varepsilon_0 = 8.85 \times 10^{-12}$ $k=1/(4\pi\varepsilon_0)$ $F_{12}=k Q_1Q_2/R^2$

Electric field due to point charge $E = k Q/ R^2$, $k = 8.99 \times 10^9$

Energy density in the Electric field is $u = e_0 E^2 / 2$ J/m^3

Electric flux $\Phi = E A \cos\theta$

Gauss's Law: Total Φ through closed surface $= Q / \varepsilon_0$

ELECTRIC POTENTIAL (CH. 20)

Electric field $E = -\Delta V/\Delta s$ Capacitor Law: $Q = CV$

Electric Potential due to point charge $V = kQ/R$, $PE = U = QV$

energy density in space due to E: $u = \frac{1}{2}\varepsilon_0 E^2$

Work done on charge moved through ΔV: $W = -Q\Delta V$,

Capacitors: $Q = CV$, with dielectric $C \rightarrow \kappa C$, energy stored $= \frac{1}{2} CV^2$

Capacitance for a parallel plate capacitor with vacuum $C = \varepsilon_0 A/d$ Farads

DC CIRCUITS (Ch. 21)

Electric Current $I = \Delta Q/\Delta t$, Ohm's Law: $V = IR$

$R = \rho L/A$, ρ resistivity

Power $= VI$

Kirchoff laws: Sum of Voltage Drops around any Loop $= 0$

Junctions: Sum of Currents In $=$ Sum of Currents Out

Series $R = R_1 + R_2 + \ldots\ldots$ Parallel $R^{-1} = R_1^{-1} + R_2^{-1} + \ldots\ldots$

Series $C^{-1} = C_1^{-1} + C_2^{-1} + \ldots\ldots$ Parallel $C = C_1 + C_2 + \ldots\ldots$

Charging a capacitor in an RC circuit

$Q(t) = Q_{max}(1 - e^{-t/\tau})$ $\tau = RC$, Q_{max} = max charge on C (at t=infinity)$= C\mathcal{E}$

Discharge: $Q(t) = Q_{max} e^{-t/\tau}$

MAGNETISM (Ch. 22)

F_B = q v B Sin (θ) [use RHR], F_E = q E (on a charge q)

F_B = I ℓ B Sin (θ) (on wire with length ℓ)

Torque on coil of N loops = N I B A Sin(θ)

Force per unit length between parallel currents = $\mu_0 I_1 I_2 / 2\pi D$

D is distance between wires

Magnetic Permeability of Vacuum $\mu_0 = 4 \pi \times 10^{-7}$

B field at distance R from a long straight wire with current I : B = $\mu_0 I / 2\pi R$

Cyclotron formula for charged particle moving perpendicular to uniform field B

R = mv/(qB) , R radius of the circular trajectory

B at center of single loop: $\mu_0 N I / 2R$

Solenoid field B = $\mu_0 N I / \ell$ (N turns over length ℓ)

INDUCTION (Ch. 23)

B flux: $\Phi = B A \cos\theta$ Faraday's Law: $\mathcal{E} = - \Delta\Phi / \Delta t$,

Lenz's Law: induced current opposes $\Delta\Phi$

Generators: $\mathcal{E} = N B A \omega \sin(\omega t)$

Inductance $L = \Delta F_m / \Delta I$ Inductance of solenoid (N turns, length *l*): $L = \mu_0 N^2 A / \ell$

$\tau = L / R$, $I(t) = (\mathcal{E}/R)(1 - e^{-t/\tau})$ charging an inductor

Energy in inductor $U = LI^2 / 2$, field energy density $u_B = B^2 / (2 \mu_0)$,

Transformers: $(V_2 / V_1) = (N_2 / N_1) = (I_1 / I_2)$

AC CIRCUITS (Ch. 24)

$V = V_{max} \sin(\omega t)$, $V_{RMS} = V_{max} / \sqrt{2}$, $I_{RMS} = V_{RMS} / X$, $X_C = 1 / (\omega C)$, $X_L = \omega L$

$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$, resonant freq $\omega_0 = 1 / \sqrt{[LC]}$, resonance → $X_L = X_C$

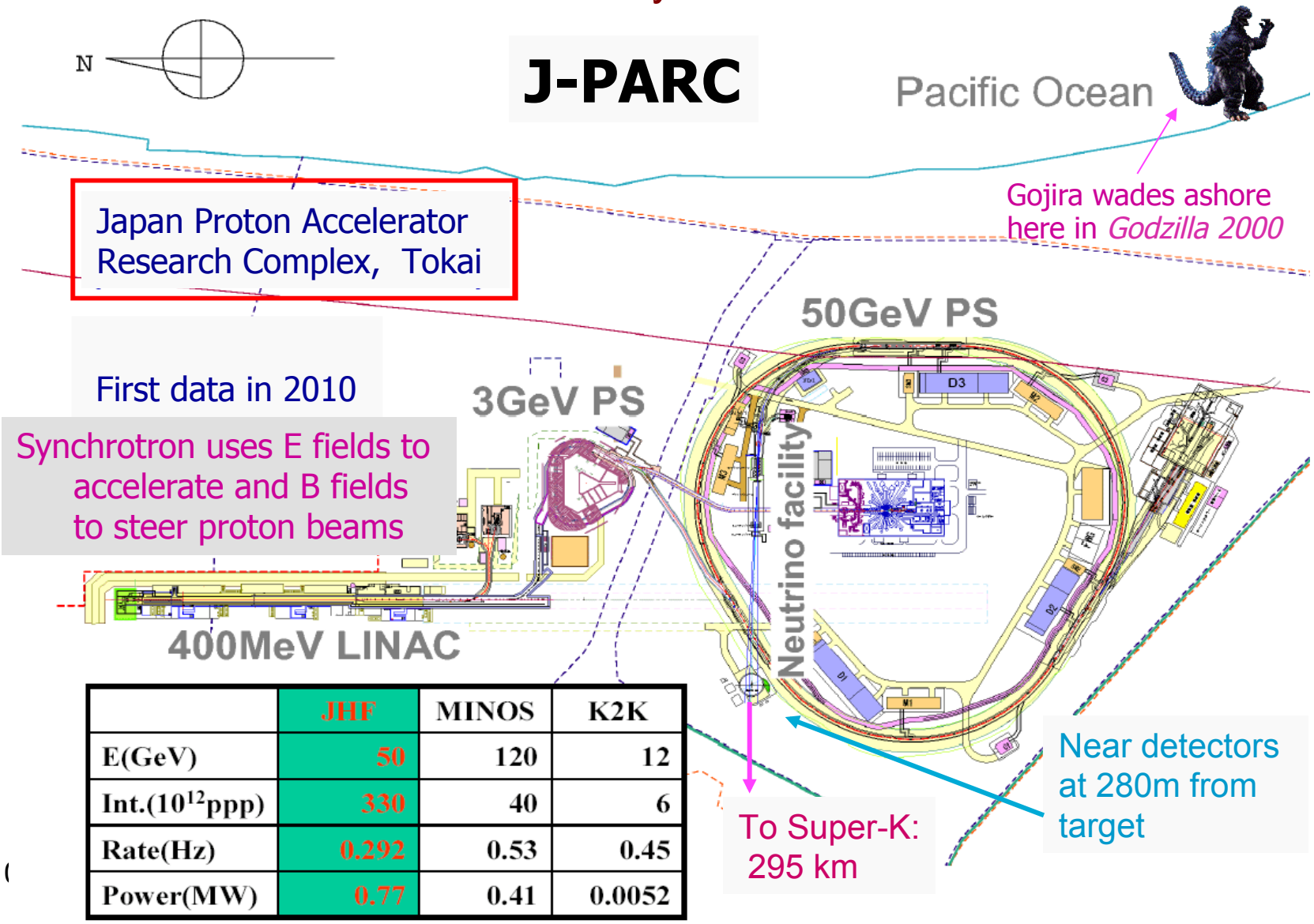
That's all, folks!

Time left? A little about basic research here...

Where I will be working next week...

T2K = neutrino experiment in Japan

Particle accelerator near Tokyo



	JHF	MINOS	K2K
E(GeV)	50	120	12
Int.(10^{12}ppp)	330	40	6
Rate(Hz)	0.292	0.53	0.45
Power(MW)	0.77	0.41	0.0052

Q: What are neutrinos?

- Neutrinos = subatomic particles with:
  - no electric charge
  - (almost) no mass
  - only weak interactions with matter

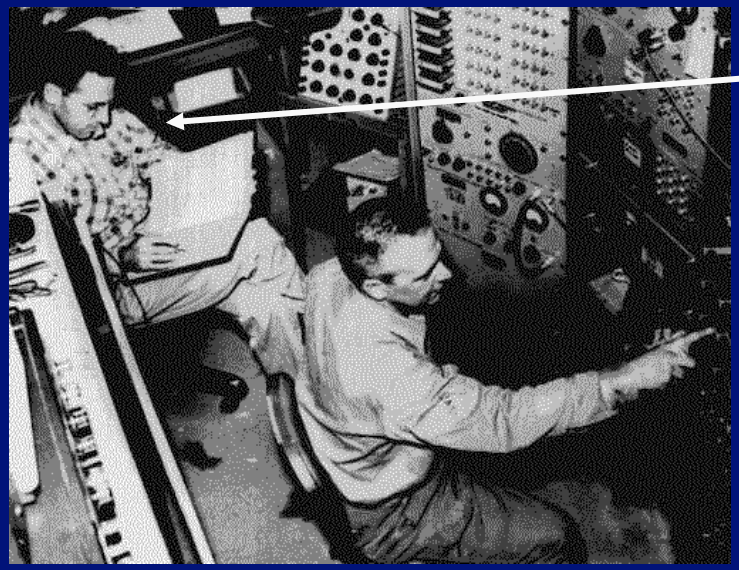
Symbol: ν
(Greek letter nu)

That doesn't sound very interesting!

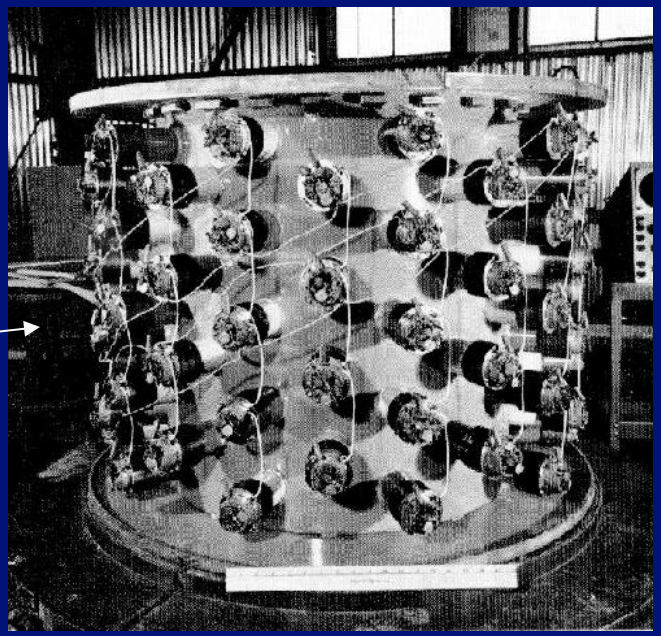
- But...
  - neutrinos are made in (almost) every radioactive decay
  - neutrinos are as abundant as photons in the Universe
    - Several hundred per cm^3 everywhere in the Universe
      - even though they are nearly massless, they make up a significant proportion of the mass in the Universe!
    - You are emitting ~ 40,000 neutrinos/sec right now (^{40}K decays)
    - Neutrinos can penetrate the entire Earth (or Sun) without blinking
      - maybe we can study earth's core with neutrinos?
      - astronomical window into places we can't see with light

Q: How were they first 'seen'?

- Fred Reines and Clyde Cowan, 1956
  - ν source: initially, nuclear reactor in Hanford, WA (later moved to Savannah River reactor)



Nobel Prize in Physics 1995
Awarded to Fred Reines "for pioneering experimental contributions to lepton physics"



  - Detector: water with $CdCl_2$
  - *inverse* beta decay: $\bar{\nu} + p \rightarrow n + e^+$

    Observed light flashes from e^+ annihilation followed by decay of neutron

T2K and Super-Kamiokande in Japan

T2K (Tokai to Kamiokande) long baseline experiment

- Neutrino beam is generated and sampled at Tokai (particle physics lab, near Tokyo)
- Beam goes through the earth to Super-K, 300 km away

Super-Kamiokande Underground Neutrino Observatory

- In Mozumi mine of Kamioka Mining Co, near Toyama City
- Detects natural (solar, atmospheric) and artificial (T2K) neutrinos

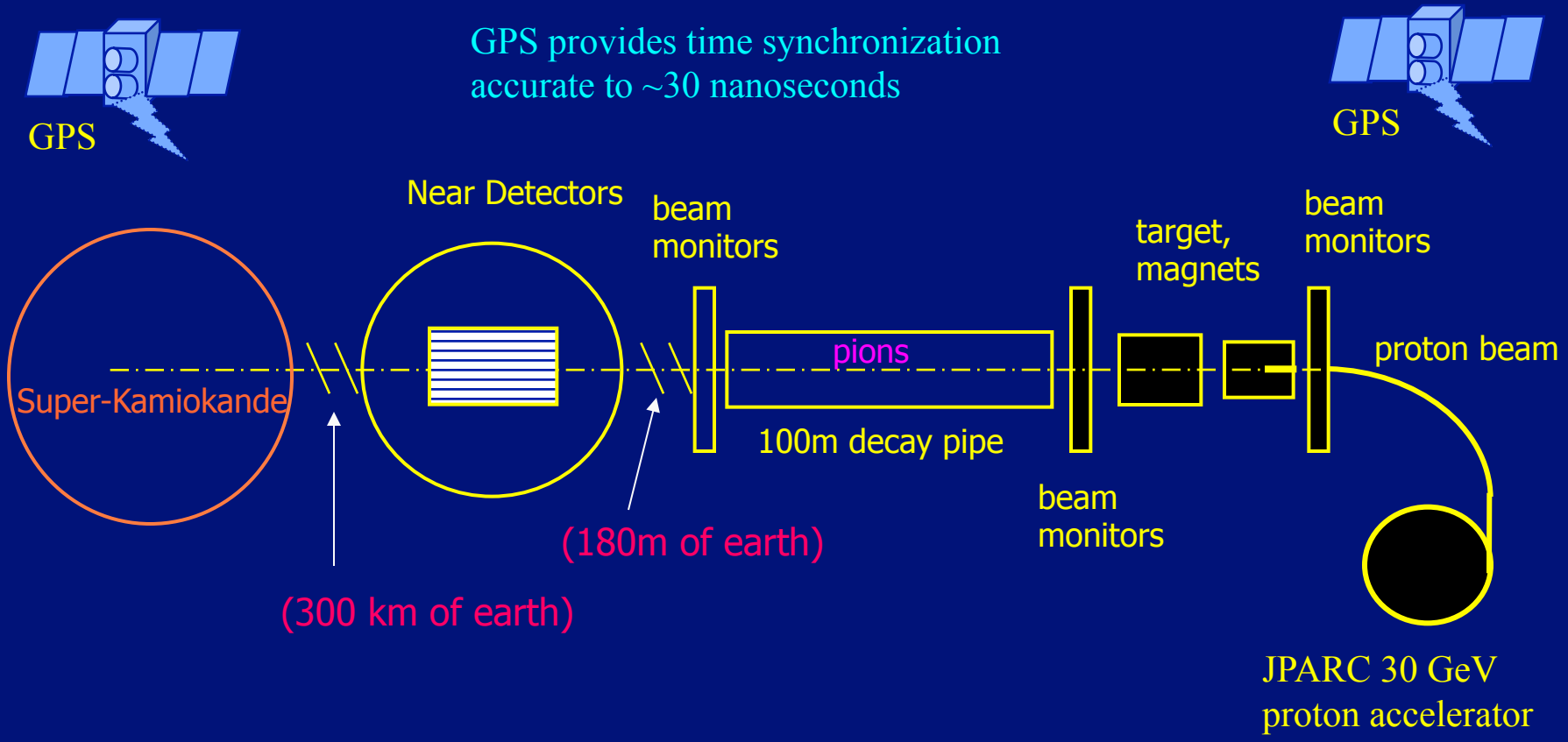
Just how big is Super-K?

- 40 meters tall by 40 meters wide, lined with 11,000 phototubes
- 50,000 cubic meters of ultra-purified water

Checking 20” phototubes by boat as the tank fills (1996)

See display case outside this room for live feed from Super-K

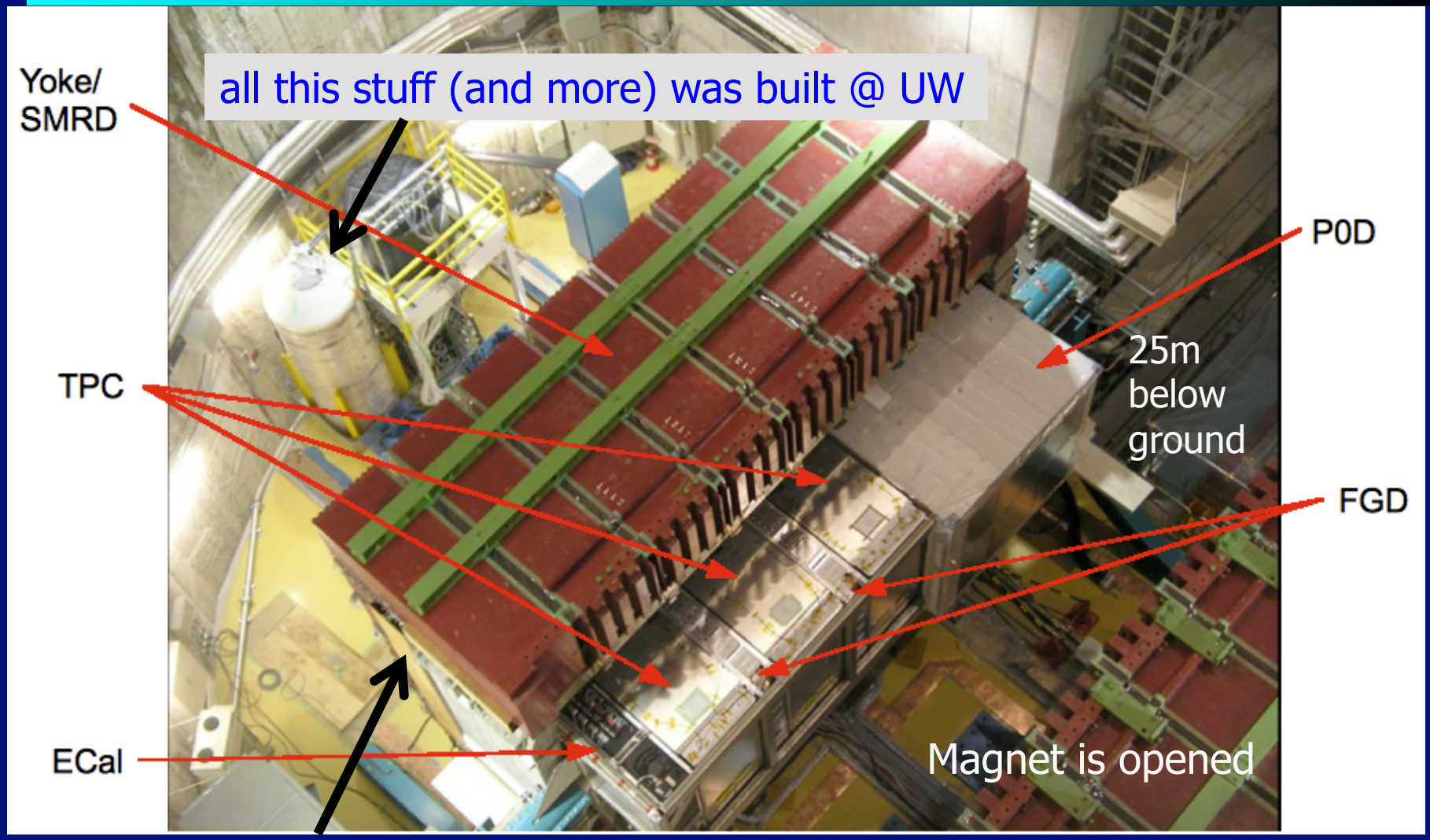
How do you make a neutrino beam?



T2K (Tokai to Kamioka)

Started data taking 2010

"Near" detectors at JPARC: view from ground level



0.2 T iron Magnet's "clam-shells" are opened in photo

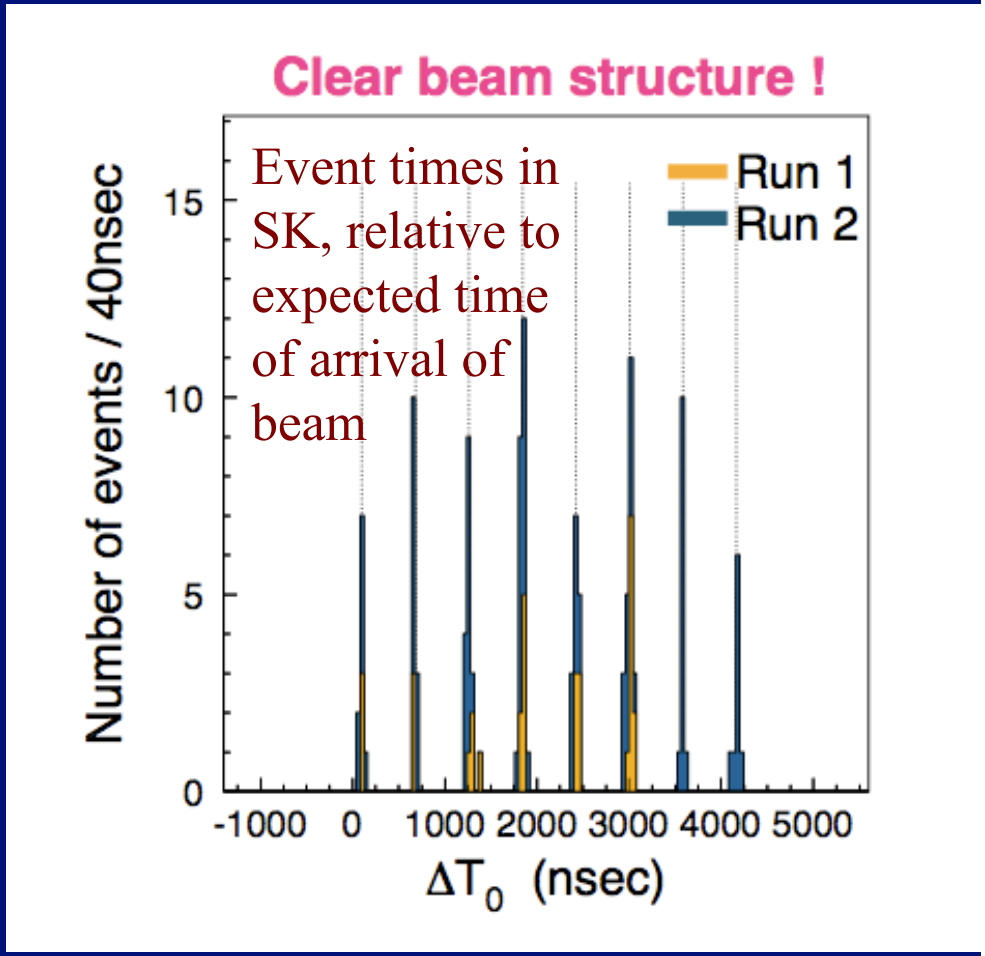
Identifying T2K beam neutrinos in SK

- Time of arrival of neutrinos from J-PARC at SuperK, relative to beam pulse time

Duplicate GPS systems (UW built) log beam spill times at both J-PARC and event times at SK

Beam's pulse substructure is clearly seen, at the nanosecond level!

THROUGH-THE-EARTH NEUTRINO TELEGRAPHY!



Message ...

1. Basic research in science is worthwhile even though we have no idea yet what future payoffs might be; examples:
    - Particle physics research at Stanford stimulated development of microprocessors → today's CPUs
    - Particle physics research at CERN led to WWW
        - Etc etc...
2. You worked hard to get into UW because it is a *research university*
    - Faculty/staff here are *learning new things* daily
    - You have many opportunities to participate !
3. What you learned in this class WILL make a difference in your life
    - You will apply it directly if you are a science/tech major
    - You will apply reasoning skills developed, in any major
    - You will be a better-informed citizen, able to evaluate information (and smell misinformation!) about science/tech